Cyclone damage & agriculture in India
Income Smoothing, Risk Diversification and Cyclone Damage in India

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EC501 Work-in-Progress Seminar
20.10.2009
The setting

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  - During 1949-2007, a cyclone on average affected 1.4 million people & caused $US290 million in damages (EM-DAT 2009)
- Since the 1960s, the costs of natural disasters has increased 14-fold (Munich Re 1995) due to
  - Economic development
  - Population growth in risky areas
  - Climate change (Emanuel 1995, 2005)
Why do we care?

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  - Informal insurance networks are vulnerable to geographically co-moving shocks (Besley 1995)
  - General equilibrium effects will depress local prices of assets and livestock & wages for off-farm employment
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- Alternative coping mechanisms fail b/c
  - Informal insurance networks are vulnerable to geographically co-moving shocks (Besley 1995).
  - General equilibrium effects will depress local prices of assets and livestock & wages for off-farm employment.
- Moreover, HHs might not correctly anticipate these low probability events.
Research question

Rural households will face large, mostly uninsured & potentially unexpected income shocks
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- If yes, how?
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And more generally,

- Does living in a disaster-prone area translate into a long-run growth disadvantage?

Note: I will not be able to address migration due to data limitations
This paper (1/2)

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Exploits the random variation of cyclone tracks over time to

- Estimate the direct cost of natural disasters on the primary sector at the district level
- Tests for the persistence of cyclone shocks
- Tests for potential adaptation to these cyclone shocks
Preliminary findings suggest that

- The elasticity of total revenue to cyclone shocks is -0.128
- For a median level of "affectedness" of 49% total revenue drops by 7.6%
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- For a median level of "affectedness" of 49% total revenue drops by 7.6%
- This effect does not persist over time
- However, the capital stock remains significantly lower even 5 years after the shock suggesting the presence of liquidity constraints
- There is some income smoothing/risk diversification across crop types
Related Literature

- Nascent literature on natural disasters & aid
  - Literature on Climate Change (Deschenes & Greenstone 2007; Guiteras 2007, Dell et al. 2008)
  - Literature on choice under uncertainty - does not seem that relevant in this case
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Cyclone damage & agriculture in India (1/5)

- Storm surges will inundate low-lying areas of the coastal regions and
  - Drown human beings & livestock
  - Destroy vegetation
  - Reduce soil fertility
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⇒ The primary sector will be most exposed to these effects
Cyclone damage & agriculture in India (2/5)

These effects should vary across crops depending on their growing season & the month the cyclone strikes.
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- There are cyclone shocks all year round, but the two main cyclone seasons in India are
  - May-June
  - September-November
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  - May-June
  - September-November

- There are two main cropping seasons in India (excluding Tamil Nadu)
  - Kharif crops are sown in spring & harvested in autumn
  - Rabi crops are sown in late autumn & harvested the following spring
  - Two season crops have varieties that can be grown in both seasons
Cyclone damage & agriculture in India (3/5)

- The farmer will face three states of the world
  - a cyclone shock in the Kharif season, which occurs with probability $pr_k$ and causes damage $d_{ki}$ to output/input i
  - a cyclone shock in the Rabi season, which occurs with probability $pr_r$ and causes damage $d_{ri}$ to output/input i
  - no cyclone shock, which occurs with probability $(1 - pr_k - pr_r)$
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- Labour $L$ hired at wage $w$
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Cyclone damage & agriculture in India (4/5)

If the farmer has full information about the event probabilities, she will maximize expected profits

$$\max_{q_k, q_r, K, L} E(\Pi) = pr_k [p_k (q_k - d_{kk}) + pr q_r - r (K - d_{kK}) - w (L - d_{kL})] +$$

$$pr_r [p_k q_k + p_r (q_r - d_{rr}) - r (K - d_{rK}) - w (L - d_{rL})] +$$

$$(1 - pr_k - pr_r) [p_k q_k + p_r q_r - r K - w L]$$

(1)

