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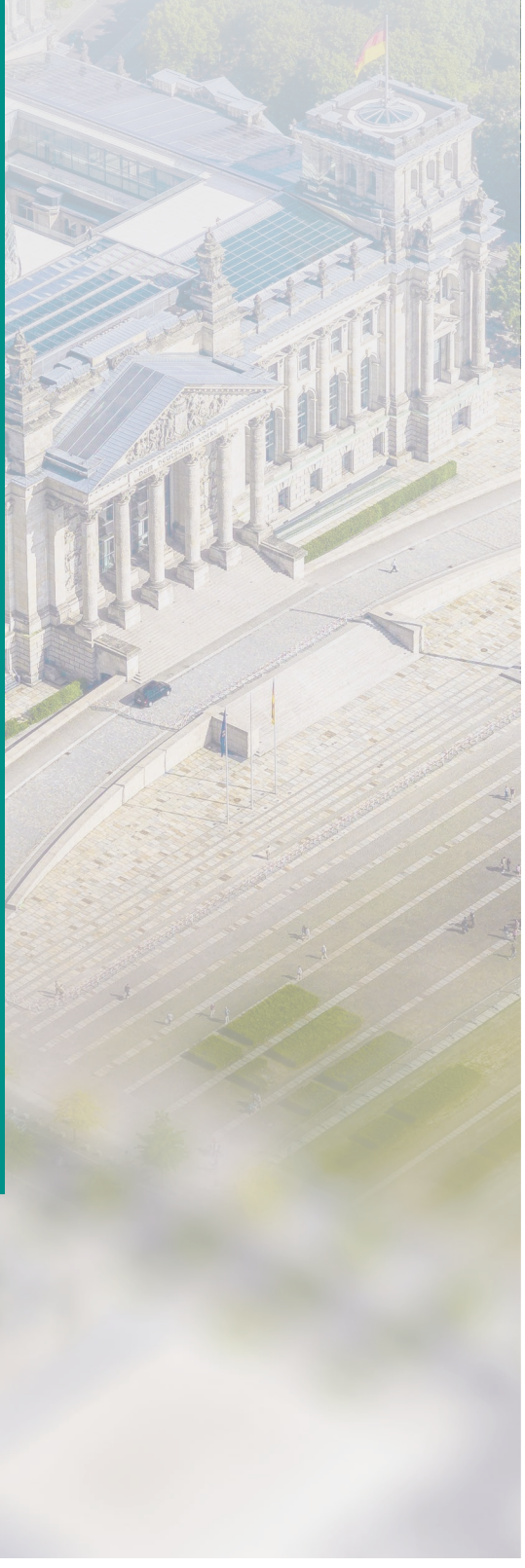

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Consequences of extreme weather events for developing countries based on the example of Mongolia

By Kati Kraehnert and Claudia Kemfert

In parts of Germany this summer, temperatures were extremely high and there was no rain to speak of: this is an example of an extreme weather event. Many people experienced physical discomfort and the livelihoods of some were threatened. Think of crop damage due to drought. Every unusually hot summer is not the consequence of climate change, nor are all hurricanes and all floods. Earlier decades also had their share of torrential rain and drought. But extreme weather events and climate change are directly related. Climate forecasts predict that in the future, extreme weather events will occur even more frequently and with higher intensity.

Prosperous countries such as Germany can cope with the damage caused by extreme weather comparatively well. Many people and households are insured and when damage is caused by drought, farmers can receive state aid for particularly hard-hit farms. The picture looks quite different in many developing countries. Due to their geographical location, they are subject to extreme weather events more frequently than developed countries. At the same time the damage is of higher magnitude, because there is often no system of precautionary financial provisions (for example, insurance). One reason for this is that many people in developing countries live close to the minimum subsistence level. After an extreme event occurs, many people may no longer be able to meet their basic needs. And the infrastructure and national social security systems in many developing countries are hardly viable. Often, households must fend for themselves when it comes to coping with negative events or shocks.

There is only a rudimentary body of knowledge about the consequences of extreme weather events for people in developing countries. However, we need this knowledge to be able to plan useful policy measures—both in affected countries and for development aid. In most cases, we have little or no microdata, that is, data at the household or individual level that are essential for developing systematic, individual solutions. The relevant panel datasets either do not exist, are qualitatively too poor for well-founded analysis, or not accessible for scientific purposes.

This is the starting point for the current issue of the DIW Weekly Report. It consists of three studies based on a project funded by the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF): Coping with Shocks in Mongolia. As part of the project, researchers at the German Institute for Economic Research (DIW Berlin) collected household panel data in Mongolia and evaluated the data with econometric methods. They focused on three questions: how do extreme weather events—in the case of Mongolia, an extremely cold, snowy winter—affect household assets? Do extreme winters influence schooling? And would index-based weather insurance provide households with effective protection against the consequences of extreme weather events?

Mongolia is representative of developing countries that are vulnerable to extreme weather events due to their geographical location. Extreme winters with temperatures that often drop to below -40 degrees Celsius make many rural regions uninhabitable, particularly because agriculture is not viable under those conditions. Large parts of Mongolia's rural population migrate to urban areas, but they are often unqualified for the urban job market and many end up living in poverty.

The findings of this research project show that index-based weather insurance is an instrument that can provide households with support—a tangible, important realization for development assistance agencies in wealthy countries.

Because of their decades of greenhouse gas emissions, wealthy countries have a moral obligation to help poorer countries successfully deal with climate change.

But merely mitigating the consequences of extreme weather events in other countries is not enough. Developed countries must lift their heads from the sand and take action to reduce the level of pollution their own countries are emitting. In addition to the energy transformation toward renewable energy sources that is underway in some European countries, such as Germany (but not by any means complete), a turnaround in the transportation sector is also required—away from subsidies for combustion motors that damage the environment and toward greater electromobility and more rail transport—to mention but one field of activity. Much potential is waiting to be tapped in the building sector as well. More energy upgrades must be completed faster to lower energy consumption. Industrial countries need a two-pronged strategy: on the one hand, active climate protection and on the other, aid for the countries affected by the consequences of climate damage.

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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).

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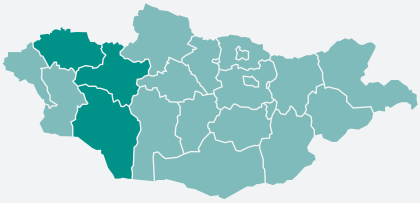
AT A GLANCE

Extreme weather events threaten the livelihood of herding households in Mongolia

By Katharina Lehmann-Uschner and Kati Kraehnert

- Analysis of a household survey examines effects of the extremely harsh winter of 2009/2010 on Mongolian households' livestock
- Extremely harsh winter led to massive livestock death
- Many severely affected households quit herding and moved to the city, their income and wealth suffering considerably as a result
- Extreme winter also has long-term effects for strongly affected herding households: their herds grow more slowly than those of unaffected households
- Rural households require support to be able to adapt to an increasingly extreme climate

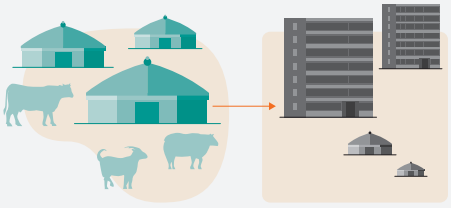
The extremely harsh winter of 2009/2010 had devastating consequences for herding households in western Mongolia



Between 2012 and 2015, 1,768 households in three Mongolian provinces, Govi-Altai, Uvs, and Zavkhan, were surveyed about their past and present livestock numbers, among other things.

