2024 RESILIENCE LEARNING MONTH

ADB

The Economic Impact of Weather Shocks on a Cold Climate Developing Economy: Evidence from Mongolia

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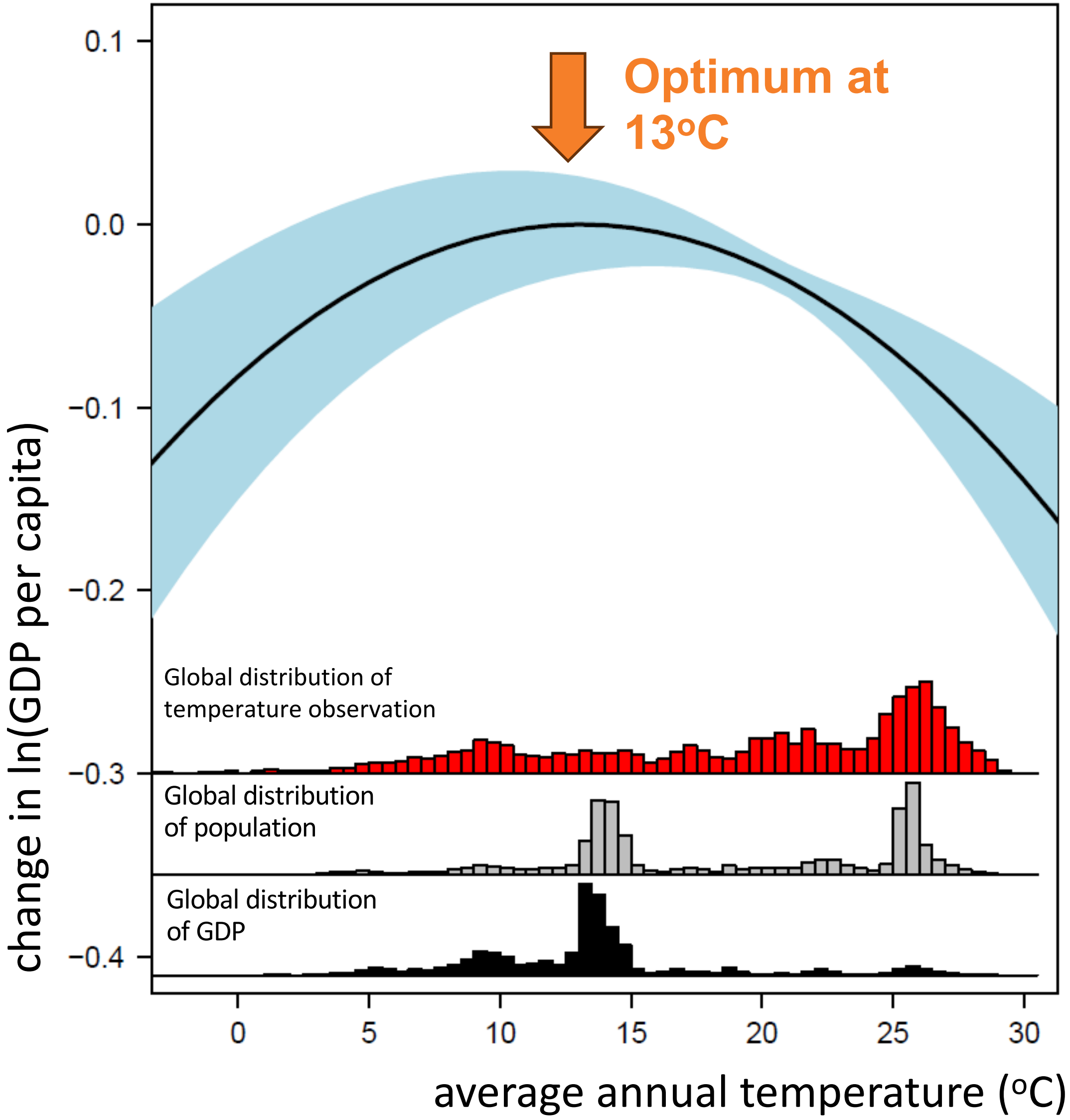
Research Motivation

Global non-linear effect of temperature on economic production

Burke, Hsiang, & Miguel (2015)

- Country-level log gross domestic product (GDP) per capita from 1960-2010 is non-linear and concave with temperature, with maximum at 13 ^{o}C
- Cold-country increases productivity as temperature increases until optimum (13 ^{o}C)

NOTE: The relationship is not necessarily causal (e.g., more temperate climate countries have higher GDP), but it's not necessarily (at least entirely) BECAUSE their climate is better than they do better)

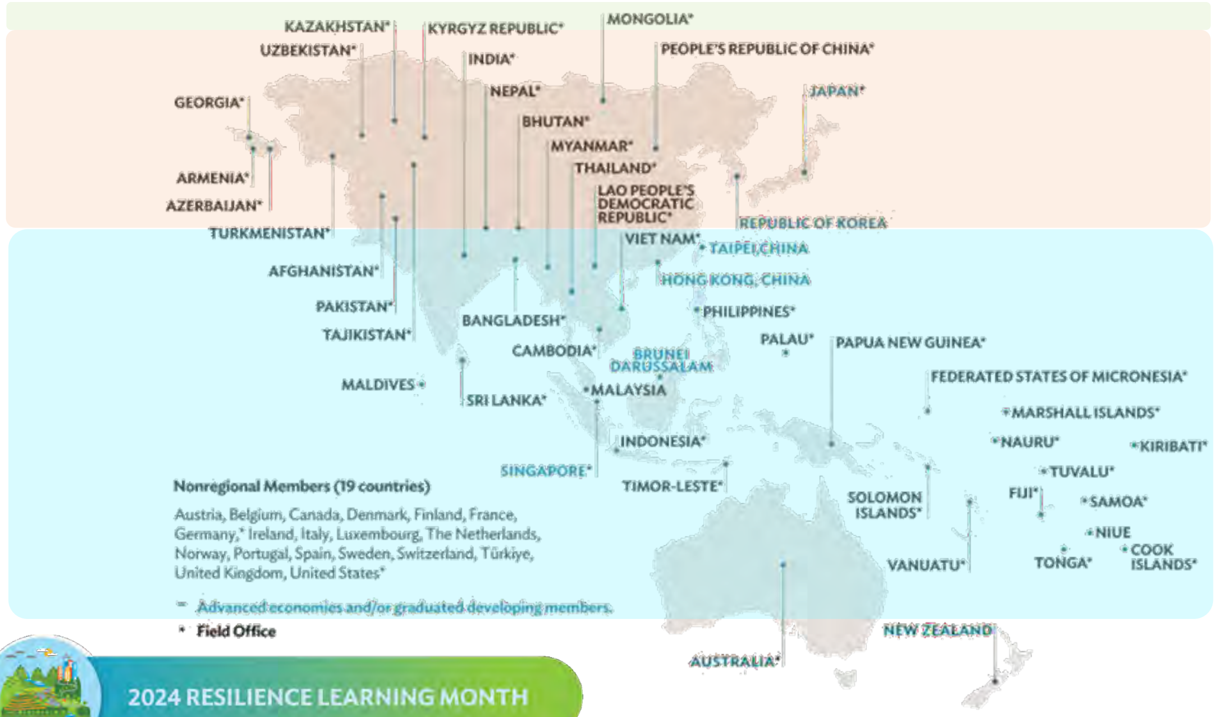


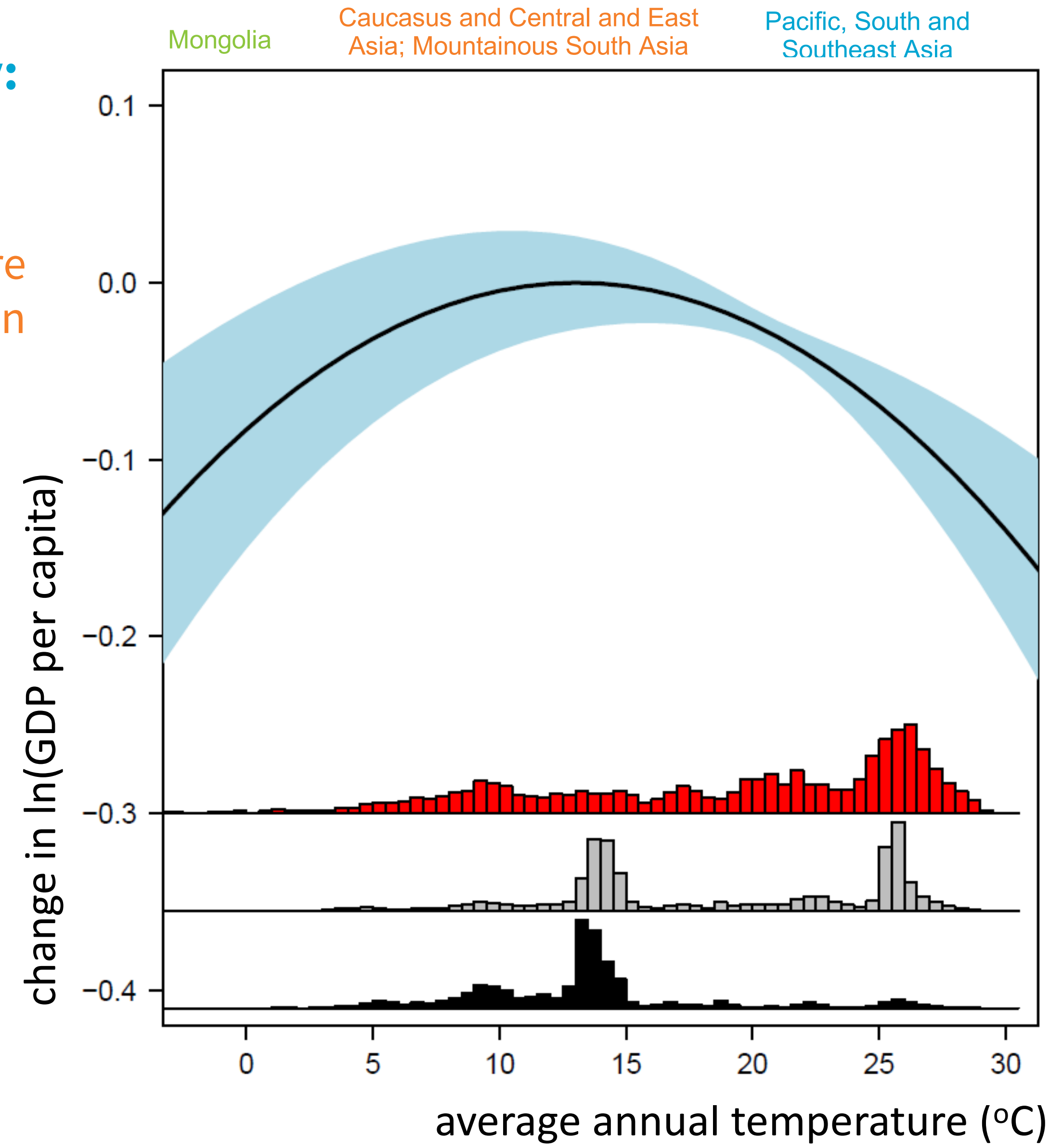
Research Motivation

The Effects of Weather Shocks on Economic Activity: What are the Channels of Impact?