Subject to production functions $q_k = f_k (K, L)$ and $q_r = f_r (K, L)$
Cyclone damage & agriculture in India (5/5)

If the farmer has incomplete information $I$ about the event probabilities, she will maximize expected profits

$$\max_{q_k, q_r, K, L} E(\Pi|I) = pr_k(I)[p_k(q_k - d_{kk}) + p_r q_r - r(K-d_{kK}) - w(L-d_{kL})] +$$

$$pr_r(I)[p_k q_k + p_r (q_r - d_{rr}) - (K-d_{rK}) - w(L-d_{rL})] +$$

$$(1-pr_k(I)-pr_r(I))[p_k q_k + p_r q_r - rK - wL] \quad (2)$$

Subject to production functions $q_k = f_k(K, L)$ and $q_r = f_r(K, L)$

Note: $I$ is assumed to increase with the exposure to recent cyclone shocks
Predictions (1/2)

In the year of impact, a cyclone should

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- Destroy Kharif crops (harvest & storage)
- Have an ambiguous effect on Rabi crops (destruction vs. income smoothing)
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  - A quicker recovery
    - In richer states
    - In states with more responsive state governments
    - In states with better financial development
    - The higher the disaster aid
- If HHs have updated their expectations, we should observe
  permanent changes in
  - The crop mix
  - Input choices
  - Area planted
- If expected profits are lower than the outside option, the farmer should migrate
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Empirical strategy (1/2)

- Identifying assumption: variation in cyclone tracks over time is exogenous (only driven by oceanic & climatic conditions)
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  - Macroeconomic shocks & region-specific time trends with year FE and either (distance to sea)\*year FE or state*year FE
Empirical strategy (1/2)

- Identifying assumption: variation in cyclone tracks over time is exogenous (only driven by oceanic & climatic conditions)
- Use a fixed effects specification to control for
  - Time-invariant district-level characteristics
  - Macroeconomic shocks & region-specific time trends with year FE and either (distance to sea)*year FE or state*year FE
- Control for other exogenous factors influencing agricultural production, namely precipitation & temperature shocks (Guiteras 2007, Schlenker & Roberts 2008)
Empirical strategy (2/2)

- To estimate direct economic cost of cyclone exposure include:
  - A measure of cyclone exposure in year $t$ to estimate the contemporaneous effect
  - Lags of the cyclone exposure variable to estimate the persistence of the cyclone shock
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- Main problem with including lags: cannot isolate potential change in expectations from effect of past shocks on current agricultural production
  - To estimate effect on expectation use cyclone exposure of neighboring districts
  - This is ONLY valid, if can show that neighboring districts do not affect local markets through prices
Regression specification for cyclone impact

Various LHS variables, e.g. $\ln(revenue_{tot})_{dt}$ for district $d$, year $t$

$$\ln (y_{dt}) = \alpha + \beta_0 shock_{dt} +$$

$$+ \sum_{m=4}^{12} \theta_1 m rainshock_{dmt} + \sum_{m=1}^{3} \theta_2 m rainshock_{dmt+1} \quad (4)$$

$$+ \sum_{m=4}^{12} \theta_3 m tempshock_{dmt} + \sum_{m=1}^{3} \theta_4 m tempshock_{dmt+1}$$

$$+ \delta_d + \mu_i t + \varepsilon_{dt}$$

- Standard errors clustered at the district level
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- Standard errors clustered at the district level
- Variable for cyclone impact $shock_{dt}$ for district $d$ in year $t$
- $\delta_d$ district FE, $\mu_i t$ region $i$*year $t$ interactions, $\epsilon_{dt}$ error term
- Weather shocks $rainshock_{dmt,dmt+1}$ & $tempshock_{dmt,dmt+1}$ for district $d$ in month $m$ of year $t$ and $t + 1$
Regression specification for cyclone impact, by season

