Weather and Death in India: Mechanisms and Implications of Climate Change

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Weather and Health: Empirical Questions

1. How large are the effects of weather shocks on health in developing countries?

2. Why are there effects?

3. What do these effects imply for policy?
Weather and Health: Motivation

- Rural LDC citizens seem highly exposed to weather shocks (incomes, prices, ability to adapt). But how large are the consequences of this exposure?

- Climate change costs and benefits: Size of health risks not yet understood (especially in LDCs)

- Sen: ‘There has never been a famine in a democratic country (like India)’. But how large are the sub-famine effects of weather on death?
Approach of This Paper

- Estimate effect of ‘weather’ (temperature and precipitation) variation on the mortality rate in India, at the district-level, from 1956-2000

- Explore competing predictions from two different mechanisms relating weather to death:
  - ‘Direct’: heat stress, disease, dehydration
  - ‘Indirect’:
    - agricultural income falls
    - ⇒ consumption falls
    - ⇒ probability of dying rises

- Implications for policy:
  - What would an income support policy cost?
  - Upper bound costs of predicted climate change
Summary of Results I: India vs. USA

India: 1° C rise in average annual temperature increases the mortality rate by 10%

Estimated Impact of a Day in 15 Temperature (C) Bins on Log Annual Mortality Rate, Relative to a Day in the 22° - 24°C Bin

- US
- 2 std err
- India
- +2 std err
Summary of Results II

- Cluster of findings consistent with an ‘indirect’ (agricultural income) mechanism:
  - No weather-death effect in urban India (not even on infants)
  - Within rural India, no weather-death effect in the non-growing season
  - Rural incomes: Agricultural yields fall, agricultural wages fall, agricultural prices rise.
  - Urban incomes: Manufacturing wages do not change, urban prices don’t change.
  - Bank deposits: Fall in rural areas; no change in urban areas
Outline of Talk

Conceptual Framework

Reduced-Form Results: Weather and Death

Mechanisms: ‘Direct’ vs ‘Indirect’ Effects

Implications for Policy

Conclusion
Outline of Talk

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Direct Health Effects (Human Physiology)

- **Heat stress (cardiovascular):**
  - e.g. survey: Basu and Smet (2003)
  - Hajat et al (2005): small effects in Delhi (around one heat wave)
  - Deschenes-Moretti (2009): small effects in the US, largely offset by ‘harvesting’

- **Change in disease environment:**
  - Malaria thrives in hot and wet conditions, but malaria rarely fatal in India
  - Intestinal infections peak in rainy season (Dyson, 1991; Matlab studies in Bangladesh)
Indirect Health Effects (Plant Physiology)

- Temperature and rainfall extremes damage plants.
- Consequences of extreme weather during the growing season for observables:
  - Lower agricultural yields
  - Higher agricultural prices
  - Lower real incomes in R but not U
  - Lower bank deposits in R but not U
  - Lower consumption levels (if incomplete credit markets and insurance) in R but not U
  - More death due to malnutrition in R but not U
- Extreme weather in the non-growing season has no effect (on $Y$, $p$, $w$, or death) in R or U
Outline of Talk

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Reduced-Form Results: Weather and Death

Mechanisms: ‘Direct’ vs ‘Indirect’ Effects

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Data Sources

• Mortality Rates:
  • *Vital Statistics of India (VSI), 1957-2001*
  • Universe of registered deaths
  • Check results against DHS maternal histories data
  • And future work: SRS data

• Historical Weather:
  • High-resolution modeled daily weather at each $1 \times 1$ degree lat/long gridpoint
  • Source: National Center for Atmospheric Research (US Government)
  • Gridpoints mapped to districts by inverse-distance weighting (within 100 km radius)
Daily Temperatures in India: 1957-2000

Distribution of Daily Mean Temperature (C)
(Days Per Year in Each Interval)

- <10: 4 days per year
- 10-12: 3 days per year
- 12-14: 5 days per year
- 14-16: 9 days per year
- 16-18: 13 days per year
- 18-20: 18 days per year
- 20-22: 24 days per year
- 22-24: 34 days per year
- 24-26: 56 days per year
- 26-28: 73 days per year
- 28-30: 63 days per year
- 30-32: 31 days per year
- 32-34: 20 days per year
- 34-36: 10 days per year
- 36+: 3 days per year
Empirical approach I