43 %

After the extremely harsh winter of 2009/2010 where temperatures reached −40 degrees Celsius, herding households lost 43 percent of their animals on average ...



13 %

... and 13 percent of them gave up herding entirely. Many moved to cities.

Source: Authors' own depiction.

FROM THE AUTHORS

"Livestock is the most important asset owned by the households we studied. After the extremely severe winter of 2009/2010, many animals died—so many that a large number of herding households were unable to continue their livelihood in the herding economy."

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

MEDIA

Audio Interview with Kati Kraehnert (in German)
www.diw.de/mediathek

Extremely harsh winters threaten the livelihood of Mongolia's herders

By Katharina Lehmann-Uschner and Kati Kraehnert

ABSTRACT

Households in developing countries are exposed to increasingly extreme weather events that could endanger their prosperity. This study examines the impact of the unusually cold, snowy winter of 2009/2010 on the livestock of Mongolian households. Livestock represents on average more than 90 percent of the value of all assets owned. It is essential for current consumption and—due to the insufficient financial infrastructure—the most important means to provide for the future. The econometric analysis is based on three waves of a household panel survey that the German Institute for Economic Research carried out in collaboration with the National Statistical Office of Mongolia two to five years after the extreme event. The extremely hard winter dramatically depleted the livestock of rural herder households. Many of those affected stopped herding as a result of the extreme winter, settling in cities to earn their wages as hired hands—which in turn had a negative impact on their wealth. Even five years after the event, severely affected households that continued to herd animals recorded lower herd growth than those that were moderately affected, likely increasing inequality further in the future. The findings show that extreme weather events have long-term negative consequences on households and underscore the need for systematic aid for those affected.

As the global climate continues to change, extreme weather events are expected to occur more frequently and with greater intensity. Between 1995 and 2015, weather-related disasters have taken over 500,000 lives worldwide, and four billion people were affected by the consequences of extreme weather events.[1] Extreme events such as storms, floods, and periods of extreme cold typically affect entire regions; hence it is usually impossible to deploy informal response strategies such as loans among (nearby) friends and relatives.[2] In developing countries in particular, the markets for formal insurance often function only partially or not at all. When extreme weather events occur, many of the affected households must fall back on their assets to finance their basic needs, exposing them to a high risk of poverty.

More knowledge on the consequences of extreme weather events is needed in order to support households as they deal with such events. There has been little research on the long-term effects of extreme weather events on households in developing countries—mainly because of the lack of suitable microdata.

Based on a household survey of herders in Mongolia, this study shows how an extreme weather event has long-term negative effects on the households' asset base and asset growth rates. It focuses on the winter of 2009/2010, which caused the highest loss of livestock in the past 50 years in Mongolia.[3]

1 United Nations Office for Disaster Risk Reduction, *The human cost of weather-related disasters 1995–2015*, United Nations Office for Disaster Risk Reduction, Geneva and Centre for Research on the Epidemiology of Disasters, Brussels (2015).

2 Barry J. Barnett, Christopher B. Barrett, and Jerry R. Skees, "Poverty Traps and Index-Based Risk Transfer Products," *World Development* 36 (10) (2008): 1766–1785.

3 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 events presented here has been published as Katharina Lehmann-Uschner and Kati Kraehnert, "When shocks become persistent: Household-level asset growth in the aftermath of an extreme weather event," *DIW Discussion Paper* 1759 (2018). (Available online, accessed September 26, 2018).

Extreme weather conditions pose challenge to herding

Herding is a key sector of the Mongolian economy. In 2012, 35 percent of the population was employed in agriculture and 19 percent of Mongolians earned a living from herding alone.[4] Mongolian herding households procure meat, milk, and other dairy products from their animals, while the sale of animals and animal products is the most significant source of income for these households. Herders typically possess a mix of sheep, goats, horses, cows, and camels. In order to make a living from herding in Mongolia, owners must have a minimum herd size of between 100 and 150 animals.[5] For most herder households, the animals are the most valuable household asset. In the households of the sample examined here, the value of the animals is equal to approximately 90 percent of their total assets.

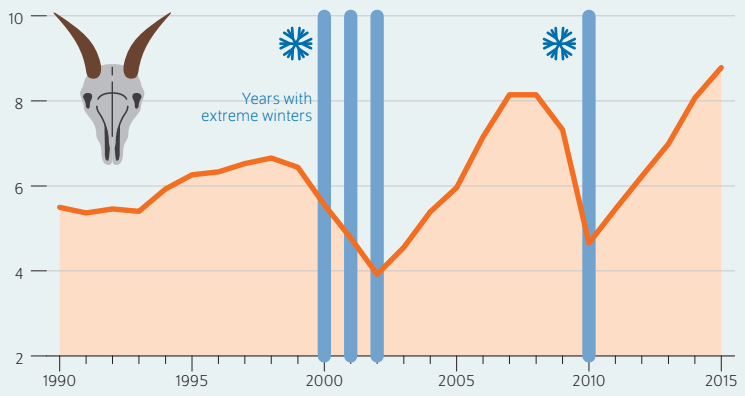
In most regions of Mongolia, the continental climate is unsuitable for cultivating forage crops. For this reason, animals are pastured all year long. Most herding households lead a nomadic or semi-nomadic life, changing pastures with their herd up to 25 times a year. In the process, households typically follow the same migratory movement year in and year out, since a complex system of norms and common law controls access to grazing land.[6]

Unusually harsh winters are the greatest threat that Mongolian herders have to face. Extreme winters—called *dzud* in Mongolian—are caused by a complex interplay of unfavorable weather conditions. They cause the death of animals on a massive scale. Since 1990, there have been four extreme winters in Mongolia (Figure 1). The focus of the present study is the winter of 2009/2010, which caused the greatest livestock depletion in the past 50 years.

A drought in summer 2009 that inhibited the growth of vegetation kicked off a series of unfavorable weather conditions. As a result, animals were unable to create adequate fat reserves for the coming winter. The first snowfall began unusually early, in October 2009, making it difficult for animals to graze. Extremely low temperatures were measured in December 2009 and January 2010. At temperatures below –40 degrees Celsius, many weakened animals froze to death. When the snow melted in May 2010, there was flooding in many regions. This in turn caused more animals to die. In January 2010, the Mongolian government declared a state of emergency.[7]

Figure

Annual number of livestock in western Mongolia[1], 1990 to 2015
In million



1 Uvs, Zavkhan, and Govi-Altai provinces.

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

Extreme winters drastically increase livestock mortality.

Extreme winter of 2009/2010 drastically reduced households' herd size

A household survey in western Mongolia provided the database for the analysis presented here (Box).

On average, the households in the sample lost 43 percent of their herd in 2010.[8] A few households did not lose any animals at all, while a larger group of households lost their entire herd. In order to empirically examine the extent to which the winter of 2009/2010 was responsible for this, the livestock mortality suffered by the sample households in 2010 was regressed on the average livestock mortality per district, determined by the livestock census, plus a large number of control variables. This methodology allows to pinpoint to what extent socio-demographic characteristics, such as experience in herding and response strategies applied by households in the midst of the extreme winter, influenced the death of the animals.

The findings show that the intensity of the extreme winter had a significant and strong effect on the loss of animals suffered by households (Table 1). An increase in livestock mortality per district by ten percent raised household livestock mortality by seven percentage points.[9] On the other hand, the herd size a household owned before the extreme winter did not have a significant influence on the livestock mortality rate: households with smaller herds and those with larger herds lost a similarly high proportion of their animals. Experience in herding did not protect against loss either. Neither the

4 National Statistical Office of Mongolia, *Mongolian Statistical Yearbook 2012*, (Ulaanbaatar: National Statistical Office, 2013).