Various LHS variables, e.g. $\ln(revenue\_tot)_{dt}$ for district $d$, year $t$

\[
\ln(y_{dt}) = \alpha + \beta_{0k}shock_{dt} \ast kari_{t} + \beta_{0r}shock_{dt} \ast rabi_{t,t+1} \\
+ \sum_{m=4}^{12} \theta_{1m}rainshock_{dmt} + \sum_{m=1}^{3} \theta_{2m}rainshock_{dmt+1} \\
+ \sum_{m=4}^{12} \theta_{3m}tempshock_{dmt} + \sum_{m=1}^{3} \theta_{4m}tempshock_{dmt+1} \\
+ \delta_{d} + \mu_{i,t} + \epsilon_{dt} \tag{5}
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+ \delta_d + \mu_i t + \varepsilon_{dt}
\] (5)

- Standard errors clustered at the district level
- Dummy for Kharif season $kharif_t = 1$ if cyclone in year $t$ occurs in month $m = [4, 8]$, $= 0$ otherwise
- Dummy for Rabi season $rabi_{t,t+1} = 1$ if cyclone in year $t$ occurs in month $m = [9, 12]$ or cyclone in year $t = +1$ occurs in month $m = [1, 3]$, $= 0$ otherwise
Regression specification for persistence

Various LHS variables, e.g. $ln(revenue\_tot)_{dt}$ for district $d$, year $t$

\[
\ln (y_{dt}) = \alpha + \beta_0 \text{shock}_{dt} + \beta_1 \text{shock}_{dt-1} + \beta_2 \text{shock}_{dt-2} + \ldots + \beta_5 \text{shock}_{dt-5} \\
+ \sum_{m=4}^{12} \theta_1 m \text{rainshock}_{dmt} + \sum_{m=1}^{3} \theta_2 m \text{rainshock}_{dmt+1} \\
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- Standard errors clustered at the district level
- Variable for cyclone impact $shock_{dt}$ & associated lags $shock_{dt-i}$ for $i = 1, 2, \ldots, 5$
Regression specification for persistence, by season

Various LHS variables, e.g. $ln(revenue\_tot)_{dt}$ for district $d$, year $t$

$$
\ln (y_{dt}) = \alpha + \beta_{0k} shock_{dt} \times kharif_t + \beta_{1k} shock_{dt-1} \times kharif_t + \beta_{2k} shock_{dt-2} \times kharif_t + ... + \beta_{5k} shock_{dt-5} \times kharif_t + \beta_{0r} shock_{dt} \times rabi_{t,t+1} + \beta_{1r} shock_{dt-1} \times rabi_{t,t+1} + \beta_{2r} shock_{dt-2} \times rabi_{t,t+1} + ... + \beta_{5r} shock_{dt-5} \times rabi_{t,t+1} + \sum_{m=4}^{12} \theta_{1m} rainshock_{dmt} + \sum_{m=1}^{3} \theta_{2m} rainshock_{dmt+1} \\
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Cyclone Data

- Source: Cyclone eAtlas from India Meteorological Department (electronic version 1.0/2008)
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- Time Period: 1891-2007 (daily)
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- **Track records of**
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  - Cyclones (33-47 knots/60-88kmph)
  - Severe Cyclones (>47 knots/88 kmph)
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- Advantage of meteorological measurements:
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- Two variables constructed:
  - \( cyclone_{hit} dt = 1 \) if cyclone passed over district \( d \) in year \( t \), 0 otherwise
  - \( percent_{affected} dt = \frac{area_{affected} dt}{total_{area} d} \)
Cyclones & Severe Cyclones, 1946-1987

Legend
- Cyclonic storm (33-47 knots)
- Severe Cyclone (>47 knots)
Cyclones & Severe Cyclones, 1946-1987 - buffered
Outcome Data (1/2)

Outcome Data (1/2)

- Time period: 1956-1987 (annual)
- Agricultural year $t \equiv$ April $t -$ March $t + 1$
- Number of districts: 259 (1966 boundaries, excl. Tamil Nadu)
Outcome Data (1/2)