- Estimate regressions of following form:

\[
Y_{dt} = \sum_{j=1}^{15} \theta_j T_{dt}^j + \sum_{m=1}^{12} \delta_m^1 P_{dt}^m + \sum_{m=1}^{12} \delta_m^2 (P_{dt}^m)^2
\]
\[
+ \alpha_d + \beta_t + \{\gamma_r t^3\} + \varepsilon_{dt}
\]

- \(dt\): unit of observation is a district \(\times\) rural/urban area, observed annually
- \(Y_{dt}\): log of annual death rate (deaths per 1,000)
- \(T_{dt}^j\): Number of days in \(dt\) in which daily mean temperature was in ‘bin’ \(j\)
- \(P_{dt}^m\): Total monthly precipitation in month \(m\)
- \(\{\gamma_r t^3\}\): region-specific cubic polynomials in time
Empirical approach II

\[ Y_{dt} = \sum_{j=1}^{15} \theta_j T_{dt}^j + \sum_{m=1}^{12} \delta_m P_{dt}^m + \sum_{m=1}^{12} \delta^2_m (P_{dt}^m)^2 + \alpha_d + \beta_t + \{\gamma_r t^3\} + \varepsilon_{dt} \]

- **Intuition:**
  - Temperature is not storable, so total annual impact is sum of each day’s impact (with unknown lags).
  - Water is somewhat storable. But effects of rain may differ throughout agricultural year.

- **Other adjustments:**
  - Weight by population
  - Cluster at district level

- Will present temperature results first (15 coefficients best seen graphically), then rainfall.
Temperature and All Ages Death Rate

\[ Y_{dt} = \sum_j \theta_j T_{dt}^j + \sum_{m=1}^{12} \delta_m P_{dt}^m \sum_{m=1}^{12} + \delta_m (P_{dt}^m)^2 + \alpha_d + \beta_t + \{\gamma_r t^3\} + \varepsilon_{dt} - 15 \]

\( \hat{\theta}_j \)'s plotted

Estimated Impact of a Day in 15 Temperature (C) Bins on Log Annual Mortality Rate, Relative to a Day in the 22° - 24°C Bin
Temperature and All Ages Death Rate

VSI data: Urban India with 95% confidence interval

Estimated Impact of a Day in 15 Temperature (°C) Bins on Log Urban Annual Mortality Rate, Relative to a Day in the 22° - 24°C Bin

-2 std err  coefficient  +2 std err
Temperature and All Ages Death Rate

VSI data: Rural India with 95% confidence interval

Estimated Impact of a Day in 15 Temperature (C) Bins on Log Rural Annual Mortality Rate, Relative to a Day in the 22° - 24°C Bin

-2 std err  coefficient  +2 std err
Temperature and Infant Death Rate

VSI data: Urban India with 95% confidence interval

Estimated Impact of a Day in 15 Temperature (°C) Bins on Log Urban Annual Mortality Rate, Relative to a Day in the 22° - 24°C Bin
Temperature and Infant Death Rate

VSI data: Rural India with 95% confidence interval

Estimated Impact of a Day in 15 Temperature (°C) Bins on Log Rural Annual Mortality Rate, Relative to a Day in the 22° - 24°C Bin
Robustness Check: DHS Data

- Potential concern over quality of registration data
- Check mortality results using independent data source: DHS surveys in 1993 and 1999

DHS Surveys:
- Representative survey of all mothers aged 15-49 alive in survey year
- Mothers asked about all children
- Mothers recall year of birth of children, and age at death of dead children
- Use this to construct sample of death events among ‘children’ (aged 0-37)
- Jain (1985): 47% of deaths occur before the age of 5
Temperature and ‘Child’ Death Rate

DHS data: Urban India with 95% confidence interval

Estimated impact of Day in 15 Temp. (C) Bins on 'Child' Mortality Relative to a Day in the 22-24 C Bin

- 2 std. err.  Coefficient  + 2 std. err.
Temperature and ‘Child’ Death Rate

DHS data: Rural India with 95% confidence interval.

