The Impact of Extreme Weather Events on Children's Height: Evidence from Mongolia

By Valeria Groppo and Kati Krähnert

Shocks experienced during early childhood can harm the long term growth of children. We examine the potential impact of extreme weather events on children's height, taking the example of Mongolia, which is frequently plagued by extreme winters. Our focus is on the unusually harsh winter of 2009/10, which caused the deaths of over 10 million animals, approximately 23.9 percent of the country's entire stock. We identify causal effects by exploiting exogenous variation in the intensity of the shock across time and space. We find that the extreme winter of 2009/10 considerably impaired the growth of exposed children from herding households. Exposed children are small for their age, even three years after the event. It can be expected that the cohorts of exposed children will be smaller, poorer, and less healthy, even as adults.

External shocks, such as natural disasters, wars, and economic crises, can severely affect the lives of people. The children in developing and transition countries are particularly vulnerable to these events. In these economies, the availability of public safety nets and formal insurance schemes is often limited. Therefore, it is largely up to individual households to protect themselves against such shocks using informal strategies and to cope with the effects of shocks that have occurred. In these circumstances, households frequently prefer activities that generate a low but secure income. In the worst cases, this can lead to a vicious circle of poverty, shocks, and underdevelopment.1

A relatively new area within development economics examines the impact of such shocks on children. The motivation for this research can largely be traced back to the British physician and epidemiologist David Barker, who formulated the fetal origins hypothesis in the early 1990s.2 This hypothesis posits that fetuses adapt to malnutrition during pregnancy. According to Barker, this adaptation -a survival strategy for the unborn child- leads to permanent changes in physiology and metabolism in adulthood. The fetal origins hypothesis also states that children born underweight have a higher probability of suffering from coronary heart disease, diabetes, and high blood pressure as adults. Empirical studies testing Barker's hypothesis frequently find results consistent with the hypothesis. The empirical literature also provides evidence of a negative impact of shocks during pregnancy and in early childhood on human capital in the broad sense, including education, cognitive skills, and stature in children and adults.3

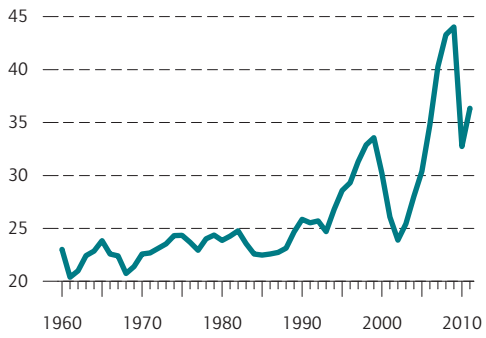
1 For example, see S. Dercon and L. Christiaensen, "Consumption risk, technology adoption and poverty traps: Evidence from Ethiopia," Journal of Development Economics 96 (2011): 159-173.

2 C. N. Hales and D. J. P. Barker, "Type 2 (non-insulin-dependent) diabetes mellitus: The thrifty phenotype hypothesis," Diabetologia 35 (1992): 595-601.

3 For an overview of the literature, see J. Currie, "Healthy, Wealthy, and Wise: Socioeconomic Status, Poor Health in Childhood, and Human Capital Development," Journal of Economic Literature 47. (2009): 87-122; and R.

Figure 1

Livestock in Mongolia
In millions



Source: Mongolia Livestock Census; calculations by DIW Berlin.

The *dzud* in the winter of 2009/10 caused the deaths of over 10.3 million animals.

The research presented here considers a shock in the form of an extreme weather event, an unusually harsh winter. Using data from Mongolia, we examined whether the winter of 2009/10 had a causal effect on the height of Mongolian children.4 Our research expands on the current state of knowledge by focusing on a shock in the form of a cold wave, while existing studies deal mostly with droughts and rainfall in tropical countries. Moreover, we provide evidence on the role of socio-economic characteristics and aid distribution in alleviating the effects of the shock.