Acevedo et al (2020)

- Supported findings that hot countries, which are overwhelmingly low-income, suffer the most from an increase in temperature.





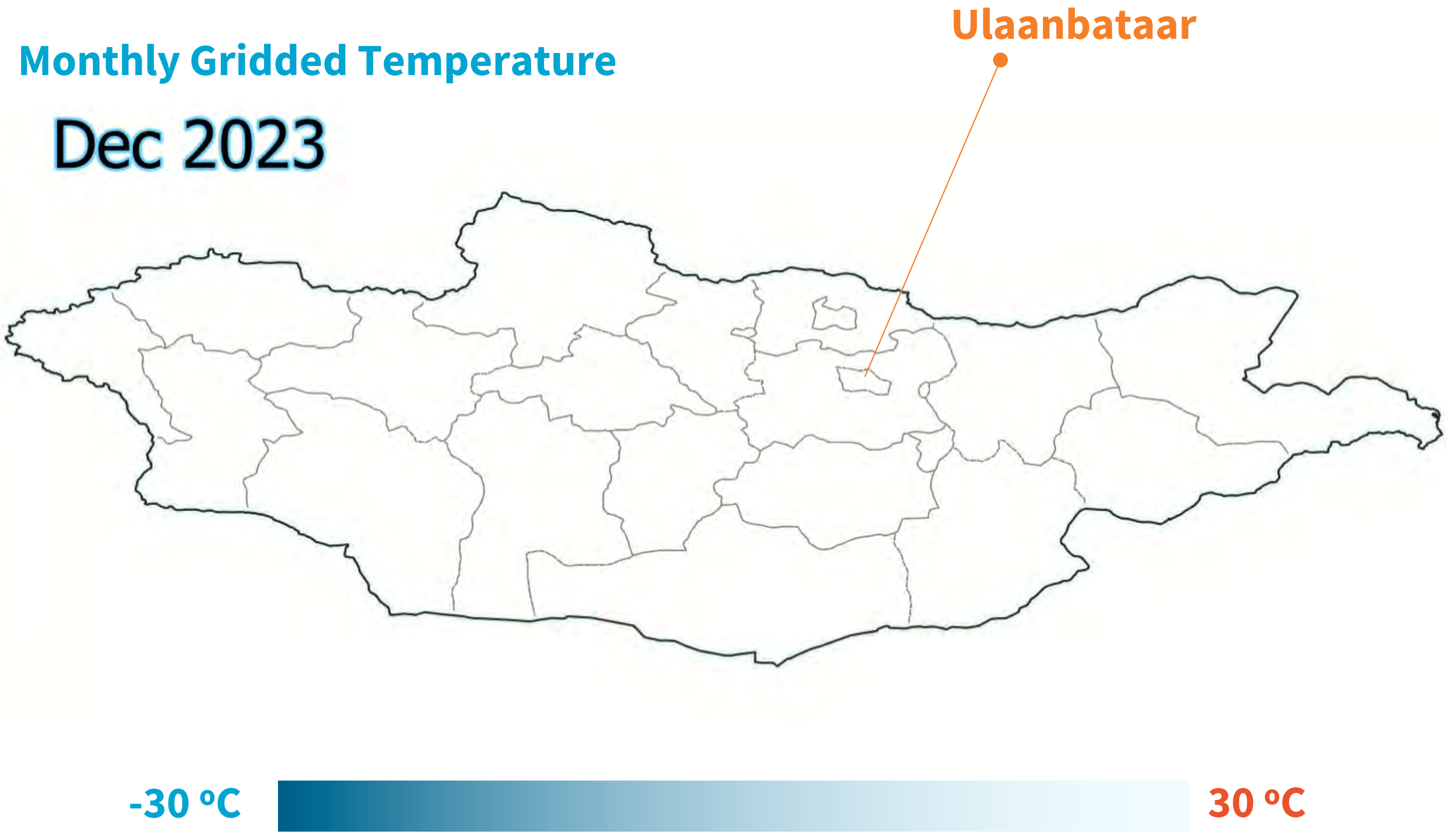
Objectives

1. Conduct a localized study for Mongolia , a developing economy in a cold climate (average annual temperature of 0.73°C from 1983 to 2023), and cross-check the application of the previous findings in developing economies in cold climates.

2. Identify the country- and sector-specific impacts of climate change—and estimating any delayed effects— for Mongolia:
   - informed macroeconomic forecasting for these economies
   - supports the design of tailored policies and plans from climate resiliency, sector development

Climate in Mongolia

Location	Between between 41° N and 53° N latitudes
Ave. Annual Temperature	0.4°C
Ave. Annual Total Precipitation	< 250mm
Climate	Continental climate with large variations in temperature between hot summers and cold winters
Geography	Landlocked with mountains and rolling plateaus (ave. elevation of > 1,500 above sea level)



Source: University of East Anglia Climate Research Unit

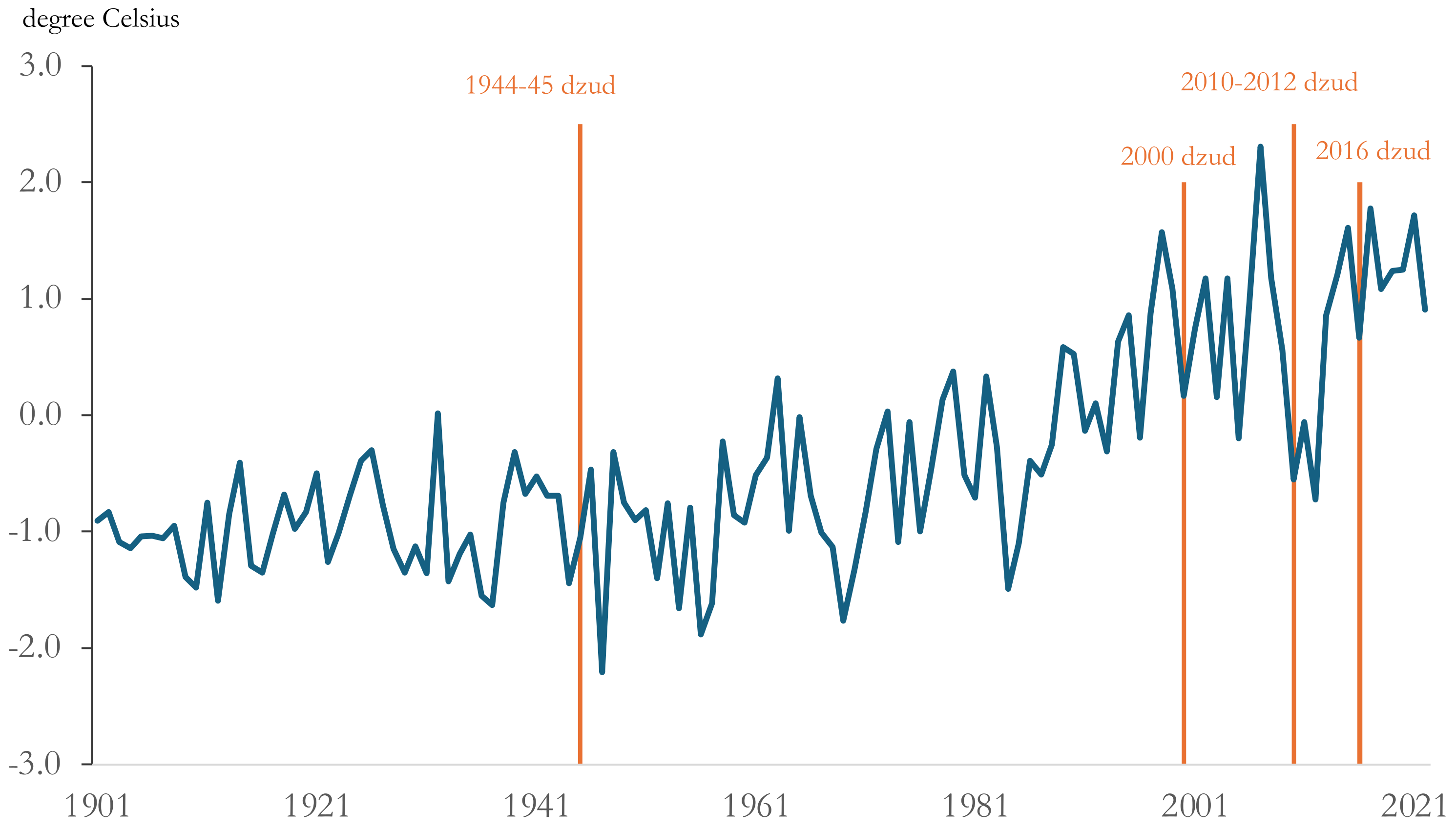
Dzuds: A Unique Weather Phenomenon

- a cold-season disaster in which anomalous climatic (i.e., heavy snow and severe cold) and/or land-surface (snow/ ice cover and lack of pasture) conditions
- leads to reduced accessibility and/or availability of forage/pastures, and ultimately to high livestock mortality during winter–spring
- severe dzuds (high mortality) result from a combination of growing-season drought and severe weather

Herds of livestock looking for foraging ground

Dzuds: A Unique Weather Phenomenon

- The 2023-2024 winter dzuds perished 7.1 million livestock, more than one-tenth of Mongolia entire livestock herd (Ghosal, 2024).
- Recent major dzuds also occurred in 2016 and 2009 to 2012.
- Instead of the expected occurrence of one or twice per decade, dzuds are happening more frequently (Kwong, 2019).



Sources: University of East Anglia Climate Research Unit, Emergency Events International Disaster Database (EM-DAT)