- **Source:** India Agricultural & Climate dataset of the World Bank (Sanghi, Kumar & McKinsey, 1998)
- **Time period:** 1956-1987 (annual)
- **Agricultural year** \( t \equiv \text{April } t - \text{March } t + 1 \)
- **Number of districts:** 259 (1966 boundaries, excl. Tamil Nadu)
- **Agricultural data on prices, output & area planted by crop**

<table>
<thead>
<tr>
<th>Kharif crop</th>
<th>Rabi crop</th>
<th>Two season crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>major crop</td>
<td>minor crop</td>
<td>major crop</td>
</tr>
<tr>
<td>bajra</td>
<td>cotton</td>
<td>wheat</td>
</tr>
<tr>
<td>maize</td>
<td>groundnut</td>
<td>gram</td>
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<td>jute</td>
<td>sugar</td>
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<td>tobacco</td>
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<td>ragi</td>
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<tr>
<td>tur</td>
<td>&amp; mustard</td>
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</table>
Outcome Data (2/2)

- Agricultural data on (cont.)
  - Number of agricultural labourers & cultivators, real wages
  - Number & price of tractors & bullocks
  - Usage & price of fertilizer
Outcome Data (2/2)

- Agricultural data on (cont.)
  - Number of agricultural labourers & cultivators, real wages
  - Number & price of tractors & bullocks
  - Usage & price of fertilizer

- Main outcome variables (in natural logs):
  - Revenue variables (in MM 1980 INR): total revenue, revenue of 6 major crops, revenue of Kharif crops, revenue of Rabi crops, revenue of two-season crops
  - Input data: agricultural labourers (in 1000), cultivators (in 1000), real wage, # of bullocks (in 1000), # of tractors, fertilizer used (in tons)
Weather Data

- Source: Terrestrial Air Temperature & Precipitation dataset (Version 1.02)
Weather Data

- **Source:** Terrestrial Air Temperature & Precipitation dataset (Version 1.02)
- **Time period:** 1956-1988 (monthly)
- **Number of weather stations:** 352
Weather Data

- **Source:** Terrestrial Air Temperature & Precipitation dataset (Version 1.02)
- **Time period:** 1956-1988 (monthly)
- **Number of weather stations:** 352
- **Construct monthly weather shocks (following Duflo & Pande, 2007):**
  - Interpolated b/n weather stations w/in 100km radius
  - Calculate mean temperature & precipitation at the district level for each month & year
  - Calculate % deviation of the district-level weather variable from the district mean 1956-1988
## Summary statistics: main outcome variables (year=1956)

<table>
<thead>
<tr>
<th></th>
<th>total (MM)</th>
<th>rev (MM)</th>
<th>rev 6 major (MM)</th>
<th>rev kharif (MM)</th>
<th>rev. rabi (MM)</th>
<th>rev. both (MM)</th>
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<tbody>
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<td>mean coast</td>
<td>800.61</td>
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<td>638.22</td>
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<td>180.82</td>
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<td>530.43</td>
<td>371.33</td>
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<th></th>
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<th>cult (1000)</th>
<th>fertilizer (tons)</th>
<th>tractors (1000)</th>
<th>bullocks (1000)</th>
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<td>205.17</td>
<td>852</td>
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<td>1159.55</td>
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<td>574.64</td>
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<td>110.76</td>
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<td>657.54</td>
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### Summary statistics: cyclone variables (1946-1986)

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## Cyclone impact: shock dummy

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<th>(2) rev 6 major</th>
<th>(3) rev kharif</th>
<th>(4) rev. rabi</th>
<th>(5) rev both</th>
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<tr>
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<td>-0.128*</td>
<td>-0.125*</td>
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<tr>
<td>dsea*yr FE</td>
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<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>weather shocks</td>
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<td>yes</td>
<td>yes</td>
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</tr>
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## Cyclone impact: shock dummy (cont.)