5 Andrew Goodland, Dennis Sheehy, and Tara Shine, "Mongolia: Livestock Sector Study," *Synthesis Report*, vol. I (Washington, DC: World Bank, 2009).

6 María E. Fernández-Giménez, "Sustaining the steppes: A geographical history of pastoral land use in Mongolia," *Geographical Review* 89 (3) (1999): 315–342.

7 United Nations Mongolia Country Team, *Mongolia 2010: Dzud Appeal*, (Ulan Bator: United Nations, 2010).

8 The loss was higher than the national average since the extreme winter affected the western part of Mongolia more severely. However, other regions of the country recorded even higher losses.

9 A similar finding was obtained when the intensity of the extreme winter was approximated by winter temperature (see Lehmann-Uschner and Kraehnert, "When shocks become persistent").

Box

Database: a household panel survey in western Mongolia

This report uses data from a household panel survey, the *Coping with Shocks in Mongolia Household Panel Survey*, conducted by DIW Berlin in collaboration with the National Statistical Office of Mongolia.[1] The data were collected in three provinces in western Mongolia: Govi-Altai, Uvs, and Zavkhan. A total of 49 of the 61 districts in the survey region were included in the data collection.[2] Both herding households and those without animals were among the 1,768 households in the survey. Based on the population census of 2010, the sample is representative for the rural and urban population in each of the three provinces. Each household in the sample was surveyed a total of three times between 2012 and 2015, exactly 12 and 24 months after the first interview for a second and third time. The study presented here only includes the sample households that possessed livestock in 2009—before the extreme winter of 2009/2010.[3]

The household questionnaire included the demographic and socio-economic characteristics of all household members. The migratory history of all adults was also part of the survey, including their districts of birth and residence in 2009. Further, all adults were asked questions about their employment history and their parents' professions. Households were asked detailed questions about their livestock. For each of the five common types of animals, the number of animals at the time of the three surveys as well as changes in the number of animals in the past 12 months before the interview were documented. There were separate questions on the purchase, sale, and slaughter of animals for personal use, the transfer of animals between households, and unexpected herd depletion. A further module contained questions about the households' past: their number of animals before the shock (in 2009) and their livestock losses in the extreme winter of 2009/2010. This retrospective information was collected twice; in the first and then again in the third panel wave. The two sets of information are practically identical, which reinforces the quality of the data. In addition to the household questionnaire, a district questionnaire was used to record responses regarding infrastructure and population characteristics.

The data of the household survey were merged with aggregated data from Mongolia's historical livestock census. Every year in December since the 1950s, Mongolia's National Statistical Office has collected data on the number of animals and herd depletion over the 12 previous months. Data on each of the five common types of animals is collected separately. Based on this data, livestock mortality per district in 2010 was calculated. This variable measures the difference in the intensity of the extreme winter of 2009/2010 among the districts in the survey region.

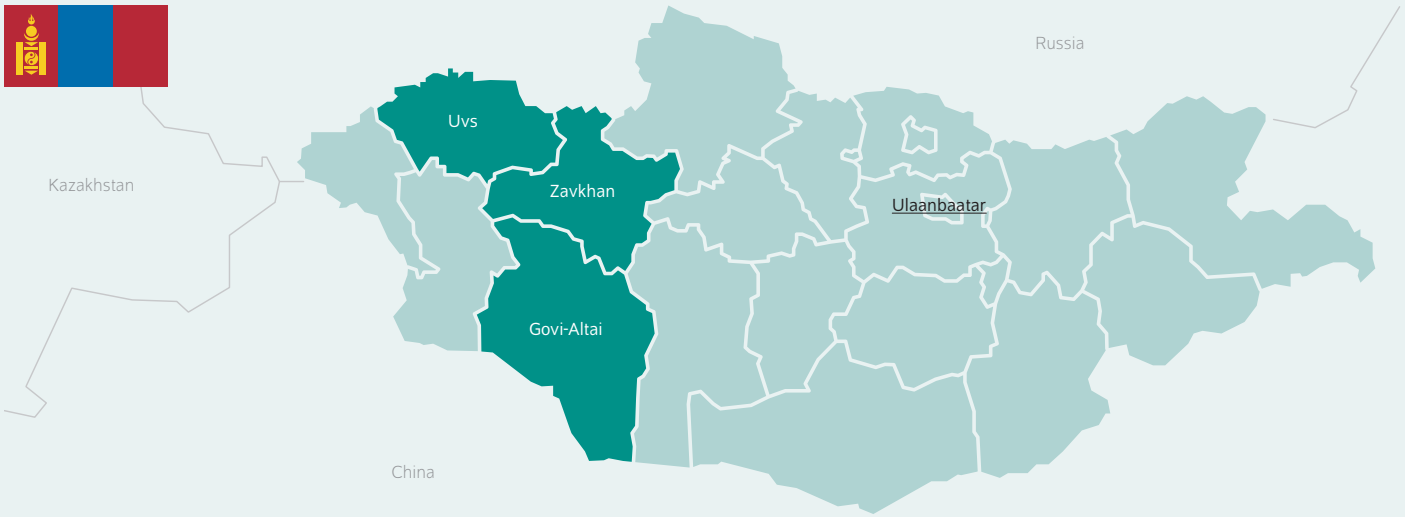
1 Kati Kraehnert, Katharina Lehmann-Uschner, Valeria Groppo and Veronika Bertram-Huemmer, *Coping with Shocks in Mongolia Household Panel Survey*, Wave 1–3, Version 1.0, German Institute for Economic Research and the National Statistical Office of Mongolia (2017).

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

3 The attrition rate—the proportion of households that dropped out of the sample between the first and third waves—is less than three percent. This very low attrition rate is striking because over half of the households in the sample are nomads.

Figure

The provinces of Mongolia



Source: Authors' own depiction.

The household panel survey was conducted in three western Mongolian provinces.

fact that the respondents' parents were herders nor the age of the head of household had a significant effect on the herd depletion suffered in 2010. The response strategies that some households deployed during the extreme winter (additional nomadic migratory movement and the sale of animals) were just as ineffective. Only those households whose head worked exclusively as a herder before the shock recorded lower losses by six percentage points. This could be the result of these households being able to deploy more labor in caring for the weakened animals during the winter months. Households headed by women recorded significantly higher losses. Such households are likely to be disadvantaged when it comes to accessing good pasture land and have fewer coping strategies available than households headed by men.

These findings suggest that neither socio-demographic characteristics nor household behavior during the shock could have reduced the loss of livestock. The spatial intensity of the extreme winter is the most robust explanatory factor for the level of household herd depletion. In view of the significance of livestock for household assets, the livestock mortality suffered by those affected represents a massive drop in assets as a direct result of the extreme winter.

Many severely affected households abandoned herding

Around 13 percent of sample households gave up herding in 2010. In a second step, the analysis examines to what extent the extreme winter caused this. To do so, a binary variable that takes the value one when a household stopped herding after the shock, was regressed on a measure of the intensity of the extreme winter and further control variables at the household and district levels.

The results show that the herd depletion suffered by households in 2010 was by far the single most important predictor for dropping out of herding. (Table 2). A rise in livestock mortality of ten percent increased the probability that former livestock owners would give up herding after the shock by 1.4 percent. A comparable finding was achieved regardless of whether the intensity of the extreme winter was measured by livestock mortality in a district or winter temperature.[10] Some household characteristics also have a significant effect on the probability of giving up herding, but the magnitude of the effect of these socio-demographic variables was much lower than that of the weather's effect.