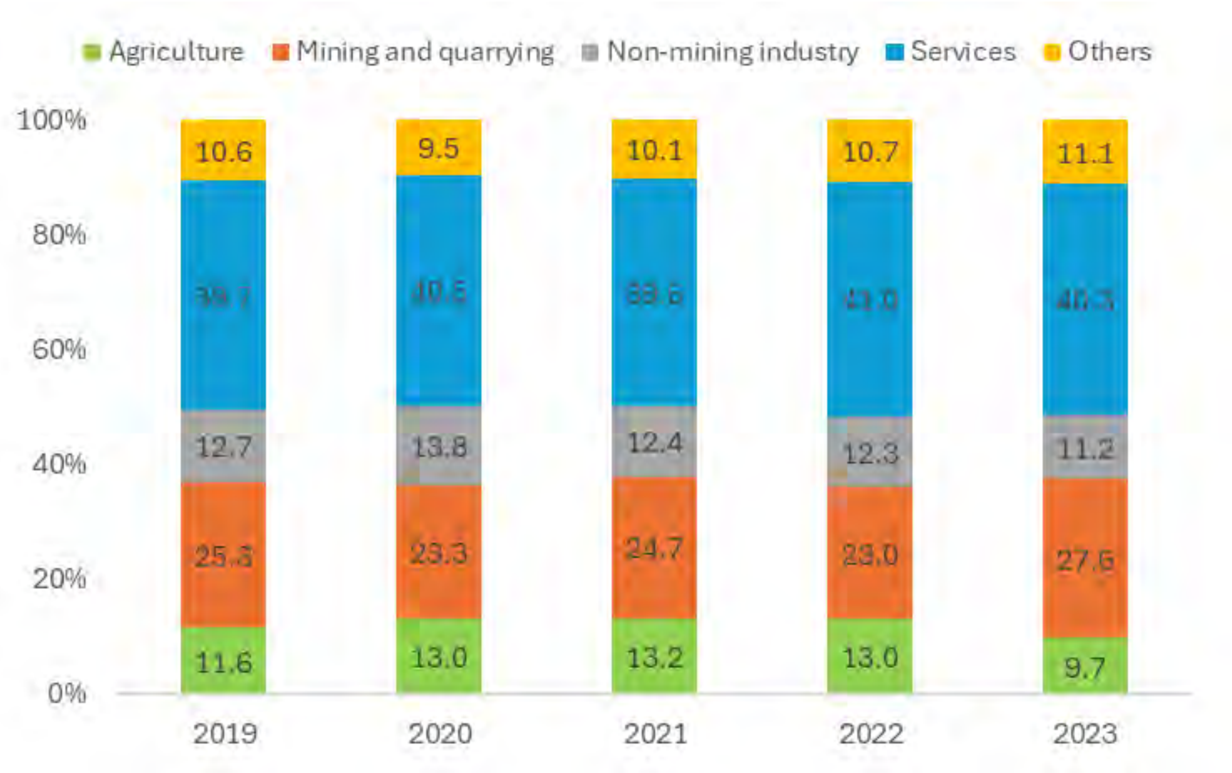
Weather and disaster variables

- Average annual temperature and precipitation
  - national and province-level analysis
- Quarterly average temperature and precipitation
  - national quarterly analysis
- Disaster
  - Derived from the Emergency Events International Disaster Database (EM-DAT)
    - This database records human and economic losses at the country level for disasters that meet at least one of the following criteria: (1) 10 or more fatalities, (2) 100 or more people affected, (3) a declaration of a state of emergency, or (4) a call for international assistance.
  - Represents the frequency of the following events: (1) droughts, (2) extreme temperatures, (3) floods, (4) avalanches, and (5) storms, including dzuds

Economy of Mongolia

- Prolonged cold season can limit economic activity, even absent any climate shocks
- Agriculture highly sensitive to climate shocks
  - Accounted for 12.2% of GDP in 2019-2023 but employs 25.1% of the (mostly rural) workforce
  - Contracted in 2023-2024

Structure of the Economy, 2019-2023 (share of GDP)



Note: "Others" comprises taxes less subsidies for products.
Source: Authors' estimates based on national accounts data from the National Statistics Office of Mongolia, Mongolian Statistical Information Service. GROSS DOMESTIC PRODUCT, by production approach, by quarter, by divisions (accessed July 2024).

Macroeconomic Variables

Indicator	Unit	Frequency	Period	Source
National Real GDP per capita	USD	Annual	1983-2023	WDI
National Real GDP – Seasonally Adjusted	USD	Quarter	2010-2023	Haver Analytics
Sectoral Real Value Added (Agriculture, manufacturing, construction, services) – Seasonally Adjusted	USD	Quarter	1972-2022	Haver Analytics
Provincial GDP	Tugrug	Annual	2000-2022	Mongolia NSO
Province-level livestock	Number of heads	Annual	1972-2022	Mongolia NSO
National level livestock	Number of heads	Annual	1972-2022	CEIC

Methodology

- Following the methodologies of Dell, Jones, and Olken (2012), Burke et al. (2015), **Acevedo et al. (2020),** and Faccia et al. (2021):

  - Baseline panel regression is estimated to generate the dynamic impulse responses to weather shocks.
  - Weather shocks are defined as a 1°C increase in annual mean temperature or a 1-mm increase in precipitation.
  - This approach captures the immediate and long-term effects of weather shocks on Mongolia's economy.

$$y_{i,t+h} - y_{i,t-1} = \varphi_1^h w_{i,t} + \varphi_2^h w_{i,t}^2 + \alpha_1^h w_{i,t-1} + \alpha_2^h w_{i,t-1}^2 + \lambda_1^h \Delta y_{i,t-1} + \tau_t^h + \sigma_i^h t + \sigma_i^h t^2 + \varepsilon_{i,t}^h \quad (1)$$

Methodology

$$y_{i,t+h} - y_{i,t-1} = \varphi_1^h w_{i,t} + \varphi_2^h w_{i,t}^2 + \alpha_1^h w_{i,t-1} + \alpha_2^h w_{i,t-1}^2 + \lambda_1^h \Delta y_{i,t-1} + \tau_t^h + \sigma_i^h t + \sigma_i^h t^2 + \varepsilon_{i,t}^h \quad (1)$$

- y is the natural logarithmic transformation of the outcome of interest of province i at year t.
- h represents the estimation horizon (from horizon 0, which captures the contemporaneous effect, up to horizon 8, which captures the effect 8 quarter or years after the shock).
- Regressions for each horizon are estimated separately.
- **Dependent variable:** Cumulative growth of the outcome between horizons $t-1$ and $t+h$, measured as the difference in natural logarithms of y_i , approximating growth rate over the period.

Methodology

$$y_{i,t+h} - y_{i,t-1} = \varphi_1^h w_{i,t} + \varphi_2^h w_{i,t}^2 + \alpha_1^h w_{i,t-1} + \alpha_2^h w_{i,t-1}^2 + \lambda_1^h \Delta y_{i,t-1} + \tau_t^h + \sigma_i^h t + \sigma_i^h t^2 + \varepsilon_{i,t}^h \quad (1)$$

- Quadratic specification for weather variables (temperature and precipitation) with one lag of the dependent and weather variables (Burke et al., 2015)
- **Time fixed effects and province-specific linear and quadratic time trends.**
  - capture key growth determinants such as commodity price fluctuations, structural economic changes, and gradual shifts in productivity
- **Linear time trends**
  - capture long-term economic changes within each province, reflecting shifts in productivity, demographics, and local development patterns
- **Quadratic time trends**
  - account for nonlinear developments, such as the cyclical nature of commodity prices and fluctuating local economic activities, particularly in resource-rich provinces.

Methodology

- National and quarterly data estimations
  - quarter fixed effects, linear and quadratic time trends are included.
- Quarter fixed effects
  - control for predictable seasonal patterns within a year, such as fluctuations in agricultural output or retail sales.
  - Standard errors are clustered at the regional level

Deriving the impulse response function

$$y_{i,t+h} - y_{i,t-1} = \varphi_1^h w_{i,t} + \varphi_2^h w_{i,t}^2 + \alpha_1^h w_{i,t-1} + \alpha_2^h w_{i,t-1}^2 + \lambda_1^h \Delta y_{i,t-1} + \tau_t^h + \sigma_i^h t + \sigma_i^h t^2 + \varepsilon_{i,t}^h \qquad (1)$$

Within this estimation framework, the effect of a weather shock, such as a 1°C increase in temperature or a 1-millimeter increase in precipitation, on the level of output at the horizon h can be obtained by differentiating equation (1) with respect to the weather variable:

$$\frac{\partial (y_{i,t+h} - y_{i,t-1})}{\partial w_{i,t}} = \beta_1^h + 2\beta_2^h w_{i,t} \qquad (2)$$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variable	**GDP per capita**	**Province GDP**				**GDP per capita**	**Province GDP**			
Temperature	-0.1145	0.159	1.956	9.574*	2.501	-3.0594	-1.172	1.280	9.127**	1.503
	(1.0617)	(3.387)	(1.793)	(5.057)	(2.436)	(2.2957)	(3.045)	(1.333)	(4.630)	(1.899)
$Temperature^2$	0.6527	-0.296	-0.0933	0.0673	-0.176	1.9395	-0.283	-0.0951	0.0583	-0.179
	(0.6158)	(0.189)	(0.204)	(0.186)	(0.201)	(1.3796)	(0.187)	(0.196)	(0.171)	(0.191)
Precipitation	1.4484	0.163	-0.739	-0.634	-0.331	2.2368	0.0861	-0.767	-0.684	-0.563
	(2.0010)	(0.602)	(0.469)	(0.631)	(0.674)	(5.9231)	(0.518)	(0.481)	(0.633)	(0.489)
$Precipitation^2$	-0.0404	0.00133	0.0107	0.0162	0.0130	-0.05997	0.00193	0.0109	0.0169	0.0159*
	(0.0453)	(0.0118)	(0.0106)	(0.0128)	(0.0116)	(0.1454)	(0.0106)	(0.0111)	(0.0130)	(0.00943)
Freq. of disaster						-0.5920	-1.950	-1.423	-1.515	-1.965
						(0.7375)	(1.508)	(1.389)	(2.180)	(1.759)
Observations	41	462	462	462	462	23	462	462	462	462
No. of Regions	NA	22	22	22	22	NA	22	22	22	22
Year FE	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes
Aimag FE	No	Yes	No	No	No	No	Yes	No	No	No
Region FE	No	No	Yes	No	No	No	No	Yes	No	No
Region x Year FE	No	No	No	Yes	No	No	No	No	Yes	No
Linear & Quadratic Time Trend	Yes	No	No	No	Yes	Yes	No	No	No	Yes
Period	1983-2023	2000-2022	2000-2022	2000-2022	2000-2022	2000-2023	2000-2022	2000-2022	2000-2022	2000-2022
R^2	0.6161	0.102	0.399	0.519	0.104	0.8207	0.0923	0.403	0.522	0.141

Panel A	GDP	Agriculture	Services	Construction	Manufact-uring	Mining	GDP	Agricul-ture	Services	Construc-tion	Manufactu-ring	Mining
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Temperature	-0.962	0.462	1.616*	-7.043	1.553	-2.482	-0.808	0.244	1.577	-6.655	1.154	-1.513
	(0.636)	(0.951)	(0.937)	(7.116)	(1.422)	(1.750)	(0.740)	(1.007)	(0.948)	(7.821)	(1.591)	(1.895)
Temperature^2	-0.0234	-0.0689*	0.0546	-0.0418	0.120***	-0.0336	-0.0189	-0.0731*	0.0539	-0.0314	0.106**	-0.00483
	(0.0218)	(0.0374)	(0.0339)	(0.145)	(0.0414)	(0.0620)	(0.0251)	(0.0369)	(0.0341)	(0.166)	(0.0457)	(0.0654)
Precipitation	-0.431*	-0.201	0.456	-0.588	0.126	-1.039	-0.451	-0.118	0.485	-0.673	0.153	-1.231
	(0.249)	(0.559)	(0.489)	(2.813)	(0.725)	(0.838)	(0.270)	(0.576)	(0.486)	(3.004)	(0.701)	(0.872)
Precipitation^2	0.00292	0.00297	-0.00346	0.00223	-0.00232	0.00541	0.00315	0.00212	-0.00374	0.00308	-0.00268	0.00735
	(0.00262)	(0.00595)	(0.00533)	(0.0279)	(0.00793)	(0.00923)	(0.00278)	(0.00608)	(0.00533)	(0.0298)	(0.00786)	(0.00924)
Natural Disaster (Frequency)							0.658	-2.377	-0.532	1.789	-2.109	4.370
							(0.967)	(1.996)	(1.305)	(6.852)	(2.596)	(3.269)
Obs.	50	82	82	50	50	50	50	82	82	50	50	50
Adjusted R^2	0.222	0.0343	0.113	0.0341	0.0987	0.101	0.209	0.0423	0.101	0.00722	0.0891	0.137