Mongolia Is Prone to Extreme Weather Events

For various reasons, Mongolia provides an interesting context for studying this issue. First, the majority of the rural population lives from herding, a sector directly dependent on weather conditions.5 In 2011, 29.6 percent of Mongolian households owned livestock; for approximately 21.7 percent of households, herding represents the main economic activity.6 People live mainly nomadic or semi-nomadic lives, moving to different pastures with their herds each season. In 2013, Mongolian farmers owned an average of 213 animals (sheep, goats, cows, horses, and camels)7 providing meat, milk, milk products, and dung for heating as well as income from the sale of wool, fur, meat, and milk.

Second, Mongolia is persistently plagued by extreme weather events that cause widespread livestock deaths. The unusually harsh winters, known as dzud in Mongolian, are caused by a long-lasting combination of various unfavorable climatic factors. These include extremely low temperatures over a period of several days or weeks, too little or too much snow, and significant temperature fluctuations that melt the snow and then freeze the runoff. Dzuds were, and still are today, a major risk factor for Mongolian herders. Because dzuds are very local phenomena, it is difficult to predict when and where the next dzud will occur.

Since weather records began in Mongolia in 1950, dzuds have occurred, on average, every eight years. Climatologists argue that both the frequency and the intensity of dzuds have increased since the late 1990s and associate this trend with global warming and climate change.8

Figure 1 illustrates the development of national herd stocks from 1960 to 2011. Two particularly strong declines have occurred since the 1990s: three successive extreme winters in the years 1999 to 2002 were responsible for the deaths of 11.1 million livestock; the dzud in the winter of 2009/10 caused the deaths of over 10.3 million animals, approximately 23.9 percent of the national stock. These are the highest ever documented livestock losses in Mongolia triggered by an extreme weather event. In January 2010, the Mongolian government declared a national disaster and appealed to the international community for emergency assistance.9

The high livestock losses in the winter of 2009/10 had serious socio-economic consequences. For instance, as reported by the International Red Cross, the shock threatened the food security of severely affected fami-

Martorell, "Undernutrition During Pregnancy and Early Childhood: Consequences for Cognitive and Behavioral Development," in Early Child Development: Investing in our Children's Future, ed. M. E. Young (Amsterdam: 1997): 39-83.

4 For a detailed description, see V. Groppo and K. Schindler, "Extreme Weather Events and Child Height: Evidence from Mongolia," DIW Discussion Papers 1403 (2014).

5 Agriculture is only possible in some areas of Mongolia due to the extreme continental climate.

6 National Statistical Office of Mongolia, Monthly Bulletin of Statistics: December 2013 (Ulan Bator: 2013); National Statistical Office of Mongolia, "Mongolia has launched the main findings of its 2010 Population and Housing Census" (2011), en.nso.mn/content/49, last accessed on March 13, 2014.

7 National Statistical Office of Mongolia, Monthly Bulletin of Statistics: December 2013 (Ulan Bator: 2013).

8 P. Batima, L. Natsagdorj, et al., "Observed Climate Change in Mongolia," AIACC Working Papers 12 (2005); D. Dagvadorj, L. Natsagdorj, et al, Mongolia Assessment Report on Climate Change 2009 (Ulan Bator: 2009).

9 United Nations Mongolia Country Team, Mongolia; Zud Appeal, (Ulan Bator: 2010).

lies during winter months.10 Other studies indicate that herders limited their consumption of dairy and meat products in summer 2010.11 Approximately six percent of all herding households lost their entire livestock and thus their livelihoods; a further 19.3 percent lost half of their herd.12 The dzud also triggered a wave of distress migration by impoverished herders to the capital, Ulan Bator, with a consequent growth of informal settlements in the suburbs.

The Database

Our research is based on the Coping with Shocks in Mongolia Household Survey (see box).