Estimated impact of Day in 15 Temp. (C) Bins on 'Child' Mortality Relative to a Day in the 22-24 C Bin.
Timing: Growing Season

VSI data: Total deaths in Rural India with 95% confidence interval

Estimated Impact of a Day in 15 Temperature (C) Bins on Log Rural Annual Mortality Rate, Relative to a Day in the 22° - 24°C Bin

-2 std err  Growing Season (Jun-Dec)  +2 std err
Timing: Non-Growing Season

VSI data: Total deaths in Rural India with 95% confidence interval

Estimated Impact of a Day in 15 Temperature (C) Bins on Log Rural Annual Mortality Rate, Relative to a Day in the 22° - 24°C Bin

-2 std err  Non-Growing Season (Mar-May)  +2 std err
Adjustment? Hot vs Cold Areas

VSI data: Total deaths in Rural India

Estimated Impact of a Day in 15 Temperature (C) Bins on Log Rural Annual Mortality Rate,
Relative to a Day in the 22° - 24°C Bin

'Colder' Districts

'Hotter' Districts
Rainfall and Total Death Rate: Rural

\[ Y_{dt} = \sum_j \theta_j T_{dt}^j + \sum_{m=1}^{12} \delta_1^m P_{dt}^m + \sum_{m=1}^{12} \delta_2^m (P_{dt}^m)^2 + \alpha_d + \beta_t + \{\gamma_r t^3\} + \varepsilon_{dt} \]

12 marginal effects (\(\hat{\delta}_1^m + 2\hat{P}_m \hat{\delta}_2^m\)) plotted
Rainfall and Total Death Rate: Urban

\[ Y_{dt} = \sum_j \theta_j T_{dt}^j + \sum_{m=1}^{12} \delta^1_m P_{dt}^m + \sum_{m=1}^{12} \delta^2_m (P_{dt}^m)^2 + \alpha_d + \beta_t + \{\gamma r t^3\} + \varepsilon_{dt} - 12 \]

can be estimated using marginal effects \((\delta^1_m + 2\hat{P}_m \hat{\delta}^2_m)\) plotted
A Parametric Approach

• Use more parametric specification for temperature and rainfall

\[ Y_{dt} = \theta DD_{dt} + \delta^{kharif} P^{kharif}_{dt} + \delta^{rabi} P^{rabi}_{dt} \]
\[ + \alpha_d + \beta_t + \{\gamma_r t^3\} + \varepsilon_{dt} \]

• \( DD_{dt} \) = ‘degree-days’: Cumulative number of degrees (above 32° C)-times-days in year \( t \)

• Common approach in epidemiology/agronomy
• Justification: Living organisms (especially humans and food crops) tend to cope well until temperatures exceed 32° C
Parametric Approach: Results

\[ Y_{dt} = \theta DD_{dt} + \delta^{kharif} P^{kharif}_{dt} + \delta^{rabi} P^{rabi}_{dt} + \alpha_d + \beta_t + \{\gamma_r t^3\} + \varepsilon_{dt} \]

<table>
<thead>
<tr>
<th>Dep. var.: log total mortality rate</th>
<th>Rural (1)</th>
<th>Urban (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GROWING SEASON [Jun-Dec]:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temp. (degree-days)</td>
<td>0.0265</td>
<td>0.0081</td>
</tr>
<tr>
<td></td>
<td>(0.0047)**</td>
<td>(0.0039)**</td>
</tr>
<tr>
<td>Kharif rainfall marg. effect (mm) [Jun-Sep]</td>
<td>0.0127</td>
<td>0.0056</td>
</tr>
<tr>
<td></td>
<td>(0.0044)**</td>
<td>(0.0027)</td>
</tr>
<tr>
<td>Rabi rainfall marg. effect (mm) [Oct-Dec]</td>
<td>-0.0355</td>
<td>-0.0003</td>
</tr>
<tr>
<td></td>
<td>(0.0099)**</td>
<td>(0.0105)</td>
</tr>
<tr>
<td><strong>NON-GROWING SEASON [Mar-May]:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temp. (degree-days)</td>
<td>0.0018</td>
<td>0.0018</td>
</tr>
<tr>
<td></td>
<td>(0.0043)</td>
<td>(0.0031)</td>
</tr>
<tr>
<td>Rainfall marg. effect (mm)</td>
<td>-0.0142</td>
<td>0.0294</td>
</tr>
<tr>
<td></td>
<td>(0.0249)</td>
<td>(0.0197)</td>
</tr>
</tbody>
</table>