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variable	National Level Livestock	Province Level Livestock				National Level Livestock	Province Livestock			
Temperature	2.6038	1.8406***	0.7270	5.4175***	1.9477***	9.5996	2.2735**	2.1887	5.8822***	2.1368
	(2.2407)	(0.6130)	(2.4936)	(0.9868)	(0.7261)	(13.0193)	(0.8943)	(3.0764)	(0.6556)	(3.4810)
Temperature^2	0.2448	0.0332	0.0281	0.0688	0.0038	-4.0573	0.0219	-0.0277	0.0248***	-0.0862
	(0.5877)	(0.0702)	(0.0693)	(0.0743)	(0.0632)	(5.6338)	(0.1025)	(0.0759)	(0.0917)	(0.0686)
Precipitation	-6.0286	0.1641*	0.8740***	0.2141	0.4847**	-13.7608	0.4862***	1.6528***	0.1281	1.9833***
	(4.8459)	(0.0994)	(0.2892)	(0.3185)	(0.2160)	(14.5702)	(0.1588)	(0.3185)	(0.6065)	(0.000)
Precipitation^2	0.1442	-0.0013	-0.0095***	-0.0000121	-0.0051	0.3379	-0.0048	-0.0163***	0.0021	-0.0208***
	(0.1197)	(0.0018)	(0.0037)	(0.0031)	(0.0032)	(0.3643)	(0.0040)	(0.0031)	(0.0067)	(0.0050)
Freq. of disaster						**-2.5020**	**-1.4309*** **	**-1.9441*** **	**-1.6007*** **	**-1.8797*** **
						(1.8797)	(0.4068)	(0.5082)	(0.5662)	(0.7663)
Observations	51	1,086	1,086	1,086	1,086	23	506	506	506	506
No. of Regions	NA	22	22	22	22	NA	22	22	22	22
Year FE	NA	Yes	Yes	No	Yes	NA	Yes	Yes	No	Yes
Aimag FE	NA	No	Yes	No	No	NA	No	Yes	No	No
Region FE	NA	Yes	No	No	No	NA	Yes	NA	No	No
Region x Year FE	NA	No	No	Yes	No	NA	No	NA	Yes	No
Linear & Quadratic Time Trend	Yes	No	No	No	Yes	Yes	No	NA	No	Yes
	1970-									

Summary of Key Results

- **Temperature Impact on GDP:** A 1°C increase in temperature reduces GDP per capita by 4.8% over two years and provincial output by 3.5% after four years.
    - Highlighting the significant negative effect of temperature shocks on economic performance.
- **Precipitation and Economic Output:** Precipitation shocks have a positive impact on provincial output, increasing GDP by 1.1% to 1.3% in two consecutive years.
    - Moderate rainfall can enhance economic productivity, particularly in agriculture.
- **Livestock Sector Vulnerability:** Livestock numbers are severely impacted by disasters, with a reduction of 1.4% to 1.9%.
    - Highlights the sector's sensitivity to extreme weather events and the economic risks associated with livestock-dependent regions
- **Mining Sector Resilience:** The mining sector benefits from higher temperatures, with output increasing by 6.4%, indicating that certain sectors, such as mining, can thrive under specific weather conditions.
- **Divergent Impacts at Provincial and National Levels:** While provincial economies experience short-term gains from favorable weather conditions, national-level data shows negative impacts from temperature and precipitation increases

Effect of 1C increase in Temperature on Output

Figure A

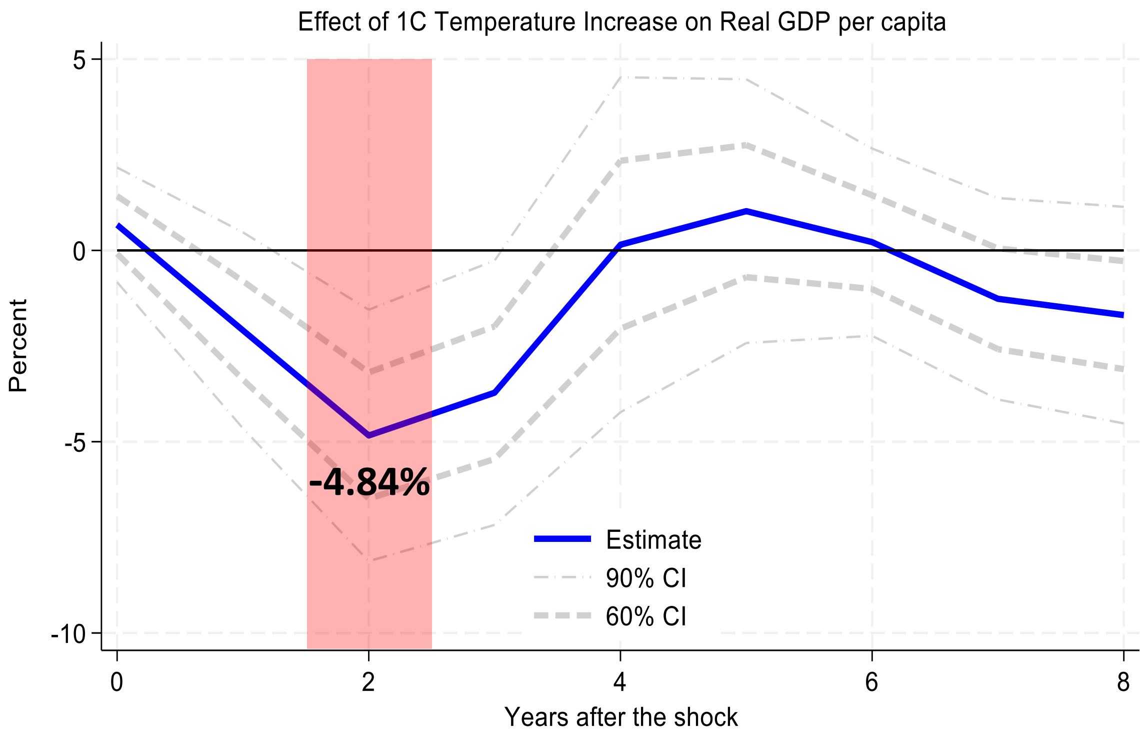
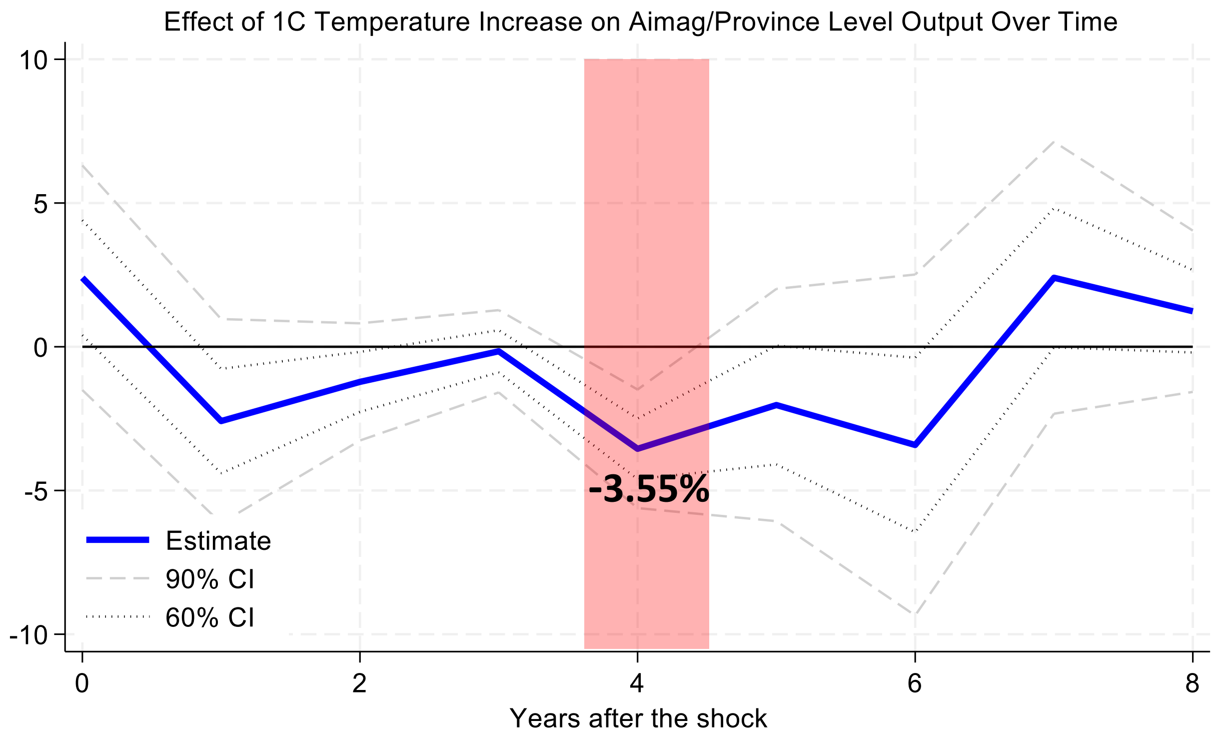


Figure B



- Difference in impact reflects the structural differences between national and provincial economies.
  - **National-level real GDP per capita:** diversified industrial base (e.g., mining, services, etc.) mitigates the persistent effects of a temperature increase.
  - **Province-level output:** reflects the heavier dependence of rural economies on agriculture and livestock, sectors that are highly sensitive to temperature fluctuations