Our outcome variable is a standardized measure of children's height, known as the height-for-age z-score (HAZ). The HAZ value is calculated for each of the 802 children aged 0 to 6 years included in our sample. Here, the actual measured height of each surveyed child is compared to the median height of children of the same sex and age. This median value is recorded in the World Health Organization's international reference dataset, which provides a worldwide representation of a child's height under optimal environmental conditions.13 A HAZ value of zero indicates that a child has the expected height for a healthy child of his or her age and sex. A HAZ value below zero indicates that a child is shorter than expected under optimal environmental conditions.

Furthermore, we use historic livestock census data to map the spatial intensity of the 2009/10 winter. A typical feature of dzuds is that they do not occur uniformly throughout Mongolia but are rather a very local phenomenon. Since the 1950s, the National Statistical Office of Mongolia has conducted an annual livestock census of all Mongolian herders every December. Data on the total number of livestock mortality per year and district are recorded in digital form since 1970. On the basis of these data, we define the intensity of dzud as the difference between a district's livestock mortality in 2010 and its average livestock mortality from 1970 to 2008, divided by the standard deviation of long-term livestock mortality, in the same district. This standardized measure of the intensity of the dzud takes into account that different ecological zones have different long-term risks of being hit by a dzud.

Figure 2 maps the intensity of the dzud from 2009/10 for each of the 49 districts in western Mongolia where the Coping with Shocks in Mongolia Household Survey is conducted. The intensity level varies from 1.7 to 13.2. It is worth noting that the measure is above zero for each of the 49 districts, indicating that mortality in 2010 is above the long-term average in all sample districts. This again illustrates the severity of the 2009/10 shock. However, the distribution of dzud intensity varies significantly: some districts were particularly badly affected by the dzud, while other districts were far less affected. To account for this heterogeneity, we transform the dzud intensity measure into an indicator variable that takes the value one if a district has a dzud intensity value above the 85th percentile of the distribution.14 This variable is then merged with data on children.

The Winter of 2009/10 Affected The Height of Children from Herding Households

Descriptive findings indicate a relatively high occurrence of malnutrition in western Mongolia. The average HAZ value for the sample of Mongolian children is -1.07. For about 14 percent of sample children, the HAZ value ranged from -2 to -3; these children are moderately stunted or small for their age by international standards. Ten percent of sample children have an HAZ value of -3 and their growth is therefore considered to be severely impaired.

We use a difference-in-differences approach to explore the causal effect of the 2009/10 shock on children's height. We exploit the spatial variation in the intensity of the dzud, by distinguishing between children who, during the shock, lived in a severely affected district and those who lived in less affected districts. We also exploit variation in children's dzud exposure based on their date of birth. We define the cohort of children who experienced the dzud in utero or as infants as the co-

10 International Federation of Red Cross and Red Crescent Societies, Mongolian Red Cross Society, Rapid Assessment of Zud Situation in Mongolia (January 18 – January 26, 2010) (Ulan Bator: 2010) (summary report).

11 See for example, M. E. Fernández-Gimenez, B. Batjav, et al, Lessons from the Zud: Adaptation and Resilience in Mongolian Pastoral Social-Ecological Systems (Fort Collins: 2012).

12 United Nations Mongolia Country Team (2010); National Statistical Office of Mongolia, Monthly Bulletin of Statistics: December 2010 (Ulan Bator: 2010).

13 The WHO Child Growth Standards dataset is based on a sample of healthy children from Brazil, Ghana, India, Norway, Oman, and the US, whose mothers followed general recommendations for childcare and nutrition. One finding from this international dataset (and other datasets) is that the height-for-age of healthy children from different countries and ethnic backgrounds is very similar. Therefore, it is a common practice in research to express the height of children in relation to an international reference value. WHO Multicentre Growth Reference Study Group, "WHO Child Growth Standards based on length/height, weight and age," Acta Pædiatrica. Suppl. no. 450 (2006): 76–85.

14 Similar results are obtained if a different percentile, for example, the 80th percentile—or the continuous intensity measure is used. A detailed description of the performed robustness tests can be found in Groppo and Schindler, "Extreme Weather Events."