<table>
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<td>tractors</td>
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<tr>
<td>bullocks</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

- Cyclone hit: dummy for cyclone impact
- LHS: left-hand side variable
- Obs: observations
- district FE: district fixed effects
- dsea*yr FE: dsea*year fixed effects
- weather shocks: weather shocks included

<table>
<thead>
<tr>
<th>Obs</th>
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<th>(4)</th>
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### Cyclone impact: % damage

<table>
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<tr>
<td>LHS in ln</td>
<td>total rev</td>
<td>rev 6 major</td>
<td>rev kharif</td>
<td>rev. rabi</td>
<td>rev both</td>
</tr>
<tr>
<td>% affected</td>
<td>-0.00158*</td>
<td>-0.00179**</td>
<td>0.00651**</td>
<td>0.00359</td>
<td>8.05e-05</td>
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<td>yes</td>
<td>yes</td>
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<tr>
<td>weather shocks</td>
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### Cyclone impact: % damage (cont.)

<table>
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<td>tractor</td>
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<tr>
<td>% affected</td>
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<td>yes</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>dsea*yr FE</td>
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<td>yes</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>weather shocks</td>
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<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>Obs</td>
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## Cyclone impact by season: shock dummy

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<th>(2) cyclone_hit*rabi</th>
<th>(3) rev kharif</th>
<th>(4) rev rabi</th>
<th>(5) rev both</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-0.130*</td>
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<td>0.0971</td>
<td>0.0459</td>
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<td>(0.0867)</td>
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## Cyclone impact by season: shock dummy (cont.)

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<td>bullocks</td>
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<tr>
<td>cyclone_hit*kharif</td>
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<td>-0.0274**</td>
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### Persistence: shock dummy

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<th>(3) rev kharif</th>
<th>(4) rev. rabi</th>
<th>(5) rev both</th>
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</thead>
<tbody>
<tr>
<td>cyclone_hit</td>
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<td>(0.619)</td>
<td>(0.197)</td>
<td>(0.0665)</td>
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| joint sig ls (pvalue) | 0.387 | 0.472 | 0.820 | 0.618 | 0.706 |
## Persistence: shock dummy (cont.)

<table>
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<th>(1) LHS in ln agri</th>
<th>(2) LHS in ln cult</th>
<th>(3) LHS in ln fertilizer</th>
<th>(4) LHS in ln tractors</th>
<th>(5) LHS in ln bullocks</th>
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</thead>
<tbody>
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<td>-0.0950*</td>
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<td>l4_cyclone_hit</td>
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<td>joint sig ls (pvalue)</td>
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### Persistence by season: shock dummy (1/4)

<table>
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<th>rev 6 major</th>
<th>rev kharif</th>
<th>rev. rabi</th>
<th>rev both</th>
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<tbody>
<tr>
<td>cyclone_hit*kharif</td>
<td>-0.129*</td>
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<td>(0.0766)</td>
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<td>(0.152)</td>
<td>(0.0852)</td>
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<td>l1_cyclone_hit*kharif</td>
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<td>(0.0921)</td>
<td>(0.207)</td>
<td>(0.214)</td>
<td>(0.109)</td>
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<tr>
<td>l2_cyclone_hit*kharif</td>
<td>0.0530</td>
<td>0.0578</td>
<td>0.206</td>
<td>0.147*</td>
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<tr>
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<td>(0.0607)</td>
<td>(0.252)</td>
<td>(0.199)</td>
<td>(0.0758)</td>
</tr>
<tr>
<td>l3_cyclone_hit*kharif</td>
<td>-0.0418</td>
<td>-0.0303</td>
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<td>l4_cyclone_hit*kharif</td>
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<td>joint sig ls (pvalue)</td>
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## Persistence by season: shock dummy (cont. 2/4)