Effect of 1mm increase in Precipitation on Output

Figure A

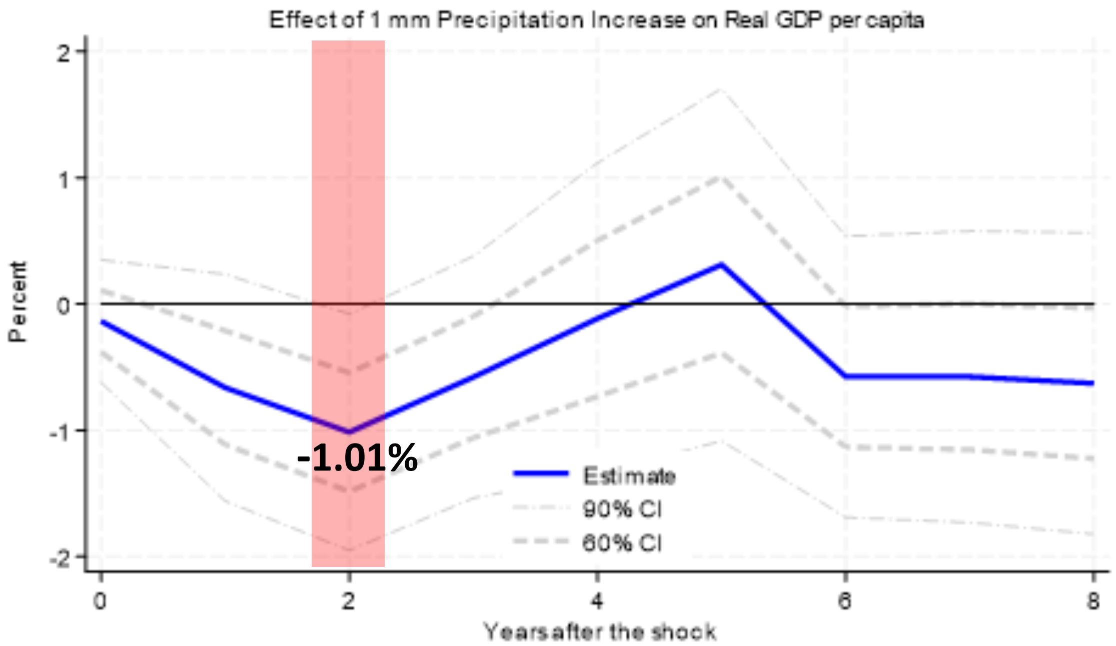
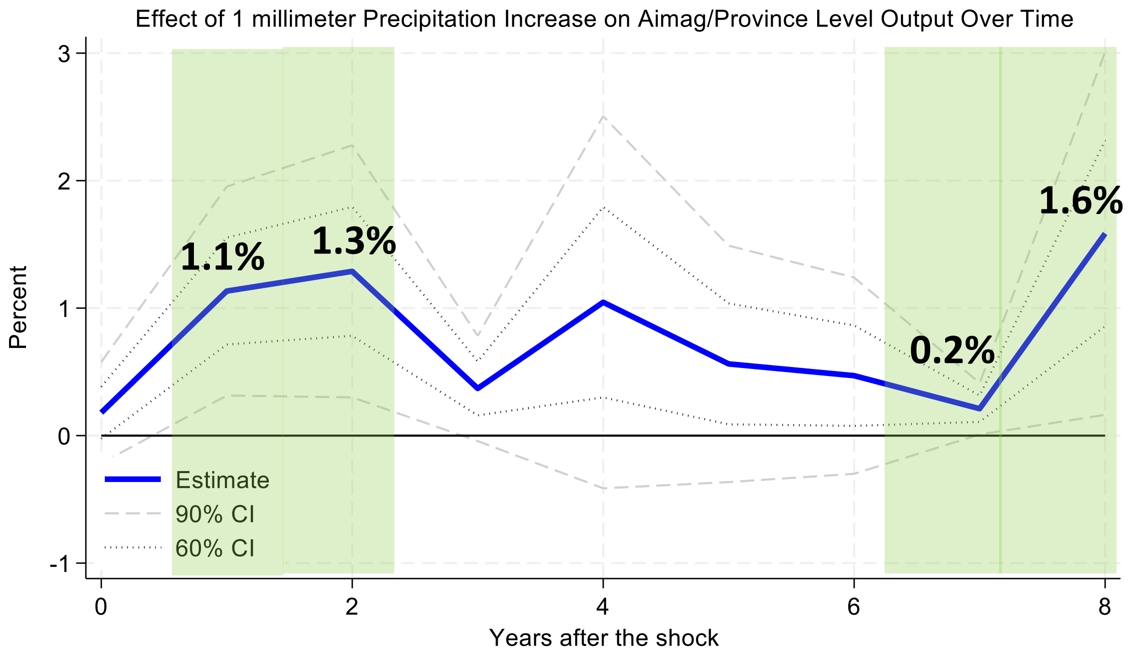
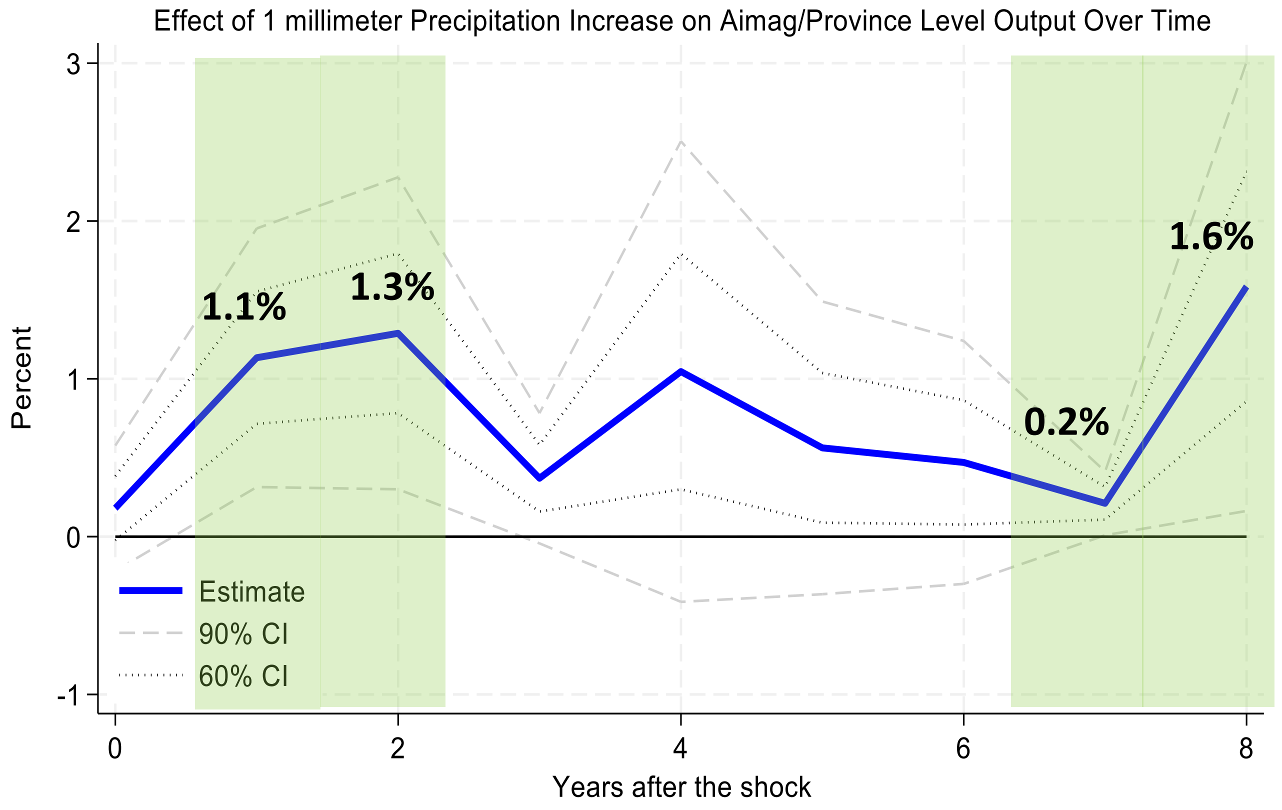


Figure B



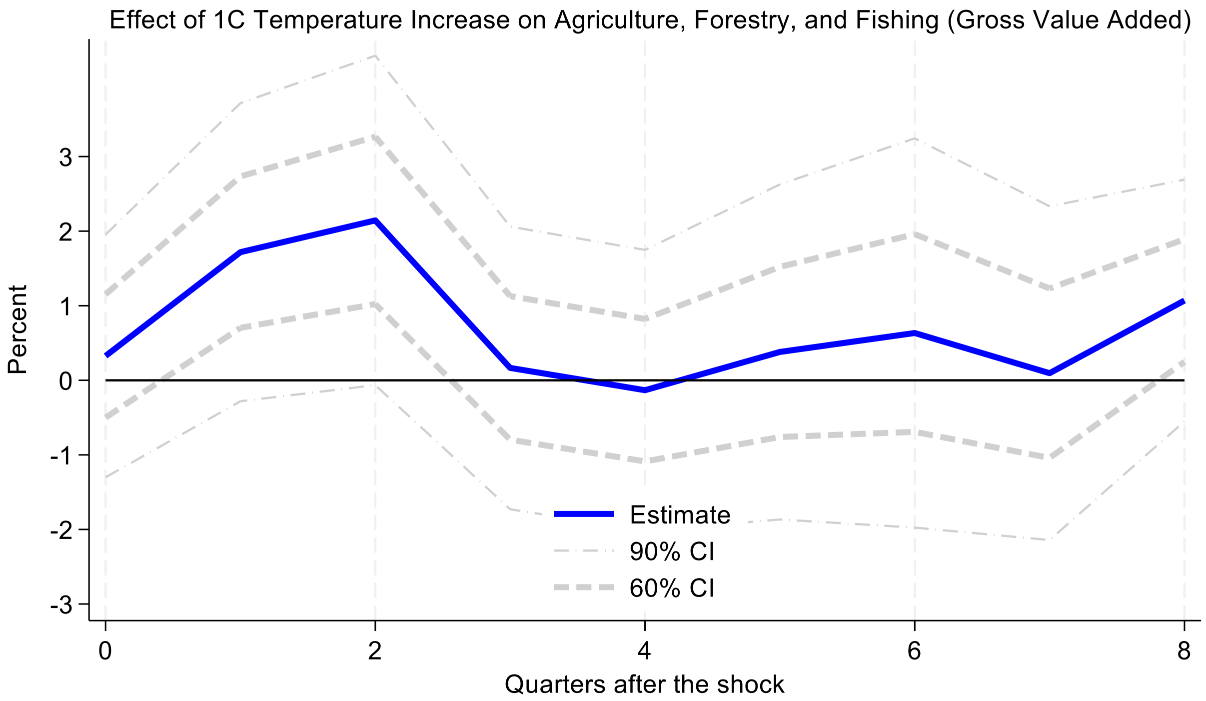
- This divergence suggests that, although rural, agriculture-dependent provinces gain from increased precipitation, the broader national economy suffers adverse effects, likely due to disruptions in infrastructure development.
- This is further supported by the negative impact of precipitation shocks on the construction sector, as demonstrated in the succeeding results.

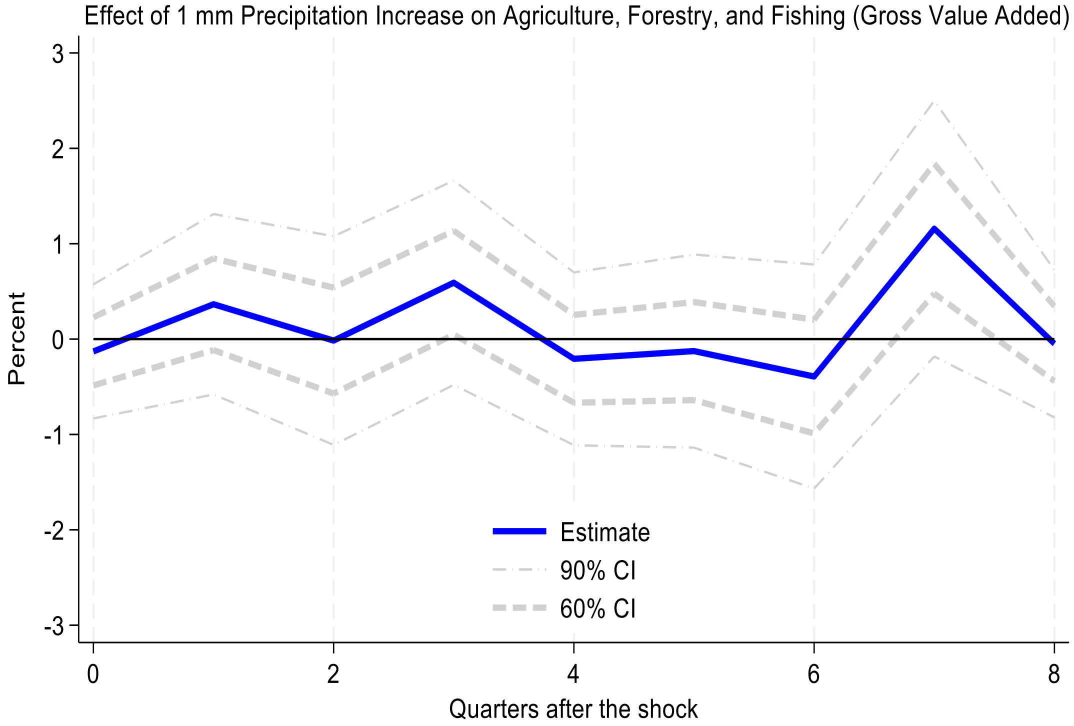
Novel contribution



- **Acevedo et al. (2020)** grouped Mongolia with LIDCs, using a median precipitation of **1,100 mm**, which didn't yield statistically significant results.
- Mongolia's average annual total precipitation is below **250 mm**, much lower than the LIDC median.
- Our study shows a **positive impact of precipitation** on provincial output in Mongolia, in contrast with the findings of Acevedo et al. (2020).
- In arid regions like Mongolia, **small increases in precipitation** have **substantial economic benefits**.
- Highlights the need to account for **regional climatic differences** when assessing weather shocks.