Box

Household Survey in Mongolia

The longitudinal survey Coping with Shocks in Mongolia is conducted by DIW Berlin in cooperation with a local partner, the National Statistical Office of Mongolia, and is funded by the German Federal Ministry of Education and Research.[1] The sample includes 1,768 households in the three aimags (provinces) of Uvs, Zavkhan, and Govi-Altai, all in western Mongolia (see figure). A multi-stage sampling design is used so that the sample is representative of the population in western Mongolia. Each household in the sample will be surveyed three times from 2012 to 2015. The questionnaire collects demographic characteristics of all household members (e.g., age, gender, education, and health), dzud experience (e.g., retrospective questions about the dzud of 2009/10, expectations of future climate shocks), risk management strategies (e.g., migration, formal and informal insurance schemes), welfare (e.g., consumption, income, wealth, and food security) and policy-relevant information (such as transfer payments, participation in government education and health programs). The household survey also collects anthropometric data (height, weight, and arm circumference) of children aged 0 to 6.

1 For more detailed information, see www.diw.de/mongolei.

Figure

Mongolei

1 Die Erhebungsregion der Coping with Shocks in Mongolia-Haushaltsbefragung ist grau markiert.

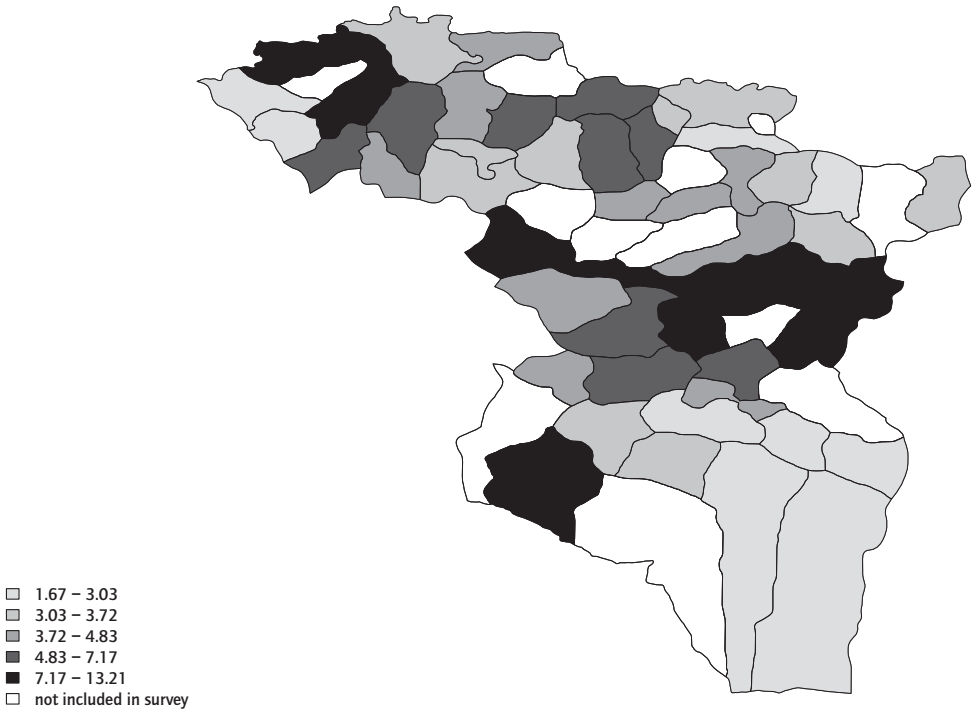
Quelle: Darstellung des DIW Berlin.

hort affected by the shock. The control group consists of children born nine months after the dzud or later (after March 2011).

In order to make causal statements about the impact of the shocks, additional factors must be taken into account in a multivariate regression. For example, it is possible that differences in height are not only due to the dzud but also to the relatively strong economic growth in recent years, which might have benefited in particular younger children. Equally, it may be that the more severely affected districts coincidentally also have poorer health infrastructures. It is also possible that households with a low level of education were more significantly affected by the shock than other households and were already experiencing a relatively less favorable food situation.