Mongolia's economic and social structures are facing major challenges because so many households have stopped herding. In the rural sections of the survey region, there are virtually no employment opportunities outside of herding. Many of those who abandoned herding moved to the city to earn their wages as hired hands. Both their gross household income and assets were lower in 2012[11] compared to those of households that continued herding and urban households that did not own any animals before the extreme winter.

Because herders are highly regarded in Mongolian culture, giving up herding also entails diminished social status.[12]

10 See Lehmann-Uschner and Kraehnert, "When shocks become persistent."

11 All assets were added together at their current value here. See Lehmann-Uschner and Kraehnert, "When shocks become persistent."

12 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).

Table 1

Effects of the extreme winter of 2009/2010 on households' livestock mortality

	Dependent variable: Household-level livestock mortality in 2010, in percent
Measure of winter intensity	
Livestock mortality per district in 2010, in percent	0.70***
Household characteristics	
Herd size in 2009 (in log)	0.01
Household lived in rural area in 2009	0.02
Household head was full-time herder in 2009	−0.06**
Spouse of household head was full-time herder in 2009	−0.02
Parents of household head were herders	−0.03
Household head always lived in current district	−0.03
Age of household head	0.00
Household head is female	0.09***
Household head has secondary or higher education	−0.03
Shock coping strategies	
Additional migration during winter of 2009/2010	0.00
Household sold livestock	−0.03
Number of households	1,056

Note: Model estimated as generalized linear model. Significance levels: ** p<0.05, *** p<0.01. Additional variables at the district level and fixed effects at the province level were used.

Sources: Coping with Shocks in Mongolia Household Panel Survey und Mongolia Livestock Census; authors' own calculations.

Table 2

The effects of the extreme winter of 2009/2010 on abandoning herding

	Dependent variable: household gives up herding after winter of 2009/2010
Measure of winter intensity	
Household-level livestock mortality in 2010, in percent	0.14***
Household characteristics	
Herd size in 2009 (in log)	−0.02***
Household lived in rural area in 2009	0.00
Household head was full-time herder in 2009	−0.03***
Spouse of household head was full-time herder in 2009	−0.04***
Parents of household head were herders	−0.04***
Household head always lived in current district	−0.04***
Age of household head	0.00
Household head is female	−0.01
Household head has secondary or higher education	−0.01
Shock coping strategies	
Additional migration during winter of 2009/2010	0.02*
Household sold livestock	0.00
Number of households	1,056

Note: Model estimated with probit. Significance levels: * p<0.1, *** p<0.01. Additional variables at the district level and fixed effects at the province level were used.

Source: Coping with Shocks in Mongolia Household Panel Survey und Mongolia Livestock Census; authors' own calculations.

Years later, herds of affected households are still growing slowly

On average, the households in the sample that continued to herd after the extreme winter possessed the same number of animals in 2014 as they did in 2009, before the shock. However, there are major differences in the extent and speed with which households recovered from the loss they suffered. Around one-quarter of households owned only half as many animals or even less in 2014 as they did in 2009.

To find out how the extreme winter of 2009/2010 affected the livestock of households that continued to herd, annual herd growth after the shock was regressed on an intensity measure of the extreme winter, plus the control variables previously used. Additional control variables are included in the regression, such as whether or not households were exposed to shocks in the previous year (unrelated to the extreme winter of 2009/2010), as those factors may also influence herd growth after the extreme winter. For the econometric estimate, data from all three panel waves are used.[13]

The results show that the extreme winter of 2009/2010 has a negative effect on the herd growth of households—also in the long term (Table 3). Households that suffered high livestock losses due to the extreme winter also show significantly lower herd growth between 2012 and 2015 in comparison to the households less severely affected by the extreme event. A rise in livestock mortality by ten percent in 2010 reduces annual growth rates by an average of 5.2 percent. And households that unexpectedly lost animals in the previous year—due to illness or wild animals, for example—have significantly lower growth rates than those that did not experience any shocks. However, the size of the effect of the recent shock is much smaller—around 33 percent—than the effect of the extreme winter of 2009/2010.

In a final step, the analysis tests whether the strategies that households applied in 2010 to cope with the extreme winter have long-term effects on herd growth. This was not the case (Table 3): neither additional nomadic migratory movement during the winter months nor the emergency sale of animals in 2010 had a significant effect on herd growth. And not only did the livestock of affected households continue to bear traces of the extreme weather event years later—other research has shown that the education and health of the children in affected families suffered significantly, which in turn has consequences on future income and prosperity.[14]

Conclusion

The present study documents that an extreme weather event has a negative effect on the asset base and asset growth rate of herders in Mongolia. On the one hand, extreme weather conditions in winter 2009/2010—very low temperatures and an unusually high amount of snow—led directly to the death of animals on a massive scale. On the other hand, the extreme winter depleted the livestock and with it, household wealth in the longer term. Even five years after the extreme event, the severely affected households recorded significantly

13 For a detailed explanation of the econometric approach, see Lehmann-Uschner and Kraehnert, "When shocks become persistent."

14 See Kati Kraehnert and Valeria Groppo, "Extreme weather events affect many Mongolian children's ability to complete schooling," DIW Weekly Report no. 40 (2018) and Valeria Groppo and Kati Kraehnert, "The Impact of Extreme Weather Events on Children's Height: Evidence from Mongolia," DIW Economic Bulletin no. 12 (2014): 3–9 (available online, accessed September 27, 2018).

Table 3

Effects of the extreme winter of 2009/2010 on post-shock herd growth

	Dependent variable: annual growth rates in herd size between 2012 and 2015		
Measure of winter intensity			
Household-level livestock mortality in 2010, in percent (in log)	−0.52***	−0.48***	−0.44***
Other shocks in previous year			
Household experienced livestock losses in previous year	−0.17***	−0.17***	−0.18***
Shock coping strategies			
Additional migration during winter of 2009/2010		−0.29	
Additional migration x household-level livestock mortality in 2010		0.12	
Household sold livestock			2.10
Household sold livestock x household-level livestock mortality in 2010			−0.29
Constant	−2.68**	−4.65***	−4.70***
Number of households	855	844	844

Note: Model estimated with the Hausman-Taylor estimator. Significance levels: ** p<0.05, *** p<0.01. Additional variables at the district level and fixed effects at the province level were used.

Source: Coping with Shocks in Mongolia Household Panel Survey und Mongolia Livestock Census; authors' own calculations.

lower herd growth than those that were moderately affected. Neither experience nor informal coping strategies were able to mitigate the consequences of the extreme winter as it occurred. A sizable group of households lost the majority of their herd, stopped herding after the extreme event, and moved to cities—typically with negative consequences for their income and wealth. Among the households that continued to herd, inequality increased. While households that were hardly affected by the extreme winter recorded relatively high herd growth in subsequent years, the group of households whose livestock was just above the minimum number of animals required for a livelihood based on herding increased. This group of households is particularly vulnerable to future extreme events.

And in the future, more and more extreme weather events can be expected.[15] Some regions of Mongolia were again exposed to extreme weather conditions in the winters of 2015/2016, 2016/2017, and 2017/2018; and again, the livestock mortality rate rose sharply. Given the circumstances, policy measures that support rural households in their effort to adjust to an increasingly extreme climate and sustainably protect their livestock are advisable.

15 Sonia I. Seneviratne 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*, eds. Christopher B. Field et al. (Cambridge and New York: IPCC, 2012): 109–230.