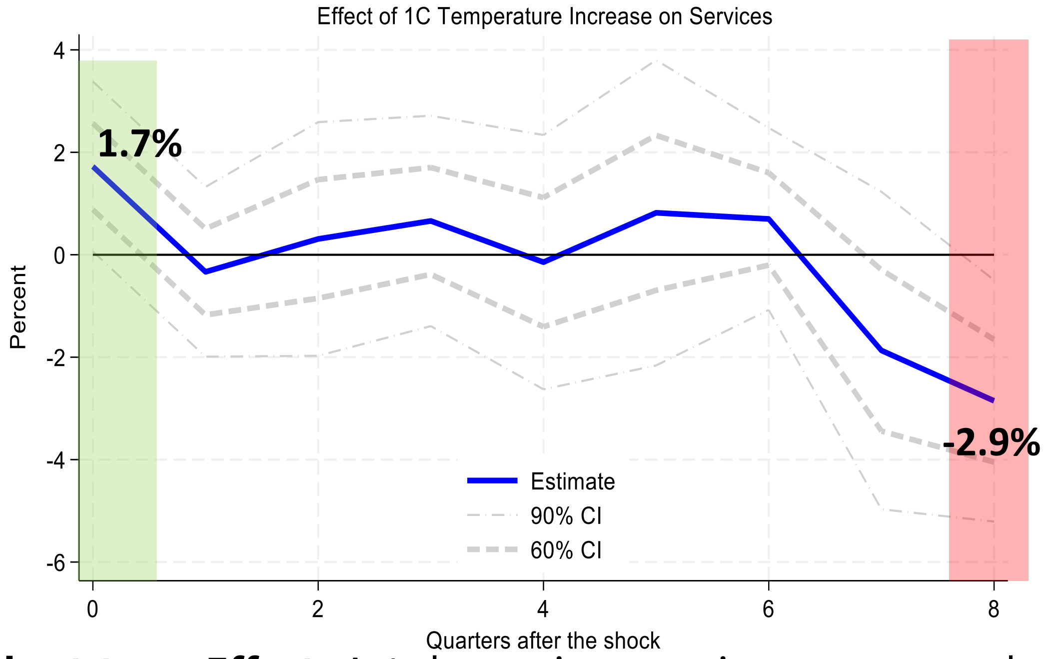
Effect of weather shock on agriculture

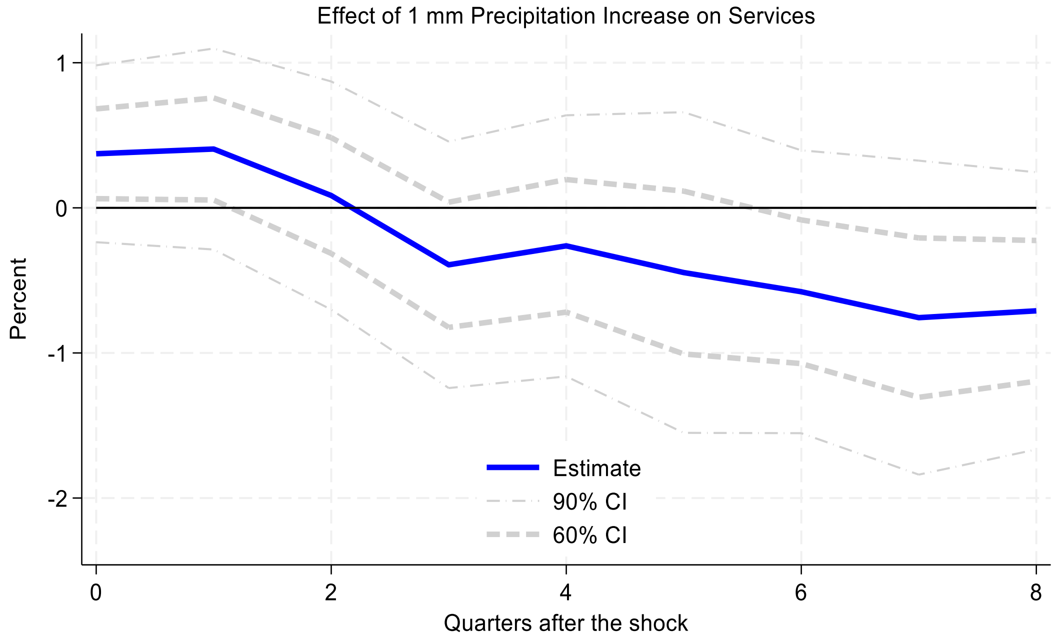




- Over eight quarters, a higher temperature and precipitation show no statistically significant impact on Mongolia's agriculture.
- Since livestock is a key component of agricultural output, a possible explanation for this result is that livestock breeds are adapted to extreme climates, and herders employ adaptive practices like seasonal migration, mitigating negative temperature effects.
- Positive impacts like extended grazing seasons may be balanced by negatives like heat stress, resulting in no net effect.

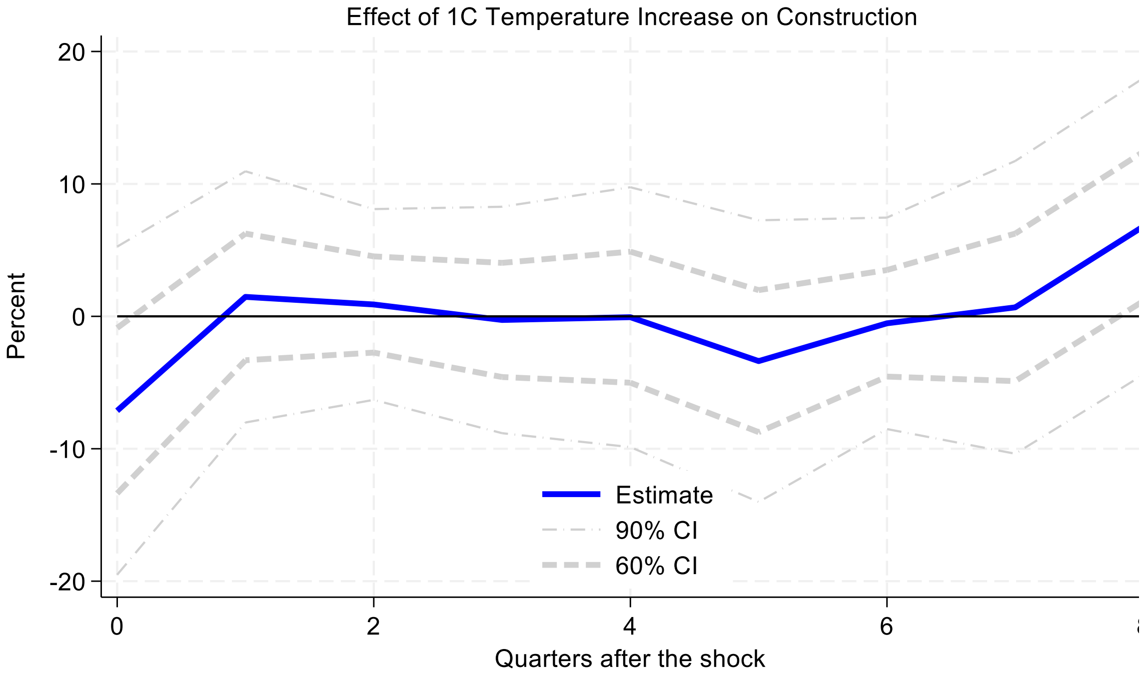
Effect of weather shock on services

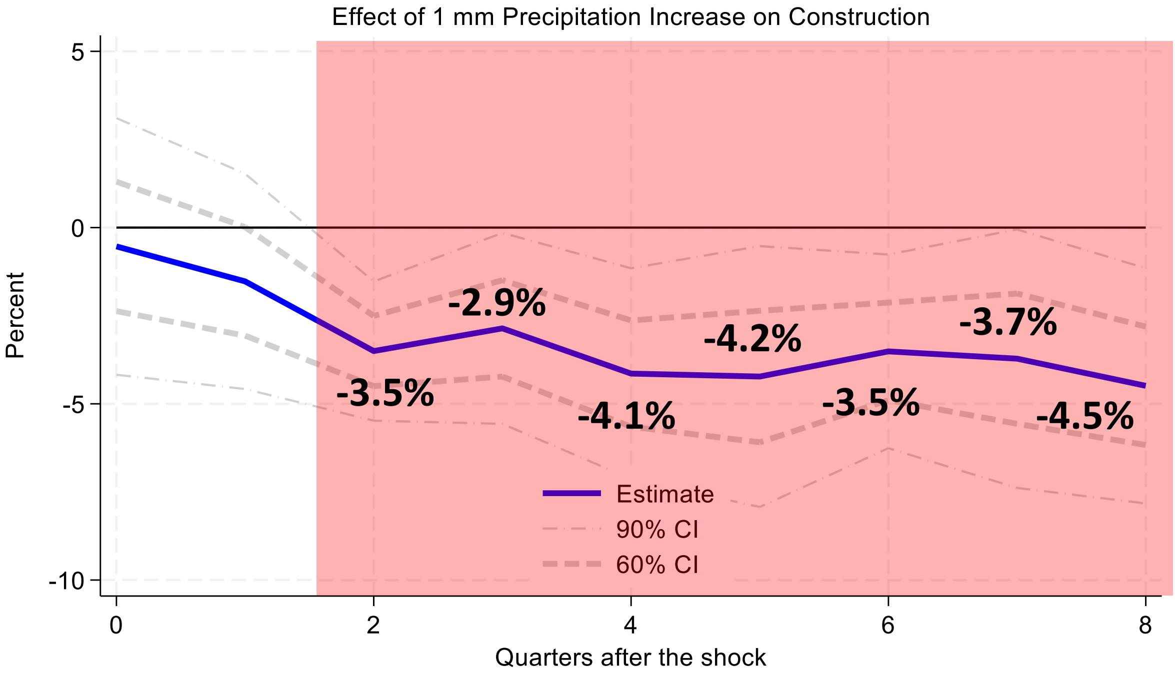




- **Short-term Effect:** A 1-degree increase in temperature boosts services sector output by 1.7%. This sector includes health, ICT, trade, hotels, restaurants, and financial services.
  - Warmer weather promotes tourism and retail activity, while reducing heating costs, stimulating spending in hospitality and other commercial activities.
- **Long-term Effect:** Eight quarters after the temperature increase, services output declines by 2.9%.
  - Over time, higher temperatures may lower agricultural productivity, decreasing rural incomes and service demand.
  - Increased cooling costs, health issues related to heat stress, and infrastructure strain contribute to higher operational expenses and lower disposable income.