Notes: Regressions include district fixed effects, year fixed effects and region-specific cubic time trends. Regressions weighted by population. Standard errors clustered by district.
Outline of Talk

Conceptual Framework

Reduced-Form Results: Weather and Death

Mechanisms: ‘Direct’ vs ‘Indirect’ Effects

Implications for Policy

Conclusion
Mechanisms: Weather and Income

• Recap: Large effects of both temperature and rainfall on death rates in rural India but not in urban India (not even infants).

• Begs important questions:
  1. Why are there large effects of weather on death in rural India, and why not in urban India?
  2. Why are these effects absent during the non-growing season (the hot season), even in rural India?
Indirect Effect: Implications

- Bad GS weather (but not NGS weather) causes:
  - Lower agricultural yields
  - Higher agricultural prices
  - Lower Rural wages (but not Urban wages)
  - Lower Rural bank deposits (but not Urban bank deposits)
  - Higher adult and infant Rural mortality rate (but not adult or infant Urban mortality rate)

Temperature and Agricultural Yields

Yield: Real aggregate agricultural output per acre

Estimated Impact of a Day in 15 Temperature (C) Bins on Log Agricultural Total Product (Sum Weighted by Average Crop Price), Relative to a Day in the 22° - 24°C Bin

-2 std err  coefficient  +2 std err
Temperature and Agricultural Prices

Agricultural price index

Estimated Impact of a Day in 15 Temperature (C) Bins on Log Agricultural Prices (Sum Weighted by Average Crop Production), Relative to a Day in the 22° - 24°C Bin

-2 std err  coefficient  +2 std err
Temperature and Urban Wages

Urban wage: state-level real manufacturing earnings per worker

Estimated Impact of a Day in 15 Temperature (C) Bins on Log Manufacturing Wage, Relative to a Day in the 22° - 24°C Bin
Temperature and Bank Deposits:
Bank deposits per capita in Rural areas

Estimated Impact of a Day in 15 Temperature (C) Bins on Log Bank Deposits Per Capita, Relative to a Day in the 22° - 24°C Bin

-2 std impact +2 std

Estimated Response Function Between Temperature Exposure and Log Bank Deposits Per Capita, Rural Areas
Temperature and Bank Deposits:

Bank deposits per capita in **Urban** areas

Estimated Impact of a Day in 15 Temperature (C) Bins on Log Bank Deposits Per Capita, Relative to a Day in the 22° - 24°C Bin

-2 std  impact  +2 std
Rainfall and Agricultural Yields

Yield: Real aggregate agricultural output per acre

Estimated Impact of Monthly Precipitation on Log Total Agricultural Productivity
Rainfall and Agricultural Wages

Real agricultural laborers’ wages

Estimated Impact of Monthly Precipitation on Log Real Agricultural Wage
Parametric Approach: Results

\[ Y_{dt} = \theta DD_{dt} + \delta^{kharif} P_{dt}^{kharif} + \delta^{rabi} P_{dt}^{rabi} + \alpha_d + \beta_t + \{\gamma_r t^3\} + \varepsilon_{dt} \]

<table>
<thead>
<tr>
<th>Dependent variable: log...</th>
<th>Yields (1)</th>
<th>Prices (2)</th>
<th>Ag. W (3)</th>
<th>Man. W (4)</th>
</tr>
</thead>
</table>

**GROWING SEASON [Jun-Dec]:**

<table>
<thead>
<tr>
<th>Temp. (degree-days)</th>
<th>-0.0090 (0.0033)***</th>
<th>0.0022 (0.0007)***</th>
<th>-0.0037 (0.0015)***</th>
<th>-0.0014 (0.0104)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kharif rainfall marg. effect (mm)</td>
<td>0.0268 (0.0040)***</td>
<td>-0.0031 (0.0007)***</td>
<td>0.0047 (0.0018)***</td>
<td>0.0005 (0.0103)</td>
</tr>
<tr>
<td>Rabi rainfall marg. effect (mm)</td>
<td>0.0520 (0.0071)***</td>
<td>-0.0088 (0.0022)***</td>
<td>0.0078 (0.0053)</td>
<td>-0.0656 (0.0506)</td>
</tr>
</tbody>
</table>