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DIW Weekly Report 40 2018

AT A GLANCE

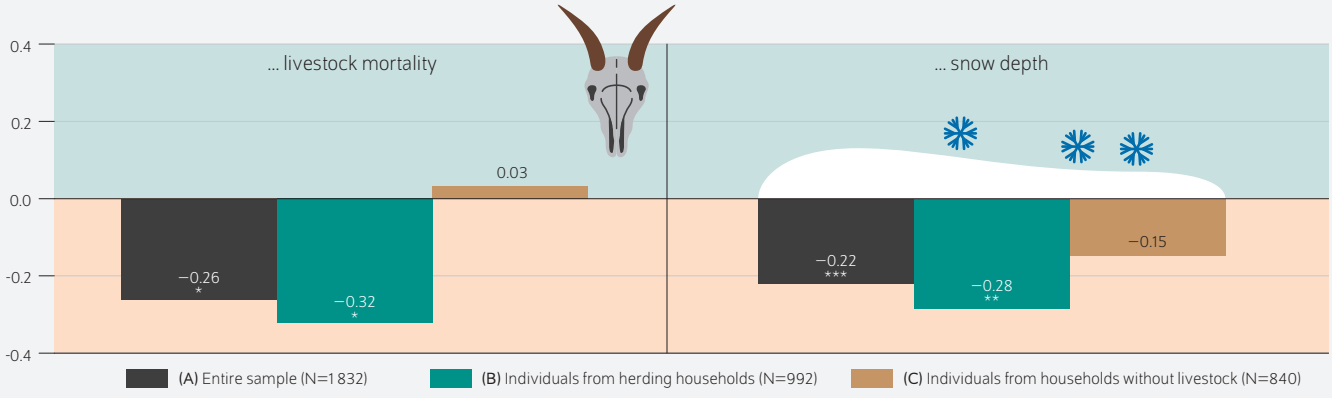
Extreme weather events drastically reduce school completion by Mongolian children

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).

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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

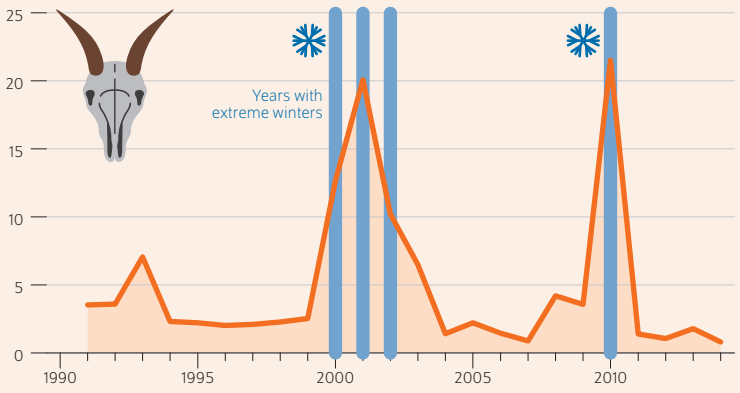
Mongolia's continental climate is not very suitable for commercial agriculture. Moreover, as manufacturing companies are based almost exclusively in the capital Ulaanbaatar, herding is the country's most important employment sector: in 2012, around 35 percent of the Mongolian workforce was employed in 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).

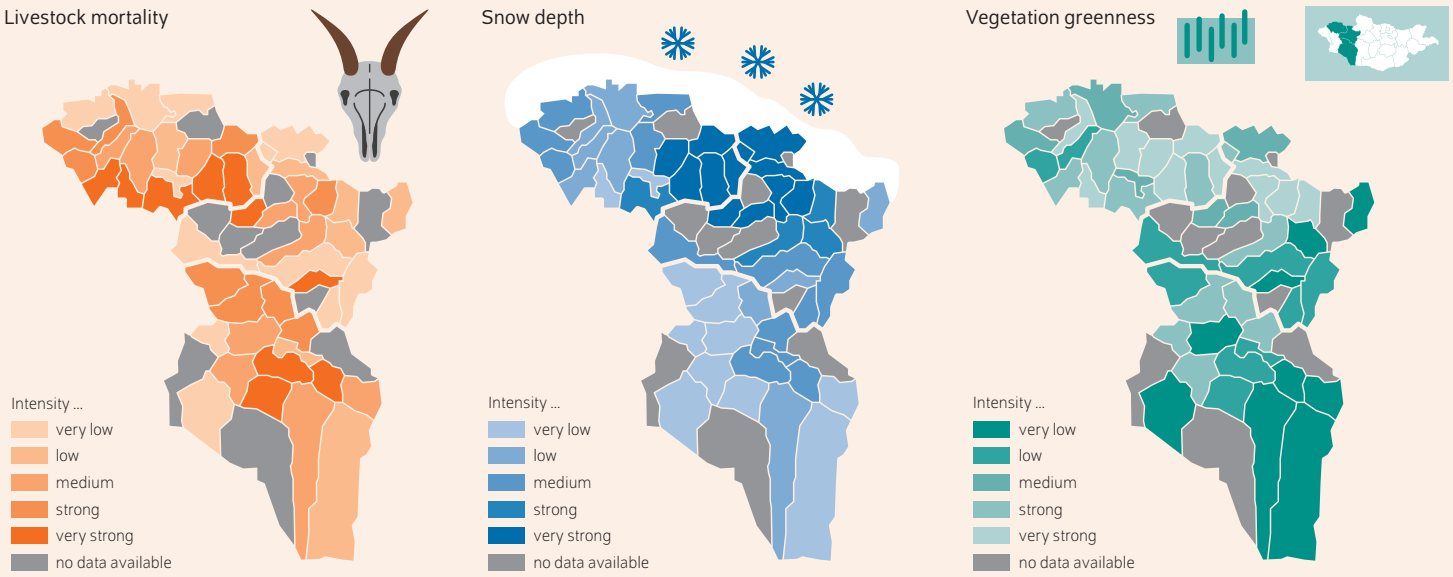
11 Kati Kraehnert, Katharina Lehmann-Uschner, Valeria Groppo, and Veronika Bertram-Huemmer, "Coping with Shocks in Mongolia Household Panel Survey," Wave 1-3, Version 1.0. German Institute for Economic Research and the National Statistical Office of Mongolia (2017).

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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AT A GLANCE

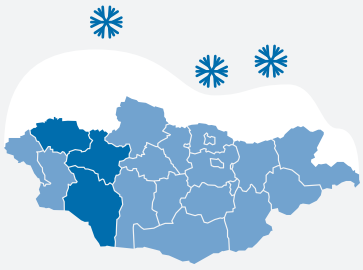
Weather index insurance can help households recover from extreme weather events

By Kati Kraehnert and Veronika Bertram-Huemmer

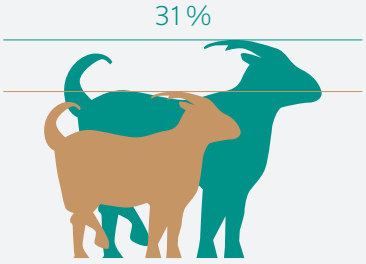
- Study is one of the first to evaluate the effects of a globally recognized weather index insurance to help people cope with the consequences of extreme weather events
- Index insurance payouts are not based on the actual losses suffered; rather, they are triggered if an objective index (regional livestock mortality) exceeds a threshold
- Results show that the Index-Based Livestock Insurance in Mongolia has a clear positive effect on the economic recovery of households after an extreme winter
- Insured households have herds up to a third larger than uninsured households in the initial three years after an extremely cold and snowy winter
- Index insurance can prevent extreme weather events from causing poverty

Herding households in Mongolia which took out a weather index insurance policy have herds almost a third larger than uninsured households two years after an extreme winter

Index insurances do not compensate policy holders based on the actual losses suffered. Instead, an insurance payout is triggered when a predefined value (in this case, for regional livestock mortality) is exceeded. Advantages include lower costs because individual damage assessment is unnecessary.