Figure 2

Intensity of 2009/2010 Dzud in Western Mongolian Districts



Source: Mongolia Livestock Census; calculations by DIW Berlin.

The intensity of the 2009/10 *dzud* varied greatly across districts in the study area.

The table shows the findings of a multivariate OLS regression where the dependent variable is the standardized measure of children's height (HAZ). The regression controls for characteristics of the child, the mother, the household, as well as for district fixed effects and time. For children from herding households exposed to the dzud as unborn babies or in infancy and who live in a severely affected district, the HAZ decreased by 1.67 standard deviations compared to same-age-children living in less affected districts.15 In contrast, children from other households (that did not own any livestock) were not affected by the dzud- the interaction term is not statistically significant. This suggests that the impact of the dzud is not only caused by the extreme weather conditions per se (which all children are exposed to) but is specifically due to the loss of livestock.16

Girls Are Affected by the Shock to a Lesser Extent than Boys

In the next step of the analysis, we highlight what socio-economic factors mitigate the negative consequences of shocks.17 An unexpected finding is obtained when considering gender differences. Both boys and girls are negatively affected by the dzud in terms of physical growth. However, this negative effect is significantly less

15 The measured effect is relatively large, as the following example shows. A boy who was 37 months old at the time of data collection and lived in a severely affected district during the d*zud* is around 5.25 cm smaller than a boy of the same age (with an otherwise identical socio-economic background) who lived in less affected districts.

16 To check the robustness of the findings, we constructed two alternative indicators of the intensity of the d*zud*. First, we use the amount of snowfall in winter 2009/10 per district. Second, we use the subjective assessment of the intensity of the 2009/10 shock from the perspective of the surveyed households (on a scale of 0 to 10). Both cases confirm the findings presented in the text: the d*zud* has significant negative effects on the height of children from herding households.

17 The findings described below refer to Tables 4 and 5 in V. Groppo and K. Schindler, "Extreme Weather Events."

Table

Effects of the 2009/10 *Dzud* on Children's Height
Estimated coefficients from OLS regressions

	Children from herding households	Children from non-herding households
Experienced the dzud as an unborn child/ infant and lived in a severely affected district[1]	−1.668**	0.355
Experienced the dzud as an unborn child/ infant	−0.024	−0.312
Observations	465	337
R^2	0.444	0.385

****, **, and * indicate statistical significance at the 1, 5 and 10 percent. Dependent variable: height-for-age z-score. Regressions also include characteristics of the child, mother, and household, as well as district, fixed effects, and time effects.*
1 Severely affected districts are districts in which the intensity of the dzud is above the 85th percentile of the intensity distribution.
Sources: Coping with Shocks in Mongolia Household Survey; Mongolia Livestock Census; calculations by DIW Berlin.

Children from herding households exposed to the dzud as unborn children or infants and who live in a severely affected district are significantly smaller than children of the same age living in less affected districts.

pronounced in girls. One possible explanation for this is that girls are not disadvantaged in the Mongolian culture or are even given slightly preferential treatment in terms of nutrition compared to boys of the same age.18 Most existing studies of other countries, however, find either no significant gender effects or a significantly adverse effect for girls.

We also find clear evidence that wealth reduces the negative effects of the dzud. Children from herding households that owned relatively larger herds before the winter of 2009/10 suffer significantly less in terms of height than children from households with smaller herds.19 A possible interpretation of these findings is that relatively wealthier households can afford to keep their consumption stable, even during a shock. In contrast, relatively poorer households seem to limit their consumption during shock months in order to maintain their livestock base and thus their livelihoods in the medium term.