**NON-GROWING SEASON [Mar-May]:**

<table>
<thead>
<tr>
<th>Temp. (degree-days)</th>
<th>0.0040 (0.0022)*</th>
<th>0.0011 (0.0007)</th>
<th>0.0013 (0.0014)</th>
<th>0.0140 (0.0077)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall marg. effect (mm)</td>
<td>0.0062 (0.0102)</td>
<td>0.0055 (0.0037)</td>
<td>-0.0163 (0.0081)**</td>
<td>-0.0123 (0.0582)</td>
</tr>
</tbody>
</table>

Notes: Regressions in columns (1)-(3) include district fixed effects, year fixed effects and region-specific cubic time trends; in column (4), state fixed effects, year fixed effects and region-specific cubic time trends. Regressions weighted by population. Standard errors clustered by district in cols (1)-(3) and state in col (4).
An Interpretation I

- Consider a simple ‘model’ of agricultural income and death:

\[
\ln \left( \frac{Y}{L} \right)_{dt} = a^K P^K_{dt} + a^R P^R_{dt} + a_T T_{dt} + \varepsilon_{dt}
\]

\[
\ln M_{dt} = \beta \ln \left( \frac{Y}{L} \right)_{dt} + d^K P^K_{dt} + d^R P^R_{dt} + d_T T_{dt} + \varepsilon'_dt
\]

- Under exclusion restriction \( d^R_p = 0 \), this system is just identified
- \( \beta \) is the agricultural income-death elasticity
Estimates based on this exclusion restriction imply:

\[ \hat{\beta} = -0.68 \]

Indirect ‘income channel’ accounts for 23% of reduced-form temperature-death effect.

Kharif rainfall-death effect: ‘income channel’ is \[ \hat{\beta}_{a^K} = -0.01822 \], while ‘direct’ (eg disease) channel is \[ \hat{d^K} = 0.0127 \]. They are roughly offsetting.
Outline of Talk

Conceptual Framework

Reduced-Form Results: Weather and Death

Mechanisms: ‘Direct’ vs ‘Indirect’ Effects

Implications for Policy

Conclusion
Implications for Policy

- We have documented a large reduced-form impact of both temperature and rainfall extremes on mortality in India from 1956-2000.
- What does this imply for policy? We look at two examples with back-of-the-envelope calculations:
  1. What is the cost per life saved of an income support policy (ie ‘weather insurance’) designed to hold death rate constant?
  2. Looking into the future: As India’s climate changes throughout the 21st Century, what are the implications for mortality?
Income Support Policy

- Weather (especially temperature) is observable and verifiable
- A very simple government program could index cash transfers on the basis of daily temperature and rainfall realizations
- Estimated income-death elasticity of $\hat{\beta} = -0.68$ implies approximately $\$75$ per life saved (adult or child)
Implications of Climate Change I

- Models of C.C. predict $\Delta T_d$ and $\Delta P_d$

- We use our earlier estimates of the mortality consequences of weather variation to estimate the mortality consequences of predicted $\Delta T_d$ and $\Delta P_d$:

$$\Delta Y_d = \sum_j \hat{\theta}_j \Delta T_d^j + \sum_{m=1}^{12} \hat{\delta}_m \Delta P_d^m$$

- Likely to be an overestimate (short-run vs. long-run adaptation)
Implications of Climate Change II

- Feed in 2 standard C.C. models:
  1. Hadley Centre’s 3 A1F1 (corrected) model and NCAR’s CCSM 3 A2 model
  - Both are ‘business as usual’ scenarios
  - Both do not include ‘catastrophic scenarios’ (Himalayan glaciers melt, monsoon terminates, sea level rises, more cyclones)

- Details:
  - Models simulate full daily time path of temp. and rain from 1990-2099
  - Different time paths for each district in India
  - Define $\Delta T_d \equiv T_d^{2070-2099} - T_d^{1957-2001}$ etc
  - Compute $\Delta Y_d$ for each district $d$ and take pop-weighted average
Predicted Change in Distribution of Daily Mean Temperatures (C), Change in Days Per Year in Each Interval