If an extreme weather event occurs—such as extremely cold and snowy winters in Mongolia—**insured households receive an insurance payout.**



The results show that insured households in Mongolia recover faster from the losses suffered. **Two years after the extreme winter they have 31 percent more animals than uninsured households.**

Source: Authors' own depiction.

FROM THE AUTHORS

Households with a weather index insurance policy recover more quickly from extreme weather events, as the example of Mongolia shows. Insurance companies and politicians should take this opportunity to raise awareness of and promote index insurance.

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

DATA

Between 2012 and 2015,
1,768 households
in western Mongolia were surveyed three times each for this project.

Weather index insurance can help households recover from extreme weather events

By Kati Kraehnert and Veronika Bertram-Huemmer

ABSTRACT

Weather index insurance is considered a promising international climate policy instrument that can help households adapt better to climate change. This is especially true in developing countries where households often suffer severely from the consequences of extreme weather events. This report is one of the first to evaluate the impact of a globally recognized index insurance, Mongolia's Index-Based Livestock Insurance (IBLI). The empirical study is based on econometric methods and uses data from a survey of almost 1,800 households. It shows that index insurance has a clear positive effect on households: in the first three years after an extremely cold and snowy winter, insured Mongolian households are significantly better off than uninsured households in terms of their livestock, which is the key indicator of income and wealth in this context. Two years after the disaster, their herds were almost a third larger than those of uninsured households. In many places, index insurance could be a suitable measure to prevent poverty after extreme weather events.

Climate change is one of the greatest challenges of our time.[1] As a result of climate change, extreme weather events such as storms, heat waves, and heavy rainfall occur more frequently and with greater intensity.[2] Households in developing countries are affected in particular: a large part of the population in these countries is directly or indirectly dependent on agriculture and thus the weather, while the governments there often lack the financial and technical resources to manage climate risks.[3] Accordingly, most households in developing countries must cope with the damages caused by extreme weather events themselves. They face the threat of a vicious cycle of extreme weather events, poverty, and underdevelopment.

Against this background, there is a great need for policy instruments to help households in developing countries to adapt to climate change and reduce their vulnerability to extreme weather events. The Paris Agreement, which was agreed upon at the 2015 United Nations Climate Change Conference (COP 21), set the goal of helping developing countries adapt to climate change, which has become a key goal of Germany's development cooperation as well.[4] Index insurance is an instrument with currently high expectations.[5] During the 2017 United Nations Climate Change Conference (COP23) in Bonn, the Global Partnership InsuResilience was launched under the German G20 presidency, a global partnership which promotes index-based disaster financing

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).

2 Sonia I. Seneviratne 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. (Cambridge and New York: Cambridge University Press, 2012), 109–230.

3 World Bank, *World Development Report 2010: Development and Climate Change* (2010) (available online; accessed August 24, 2018; this applies to all other online sources in this report unless stated otherwise).

4 Deutsche Gesellschaft für Internationale Zusammenarbeit, *Climate Risk Insurance for Strengthening Climate Resilience of Poor People in Vulnerable Countries: A Background Paper on Challenges, Ambitions, and Perspectives* (2015) (available online).

5 Cf. Helen Greatrex et al., "Scaling up index insurance for smallholder farmers: Recent evidence and insights." Paper presented at the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS), Copenhagen, Denmark, 2015; Michael R. Carter et al., "Index-based weather insurance for developing countries: A review of evidence and a set of propositions for up-scaling." FERDI Development Policies Working Paper P111, 2014.

solutions.[6]So far, there are hardly any methodologically robust findings on whether or not weather index insurance achieves the desired goal of increasing household resilience to weather risks. There are two reasons for this knowledge gap: first, there are only a few household surveys in developing countries that would be suitable for evaluating the impact of an index insurance. Second, index insurance is a relatively new instrument. In most of the regions where such insurance has been offered, there have not (yet) been any extreme weather events which would have triggered an insurance payout and thus made an assessment possible.[7]

This report presents the results of a quantitative impact assessment of an index insurance which is highly regarded globally: the Mongolian Index-Based Livestock Insurance (IBLI).[8]

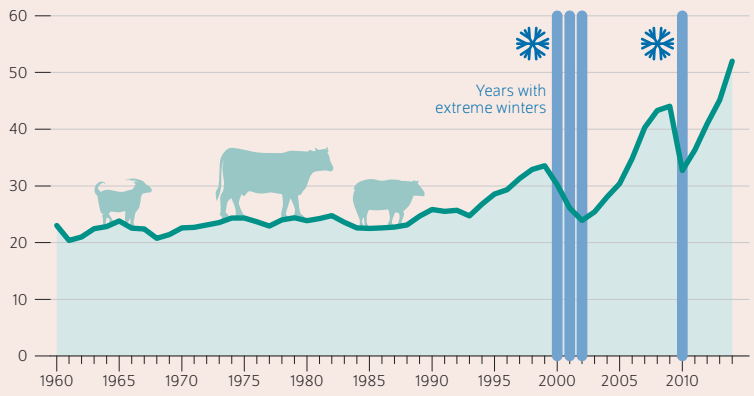
Weather index insurance a highly promising tool for adapting to climate change

Weather index insurance was first tested in the 2000s as a pilot project in developing countries.[9] Unlike traditional insurance products, the actual losses suffered by an insured household do not determine the insurance payouts of index insurances. Instead, insured households receive insurance payouts whenever an index measured at an aggregated level—such as temperatures, precipitation, or wind speeds—exceeds or falls short of a predefined threshold. Ideally, the index correlates strongly with the weather-related losses suffered by the insured household. The insurance payout should help insured households recover from damages after an extreme weather event.

Weather index insurance has several advantages over traditional insurance, which explains why its potential is a current topic of political discussion. The first advantage is that the problem of adverse selection is minimized: because the actual losses suffered by insured households do not determine the insurance payouts, it is not only primarily households with an increased risk from the outset which acquire an insurance policy. Second, the moral hazard problem is avoided: insured households have no incentive to behave in a more risk-averse manner after taking out the insurance policy and to accept losses, as the index alone determines the insurance payout. Finally, because the losses suffered do not have to be proven, transaction costs are significantly lower for index insurance compared to traditional loss-based insurance.

Figure 1

Livestock development in Mongolia between 1960 and 2014
Number of livestock (in million)



Note: The blue lines illustrate years with extreme winters.

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

Extreme winters severly decimate livestock.

Harsh winters lead to significant losses in Mongolia

The focus of the present study is on Mongolia, a country which, similar to many other developing countries and transition economies, is often affected by extreme weather events. In Mongolia, extreme weather events take the form of extremely cold and snowy winters.[10] The consequence of an unusually harsh winter is high livestock mortality. This threatens the livelihood of the rural households which depend primarily on their livestock consisting of sheep, goats, horses, cows, or camels.

Extreme winters decimated livestock drastically nationwide in 1999/2000, 2000/2001, 2001/2002, and 2009/2010 (Figure 1). In the winter of 2009/2010, the highest livestock mortality rate in the past 50 years was recorded: more than ten million animals died nationwide, which corresponds to over 23 percent of Mongolia's livestock. As a result, many rural households no longer had a herd large enough to make a living. This was followed by a mass exodus of impoverished herders to provincial centers and the capital, Ulaanbaatar, where the wage labor sector is poorly developed and poverty is rising rapidly.[11]

6 Cf. Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung, *InsuResilience Global Partnership: Eine globale Partnerschaft im Rahmen der G20 und der V20* (in German; available online).