Furthermore, our results suggest that access to external aid alleviates the effects of the dzud. The Mongolian government, international organizations, and local non-governmental organizations provided emergency aid in the form of food parcels and animal feed to households during the shock. On average, aid supplies amounted to 25.9 tons per district in the surveyed region. Regression findings show that emergency aid is significantly associated to higher height of children living in a severely affected district as unborn babies or infants. However, we cannot interpret this finding as a causal effect of emergency aid, but only as a correlation. This is because the criteria used to select households and districts for emergency relief distribution are not fully known.20

Conclusion

Our results show that the unusually harsh winter of 2009/10 impaired the physical growth of children in Mongolia. However, the negative effects of the shock are not uniform across children in the sample but vary according to their socio-economic background. For example, only children from herding households recorded a decline in physical growth. There is a statistically significant difference between girls and boys, and between children from poorer and wealthier households.

According to the current state of knowledge in nutritional science, at least to some extent, it is possible to compensate for the negative effects of malnutrition in early childhood, through nutrition programs. However, the time frame in which such programs are effective is limited. Frequently, an age limit of three years is assumed.21 In Mongolia, the negative effects of the 2009/10 dzud are still evident three years after the shock. Therefore, it is likely that these effects will persist. Studies based on long-term data from other empirical contexts have shown that malnutrition during early childhood is associated with a lower level of education, smaller stature and poorer health as adults, and lower lifetime earnings.22

18 Our finding could also be related to gender-specific mortality. For example, there is evidence that male embryos are more vulnerable to shocks than female embryos. See S. Kraemer, "The fragile male," British Medical Journal 321 (2000): 1609-1612; and J.E. Lawn, H. Blencowe, et al. "Beyond newborn survival: the world you are born into determines your risk of disability-free survival," Pediatric Research 74 (2013): 1-3.

19 A comparison was made of between herding households in the richest tercile and those in the poorest tercile of the distribution of livestock owned in 2009.

20 For example, the data from the Coping with Shocks in Mongolia Household Survey indicates that poorer households, households with a large number of children and households experienceing high livestock losses during the d*zud* were more likely to receive emergency aid. On the other hand, the worst affected districts did not necessarily receive more emergency aid, but aid was mainly distributed in districts with relatively less snowfall. Logistical costs seem to have played a role in selecting districts.

21 Martorell, "Undernutrition During Pregnancy."

22 H. Alderman and J. Hoddinott, "Long Term Consequences of Early Childhood Malnutrition," Oxford Economic Papers 58 (2006): 450–474; S. Dercon and C. Porter, "Live Aid Revisited: Long-Term Impacts of the 1984 Ethiopian Famine on Children," Journal of the European Economic Association 12 (2014): 927–948; S. Maccini and D. Yang, "Under the Weather: Health, Schooling, and Economic Consequences of Early-Life Rainfall," American

The same patterns are to be expected for the cohort of Mongolian children affected by the dzud.

Our findings lead to the conclusion that households' strategies alone are not sufficient to protect children from the negative consequences of such extreme weather events. However, our results on the positive correlation between food aid during the dzud and children's height are encouraging. It would therefore be advisable to set up support programs that can help households in case of future extreme weather events. Such programs should be primarily directed at herding households with young children and pregnant women, as well as households with small herds.

Valeria Groppo is Research Associate in the Development and Security Department at DIW Berlin | vgroppo@diw.de

Kati Krähnert is Acting Head of the Development and Security Department at DIW Berlin | kkraehnert@diw.de

JEL: I15, J13, O12
Keywords: anthropometrics, children, health, Mongolia, weather shocks

Economic Review 99 (2009): 1006–1026; J. Strauss and D. Thomas, „Health over the Life Course," chap. 54, in Handbook of Development Economics, vol. 4, ed. T.P. Schultz and J. Strauss (North-Holland, 2008): 3375–3474.

DIW BERLIN

DIW Berlin—Deutsches Institut
für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
T +49 30 897 89 -0
F +49 30 897 89 -200

Volume 4, No 12
6 March, 2015
ISSN 2192-7219