CCSM 3 A2
Hadley 3 A1FI, Corrected
Predicted Impact of CC on Mortality

Percentage impacts: \( \Delta Y_d = \sum_j \hat{\theta}_j \Delta T^j_d + \sum_{m=1}^{12} \hat{\delta}_m \Delta P^m_d \), by 2070-2099

<table>
<thead>
<tr>
<th>Impact of Change in Days with Temperature:</th>
<th>Total Temperature Impact</th>
<th>‘Early’ Precipitation Impact</th>
<th>‘Late’ Precipitation Impact</th>
<th>Temperature and Precipitation Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;16C (1a)</td>
<td>16C-32C (1b)</td>
<td>&gt;32C (1c)</td>
<td>(2)</td>
<td>(3a)</td>
</tr>
<tr>
<td>A. Based on Hadley 3, A1FI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pooled</td>
<td>-0.019</td>
<td>-0.113</td>
<td>0.732</td>
<td>0.599</td>
</tr>
<tr>
<td></td>
<td>(0.031)</td>
<td>(0.047)</td>
<td>(0.119)</td>
<td>(0.117)</td>
</tr>
<tr>
<td>Rural Areas</td>
<td>-0.038</td>
<td>-0.140</td>
<td>0.913</td>
<td>0.735</td>
</tr>
<tr>
<td></td>
<td>(0.040)</td>
<td>(0.057)</td>
<td>(0.149)</td>
<td>(0.149)</td>
</tr>
<tr>
<td>Urban Areas</td>
<td>0.045</td>
<td>0.014</td>
<td>0.159</td>
<td>0.218</td>
</tr>
<tr>
<td></td>
<td>(0.033)</td>
<td>(0.057)</td>
<td>(0.114)</td>
<td>(0.102)</td>
</tr>
<tr>
<td>B. Based on CCSM3, A2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pooled</td>
<td>-0.010</td>
<td>0.061</td>
<td>0.164</td>
<td>0.214</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.040)</td>
<td>(0.009)</td>
<td>(0.057)</td>
</tr>
<tr>
<td>Rural Areas</td>
<td>-0.017</td>
<td>0.076</td>
<td>0.206</td>
<td>0.248</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.049)</td>
<td>(0.035)</td>
<td>(0.072)</td>
</tr>
<tr>
<td>Urban Areas</td>
<td>0.011</td>
<td>0.037</td>
<td>0.043</td>
<td>0.092</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.039)</td>
<td>(0.024)</td>
<td>(0.049)</td>
</tr>
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# Predicted Impact of CC on Mortality

Percentage impacts: \[ \Delta Y_d = \sum_j \hat{\theta}_j \Delta T_d^j + \sum_{m=1}^{12} \hat{\delta}_m \Delta P_d^m, \text{ rural only} \]

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<td>(3a)</td>
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<td>A. Based on Hadley 3, A1FI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010-2039</td>
<td>-0.014</td>
<td>0.052</td>
<td>0.061</td>
<td>0.099</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.025)</td>
<td>(0.011)</td>
<td>(0.036)</td>
</tr>
<tr>
<td>2040-2069</td>
<td>-0.019</td>
<td>0.007</td>
<td>0.302</td>
<td>0.290</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.026)</td>
<td>(0.047)</td>
<td>(0.064)</td>
</tr>
<tr>
<td>2070-2099</td>
<td>-0.019</td>
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<td>0.732</td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>2010-2039</td>
<td>-0.002</td>
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Outline of Talk

Conceptual Framework

Reduced-Form Results: Weather and Death

Mechanisms: ‘Direct’ vs ‘Indirect’ Effects

Implications for Policy

Conclusion
Summary

• Both temperature and rainfall extremes play a large role in the health lives of India’s rural poor:
  • One SD more degree-days (over 32 C) leads to 68 % higher death rate
  • Temperature: $10 \times$ larger effect than in USA
  • Cluster of findings consistent with these effects working through agricultural income

• Implications:
  • Smoothing of marginal utility in rural India is far from complete
  • Weather-indexed income support policy would cost only $75 per life saved (adult or child)
  • Standard global warming scenarios imply dire upper-bound (limited adaptation) consequences