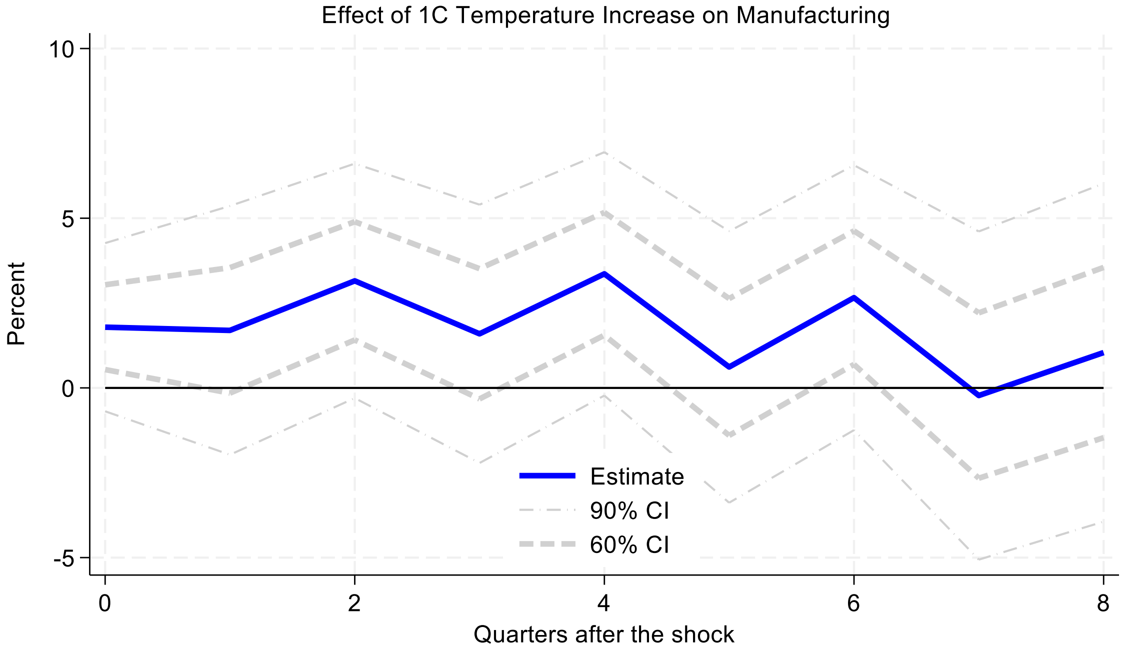
Effect of weather shock on construction

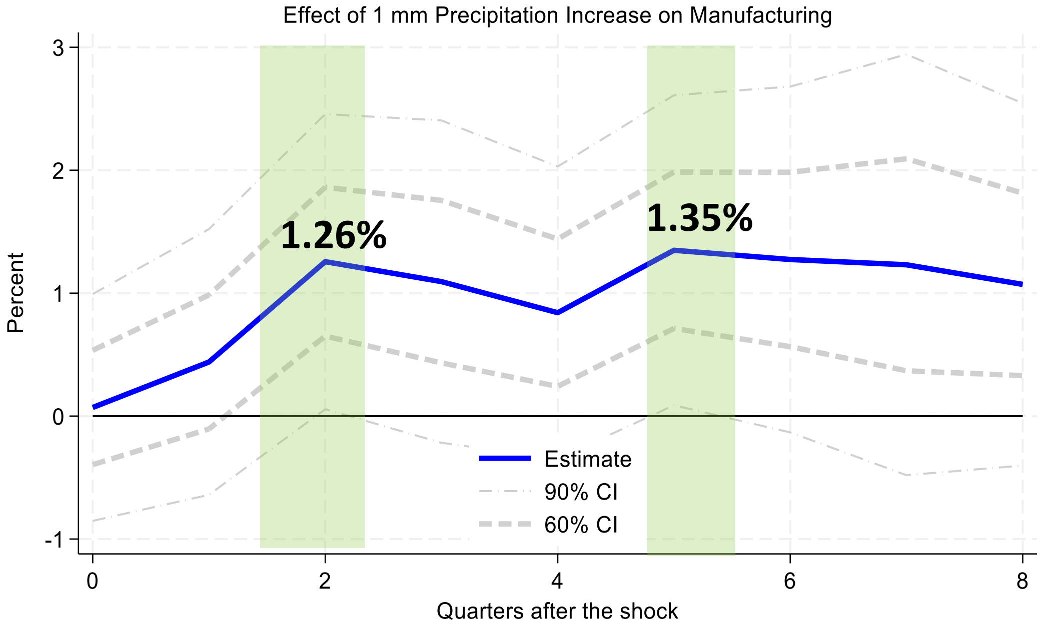




Temperature: No significant effect on output.
Precipitation: Reduces output by 3.5% to 4.9%, 2-8 quarters after the shock.
Causes: Project delays, material damage, unsafe conditions →decreased productivity, and higher costs.
Long-term Effect: Persistent negative impact on construction, even when accounting for disasters.

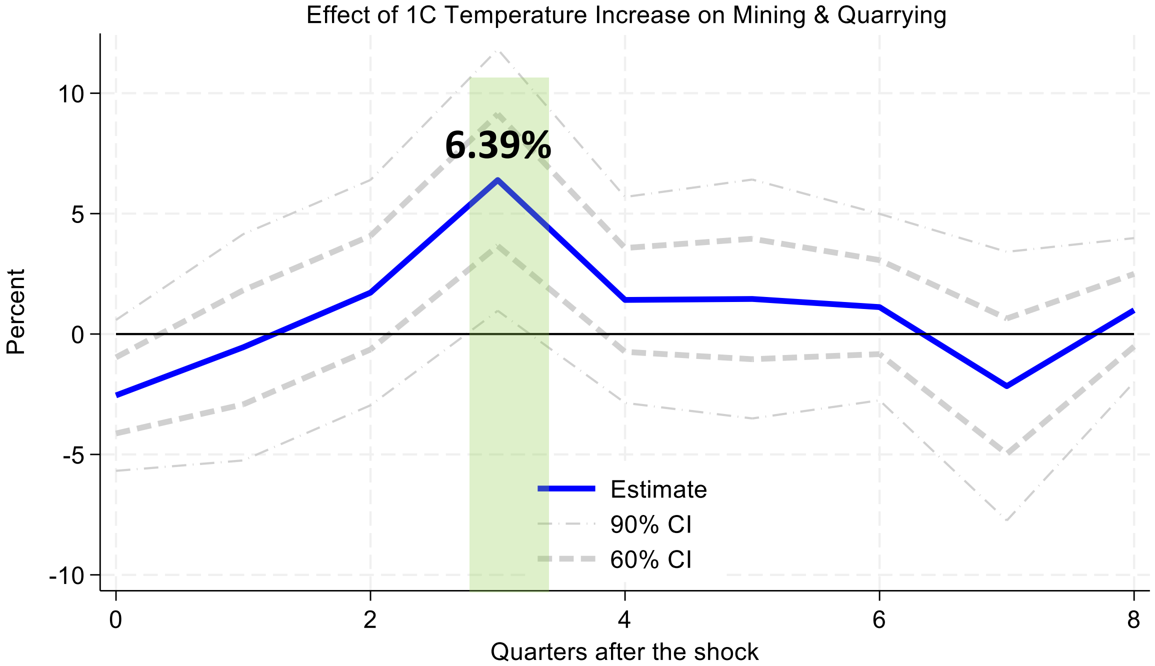
Effect of weather shock on manufacturing

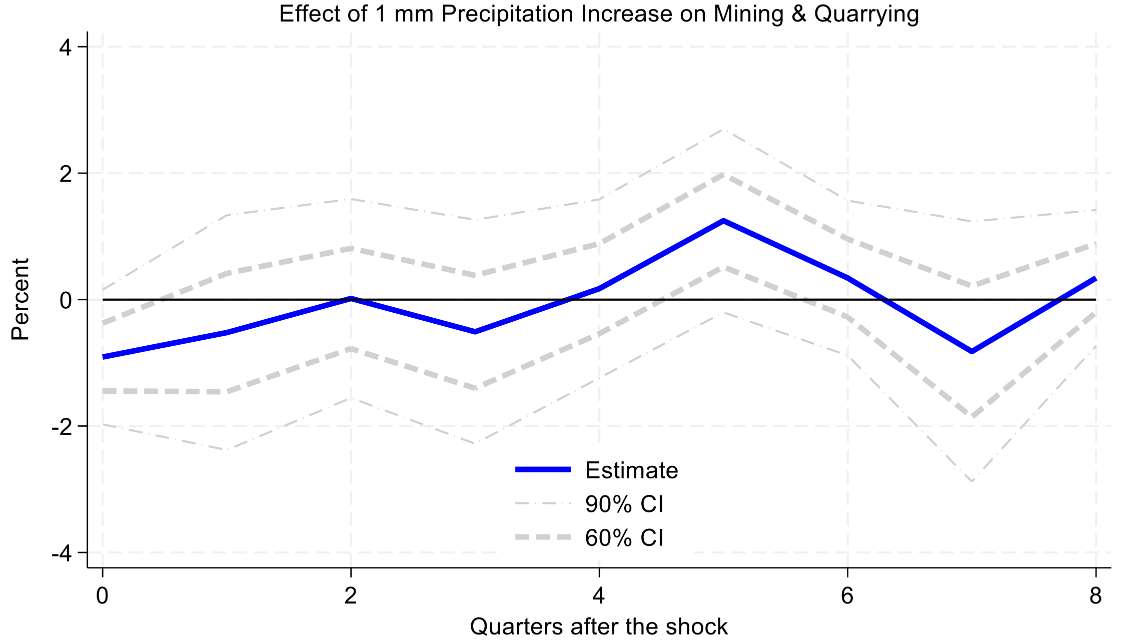




- Higher temperatures have no significant impact on manufacturing output in Mongolia.
- Increased precipitation leads to a 1.3% rise in output two and five quarters after the shock.
- Improved precipitation enhances livestock health and supply of raw materials like leather, wool, and meat.
- This boost in raw materials drives growth in the manufacturing sector.