7 Two exceptions are the studies from Sarah A. Janzen and Michael R. Carter, "After the Drought: The Impact of Microinsurance on Consumption Smoothing and Asset Protection." NBER Working Paper Series 19702, 2013; and Nathaniel D. Jensen, Christopher B. Barrett, and Andrew G. Mude, "Cash transfers and index insurance: A comparative impact analysis from northern Kenya," *Journal of Development Economics* 129, no. 1 (2017): 14–28.

8 Veronika Bertram-Huemmer and Kati Kraehnert, "Does Index Insurance Help Households Recover from Disaster? Evidence from IBLI Mongolia," *American Journal of Agricultural Economics* 100, no. 1 (2018): 145–171.

9 Cf. Jerry R. Skees and Barry J. Barnett, "Enhancing microfinance using index-based risk-transfer products," *Agricultural Finance Review* 66, no. 2 (2006): 235–250; Barry J. Barnett and Olivier Mahul, "Weather Index Insurance for Agriculture and Rural Areas in Lower-Income Countries," *American Journal of Agricultural Economics* 89, no. 5 (2007): 1241–1247; Barry J. Barnett, Christopher B. Barrett, and Jerry R. Skees, "Poverty Traps and Index-Based Risk Transfer Products," *World Development* 36, no. 10 (2008): 1766–1785.

10 There are additional climate factors causing extreme weather events in central Asia, including relatively snowless and thus very dry winters which can also lead to livestock death.

11 Troy Sternberg, "Unravelling Mongolia's Extreme Winter Disaster of 2010," *Nomadic Peoples* 14, no. 1 (2010): 72–86.

Box

The Mongolian Index-Based Livestock Insurance (IBLI)

The Index-Based Livestock Insurance (IBLI) was introduced as a pilot project in three Mongolian provinces in 2006. Demand for IBLI policies quickly rose to over 20 percent and consequently, IBLI was expanded nationwide. IBLI insurance policies have been available in all 329 Mongolian districts since 2012. Policies are currently distributed by six different commercial insurance companies in Mongolia.

Every household decides if it wants to purchase an IBLI policy or not. Households take out IBLI insurance for one year at a time. Policies are sold between April and June every year when neither households nor insurance companies can estimate the intensity of the coming winter. The policy covers the risk of livestock loss in the months of December to June of the following year. If an extreme weather event occurs, insured households receive insurance payouts beginning in August of the following year. Households can purchase IBLI insurance protection for one or more of the five most common animals in Mongolia: sheep, goats, cows, horses, and camels. Furthermore, each household decides the insurance value for each species, which can be between one and 100 percent of the animal's market value. On average they are underinsured, as Mongolian households hedge 30 percent of the market value of their herds.[1] The IBLI premium reflects the local risk of loss and varies depending on the species and district.

The index used is the livestock mortality rate per district and species. The data used to calculate the index is the Mongolian livestock census, which has been conducted annually every December since the 1950s as well as another survey of livestock losses carried out annually every June by the National Statistical Office of Mongolia. Insured households receive an IBLI payout when the loss of a certain livestock species in their district exceeds six percent.[2] In the event of an insurance payout, the amount is based on the actual livestock mortality rate calculated for the respective district. Local banks handle both the premium payment and transferring the insurance payout in the event of an extreme weather event.

In 2009, 21.4 percent of the households in the sample used in this report purchased an IBLI policy. On average, these households insured 102 animals and paid a premium of around 14 euros. The extreme winter of 2009/2010 resulted in a livestock mortality rate exceeding the triggering threshold of six percent in all districts of the survey region. As a result, all sample households that purchased an IBLI policy in 2009 received an insurance payout in 2010. The payout was 232 euros on average.

1 Project Implementation Unit, *Index Based Livestock Insurance Project Implementation Report 2005–2012* (2012).

2 In some districts, a livestock mortality rate of five percent is the threshold that triggers the IBLI payout.

After Mongolia had been affected by extreme winters for three consecutive years between 1999 and 2002, there was a large need for political instruments which can better support rural households in the event of winter extremes and prevent migration to the cities. On behalf of the Mongolian government, the World Bank developed the Index-Based Livestock Insurance (Box).

New household panel data enable quantitative impact assessment

The data used for the impact assessment of weather index insurance is a household panel survey collected in Mongolia, the *Coping with Shocks in Mongolia Household Panel Survey*, which was conducted together with the National Statistical Office of Mongolia. Altogether, 1,768 households in western Mongolia were surveyed three times between 2012 and 2015. Each household was interviewed a second and third time exactly 12 and 24 months after the first interview. The sample is representative of the rural and urban populations in three provinces, Uvs, Zavkhan, and Govi-Altai (Figure 2). Only sample herding households were used for the impact evaluation presented here.

The household survey covers, among other things, the demographic characteristics of all household members as well as information on assets, income, IBLI policy, and the losses suffered during the extreme winter of 2009/2010. Detailed herd information was gathered: for each household, the survey recorded the herd size at the time of the three survey waves (2012, 2013, and 2014). Additionally, the households reported retrospectively on their herd size in 2011 (shortly after the extreme winter), in 2009 (before the extreme winter), and the extent of their livestock losses in 2010. To check the reliability of the retrospective livestock data, each household was asked for their herd size in 2009 and the losses in the following year twice, in the first and third survey waves. The correlation of the data was 79 and 83 percent; thus, the retrospectively surveyed livestock numbers appear to be very reliable.

Study design takes into account that IBLI is purchased voluntarily

The key question of the study is if weather index insurance helped households recover more quickly from livestock losses caused by the extreme winter of 2009/2010. The analysis investigates whether households that bought an IBLI policy before the extreme winter and received an insurance payout in 2010 had a larger herd in the years after the extreme winter than households that did not purchase an IBLI policy in 2009 and consequently received no payment. A fundamental

Table 1

Comparison of characteristics across insured and uninsured households

	Average		Significance level of the difference
	Insured households (purchased IBLI in 2009)	Uninsured households (did not purchase IBLI in 2009)	
Household head characteristics			
Share without education (percent)	10	13	
Share with primary education (percent)	56	58	
Share with secondary education (percent)	34	29	
Age (years)	45.08	44.64	
Risk preference (0=risk averse; 10=risk loving)	2.59	4.40	***
Household characteristics			
Number of livestock in 2009	349.15	308.01	
Share of goats in herd in 2009 (percent)	33	38	
Number of livestock lost in 2010	130.07	141.36	
Subjective welfare in 2009 (0=amongst the poorest; 10=amongst the richest)	6.10	5.72	*
Share of households living in rural areas (percent)	81	67	**
Sub-district characteristics			
Livestock mortality in 2010 (percent)	31	37	***
District characteristics			
Share of households living in mountain steppe (percent)	20	26	
Share of households living in forest steppe (percent)	15	13	
Share of households living in grass steppe (percent)	27	28	
Share of households living in desert steppe or desert (percent)	37	32	
Cellphone coverage (1=in few areas; 4=in all areas)	2.58	2.75	
Number of transport options to provinical center	1.41	1.53	
Observations	59	608	

Note: significance levels: * p<0.1, ** p<0.05, *** p<0.01.

Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

problem of casual analysis must first be addressed to answer this question—namely the fact that only one of the two states can be observed for each sample household: for insured households, only the herd size after the IBLI payout is known, and for uninsured households, only the herd size without receiving an insurance payout.