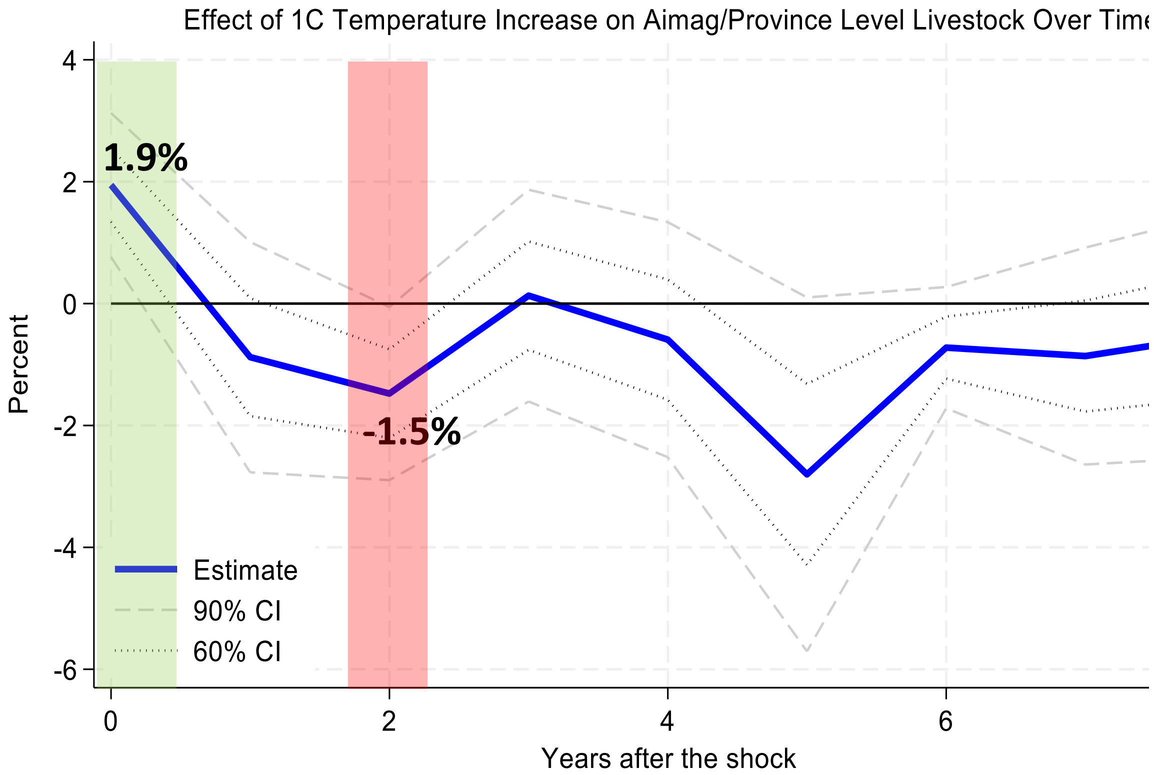
Effect of weather shock on mining

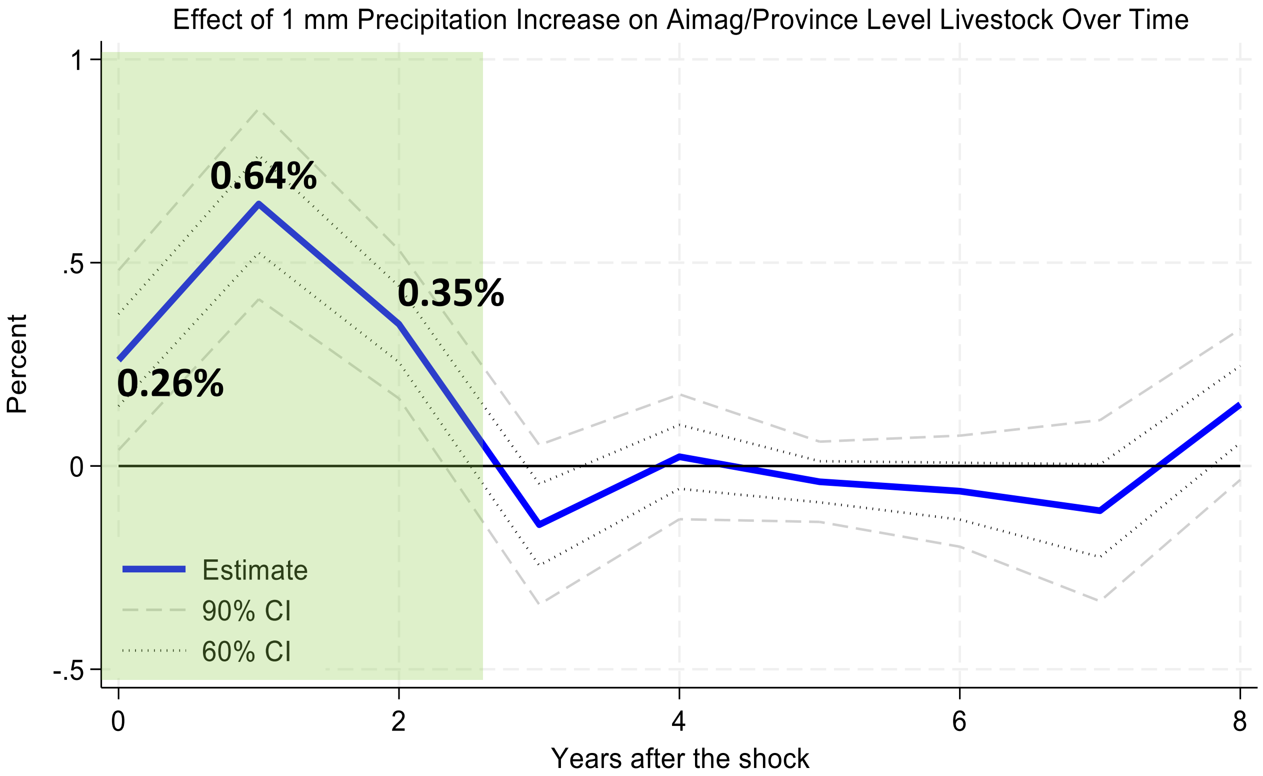




- **Higher precipitation** has no impact on **mining output**.
- **6.4% increase in mining output from higher temperatures:** Small-scale mining operations see significant growth from warmer weather.
  - **Warmer weather** aids **small-scale mining**, easing extraction processes by reducing challenges from frozen ground.
- **Large-scale mining unaffected by temperature fluctuations:** Major mining companies maintain stable output through advanced technology and infrastructure.

Effect of a weather shock on livestock

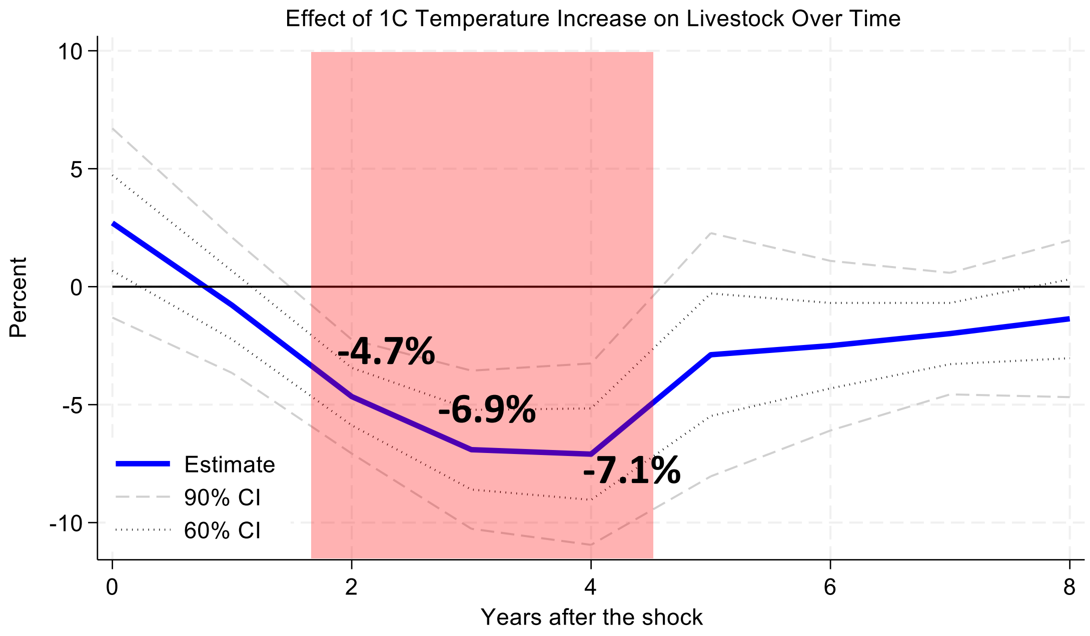


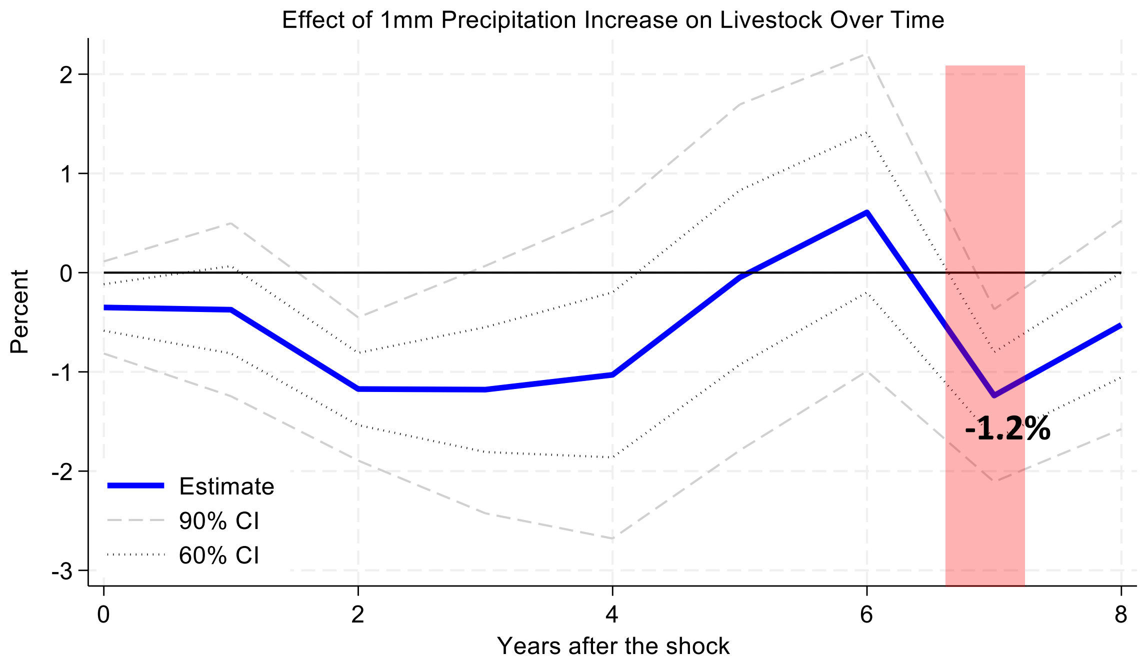


Provincial level impact:

- **1.9% increase** in livestock numbers in the year of a temperature shock, but a **1.5% reduction** two years later.
- **Precipitation boosts livestock** by **0.26% to 0.64%** from the year of impact to two years after.

Effect of a weather shock on livestock





National level impact:

- Livestock numbers **decline due to both higher temperatures and increased precipitation**.

Reasons for provincial vs. national differences:

- National-level livestock decline is due to aggregation of data from provinces, including those severely impacted by extreme weather.
- Extreme weather in key regions disproportionately affects national figures, driving overall declines.
- Resource constraints and infrastructure challenges hinder the implementation of widespread adaptation measures.

Robustness check

- All results are qualitatively the same based on the following robustness checks:
  - Different fixed effect structures
  - Inclusion of the disaster variable
  - Different sample size

Thank you.