A further methodological challenge of the impact assessment is that households voluntarily decide to purchase an IBLI policy. Households which purchased an insurance policy in 2009 differ in other respects from uninsured households: for example, insured households are significantly less willing to take risks as uninsured households, they estimated their subjective wealth to be significantly higher in 2009, and they were significantly more likely to live in rural areas and in a sub-district with significantly lower livestock mortality in 2010 (Table 1). In other important features, however, insured and uninsured households do not differ significantly. In particular, there is no significant difference in regards to livestock numbers before and livestock loss during the winter catastrophe: households in both groups had a similarly large number of animals on average before the extreme winter (349 and 308 animals) and suffered similar high livestock losses (130 and 141 animals).[12]

A quasi-experimental econometric regression method—the bias-corrected matching estimator[13]—was employed to determine the causal effect of IBLI payouts on households in order to construct a counterfactual situation. This makes it possible to take into account the fact that insured and uninsured households differ in observable characteristics. The matching estimator relies on the assumption that the two household groups do not differ in unobservable characteristics.[14] A whole series of characteristics serve as control variables (Table 1).

Insured households recover more quickly from losses

The results of the regression analysis show that IBLI helps insured households recover more quickly from losses caused by extreme winters. Insured households which received an IBLI payout in 2010 had a significantly larger herd than uninsured households with comparable socioeconomic characteristics one year, two years, and three years after the extreme winter (Figure 3). The effect of the IBLI payouts is greatest two years after the winter disaster. At that time, insured

12 Herd size information throughout this article refers to the total number of animals in a household, with the five common species being considered equal, as is usual in Mongolia.

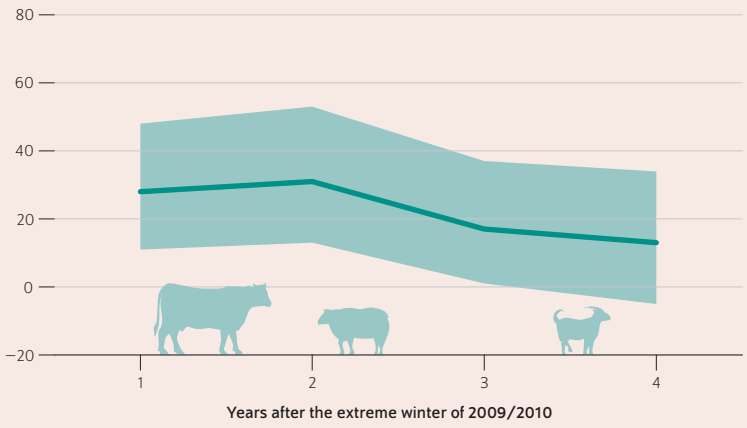
13 Alberto Abadie and Guido W. Imbens, "Bias-Corrected Matching Estimators for Average Treatment Effects," *Journal of Business & Economic Statistics* 29, no. 1 (2011): 1–11.

14 For technical details on the estimation procedure and other estimator assumptions, see Bertram-Huemmer and Kraehnert, "Does Index Insurance Help Households Recover from Disaster?".

Figure 2

Impact of IBLI payouts on the difference in herd size between insured and uninsured households after the extreme winter in 2009/2010

In percent



Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Two years after the extreme winter, insured households own 31 percent more livestock than comparable uninsured households.

households had herds larger than uninsured households by an average of 31 percent; this corresponds to around 40 animals. In the fourth year after the extreme weather event, the difference in herd sizes between insured and uninsured households is no longer statistically significant. Thus, the positive effect of an IBLI payout weakens over time.

Similar results are obtained when an alternative propensity score estimator or other control variables are used, or when the sample is reduced to households that match particularly well according to the matching method.[15] This emphasizes the robustness of the result.

Insurance likely works because it frees households from credit constraints

Initially it seems surprising that IBLI payouts have such a large economic effect on the herd sizes of insured households in the years following an extreme event; after all, insured households receive an average payment of only 232 euros. With this amount, households could have purchased 14 goats, ten sheep, two horses, or one camel at market prices in 2010.[16] The difference in herd sizes thus cannot be explained by insured households using their IBLI payouts to purchase new animals.

To determine which mechanisms of the IBLI payout benefit the insured households, the coping strategies used by households during and immediately after the winter catastrophe are analyzed. A section of the survey asks households to report retrospectively if they used any of the following five coping strategies:

- Borrowing money
- Selling livestock
- Moving livestock during harsh winters
- Organizing additional labor for herding
- Building shelter or fences for livestock

The same bias-corrected matching estimator and control variables were used to make insured and uninsured households comparable in observable characteristics. Nevertheless, in contrast to previous estimates, these results should not necessarily be interpreted causally, since, for example, other factors that could not be taken into account here play a role.

The regression results show that insured households were significantly more likely to borrow money during or immediately after the extreme winter of 2009/2010 than comparable uninsured households (Table 2). This effect is not only statistically significant, but also large. A further empirical observation fits in with this result: in 2012, households which had purchased an IBLI policy in 2009 had a significantly higher amount of outstanding loans than households without an IBLI policy. A logical conclusion to be drawn from these results is that IBLI increases the credit worthiness of insured households and, as a result, facilitates their access to credit. The IBLI policy documents the amount and value of livestock owned by an insured household and can serve as collateral at any bank. In an economy where rural households often cannot prove ownership rights on paper, livestock insurance policies serve as proof of ownership in addition to the insurance coverage.

Insurance likely prevents households from selling livestock

A further result of the regression analysis is that insured households were significantly less likely to have sold animals during or immediately after the extreme weather of 2009/2010 than comparable uninsured households. Such emergency sales are especially unprofitable: when many households sell livestock weakened by an extreme winter, the market prices for livestock sink—and thus the profit for the household selling. Further descriptive statistics reach a similar conclusion: 73 percent of insured households in the household survey stated that they used the IBLI payout to purchase food and other consumer goods for the household. Thus, it appears that insurance payouts help households avoid further decimating their herd by selling or killing them in order to meet their basic needs. With regard to the three other coping strategies—moving livestock, additional labor, and building shelters—insured and uninsured households do not differ significantly.

15 For regression results as well as further tests, see Bertram-Huemmer and Kraehnert, "Does Index Insurance Help Households Recover from Disaster?".

16 National Statistical Office of Mongolia, *Mongolian Statistical Yearbook 2010* (2011).

Table 2

The impact of IBLI payouts on the households' coping strategies after the extreme winter in 2009/10

	Borrowed money	Sold livestock	Moved livestock during extreme winter	Organized additional labor for herding	Built fences or shelter for livestock
Insured households (purchased IBLI in 2009)	0.377***	−0.159***	−0.085	0.09	0.017
Average of uninsured households	0.286	0.175	0.376	0.207	0.1
Observations	667	667	667	667	667

Note: Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

Sources: Coping with Shocks in Mongolia Household Panel Survey and Mongolia Livestock Census.

Conclusion: weather index insurance can improve recovery from weather extremes

This study is one of the first to prove that weather index insurance can effectively mitigate the negative consequences of an extreme weather event. The example of an extremely cold and snowy winter in Mongolia shows that households with index insurance are significantly better off than uninsured households in terms of their livestock and thus their financial situation. Two years after the extreme weather event, their herds were almost a third larger than those of uninsured households.

The rarity with which extreme weather events occur—although they will occur more frequently in the future due to climate change—is one of the reasons demand for index insurances is relatively low worldwide.[17] The key result of the impact assessment—that payouts from weather index insurance have a positive and significant influence on households' economic recovery after an extreme weather event—can be used by policymakers and in the insurance sector as an opportunity to raise awareness of index-based financial solutions.

17 Carter et al., *Index-based weather insurance for developing countries.*

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