<table>
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<tr>
<th>LHS in ln</th>
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<th>(3) rev kharif</th>
<th>(4) rev. rabi</th>
<th>(5) rev both</th>
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<tr>
<td>cyclone_hit*rabi</td>
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<td>(0.424)</td>
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<tr>
<td>l1_cyclone_hit*rabi</td>
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<td>-0.207***</td>
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<td>l2_cyclone_hit*rabi</td>
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<td>0.700</td>
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<td>(0.109)</td>
<td>(0.122)</td>
<td>(0.787)</td>
<td>(0.116)</td>
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<tr>
<td>l3_cyclone_hit*rabi</td>
<td>-0.0435</td>
<td>-0.0700</td>
<td>-3.443</td>
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<td>(0.0507)</td>
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<td>(0.140)</td>
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<tr>
<td>l4_cyclone_hit*rabi</td>
<td>-0.177*</td>
<td>-0.221*</td>
<td>-0.413</td>
<td>0.167</td>
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<td>(0.0975)</td>
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<td>(0.391)</td>
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<td>(0.108)</td>
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<td>0.261</td>
<td>0.250</td>
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## Persistence by season: shock dummy (cont. 3/4)

<table>
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<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
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<tbody>
<tr>
<td>cyclone_hit*kharif</td>
<td>0.0423</td>
<td>-0.0286**</td>
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<td>l1_cyclone_hit*kharif</td>
<td>0.0385</td>
<td>-0.0279*</td>
<td>-0.296</td>
<td>-0.445**</td>
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<td>(0.327)</td>
<td>(0.184)</td>
<td>(0.0395)</td>
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<td>l2_cyclone_hit*kharif</td>
<td>-0.0145</td>
<td>-0.0147</td>
<td>0.221</td>
<td>-0.467**</td>
<td>-0.0414</td>
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<td>(0.0131)</td>
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<td>(0.183)</td>
<td>(0.0389)</td>
</tr>
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<td>l3_cyclone_hit*kharif</td>
<td>-0.00434</td>
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<td>0.158</td>
<td>-0.658***</td>
<td>-0.0119</td>
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<td>(0.0150)</td>
<td>(0.118)</td>
<td>(0.194)</td>
<td>(0.0399)</td>
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<td>l4_cyclone_hit*kharif</td>
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<td>-0.0178</td>
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<td>-0.744***</td>
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<td>(0.0417)</td>
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<td>l5_cyclone_hit*kharif</td>
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<td>-0.823***</td>
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<td>joint sig ls (pvalue)</td>
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<td>0.162</td>
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## Persistence by season: shock dummy (cont. 4/4)

<table>
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<th>(1) agri L</th>
<th>(2) cult</th>
<th>(3) fertilizer</th>
<th>(4) tractors</th>
<th>(5) bullocks</th>
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<td>cyclone_hit*rabi</td>
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<td>(0.209)</td>
<td>(0.178)</td>
<td>(0.201)</td>
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<td>0.477***</td>
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<td>(0.179)</td>
<td>(0.193)</td>
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<tr>
<td>l3_cyclone_hit*rabi</td>
<td>-0.246</td>
<td>0.0898*</td>
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<td>-0.145</td>
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<td>(0.112)</td>
<td>(0.0709)</td>
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<td>l5_cyclone_hit*rabi</td>
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<td>-0.331</td>
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<td>(0.0608)</td>
<td>(0.254)</td>
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<td>joint sig ls (pvalue)</td>
<td>0.450</td>
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<td>0.863</td>
<td>0.339</td>
<td>0.0299</td>
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</table>
### Income smoothing & risk diversification: % affected

<table>
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<tr>
<th></th>
<th>(1) rev maize</th>
<th>(2) rev cotton</th>
<th>(3) rev gnut</th>
<th>(4) rev wheat</th>
<th>(5) rev gram</th>
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<tr>
<td><strong>CROP TYPE</strong></td>
<td>Kharif</td>
<td>Kharif</td>
<td>Kharif</td>
<td>Rabi</td>
<td>Rabi</td>
</tr>
<tr>
<td>% affected*kharif</td>
<td>0.00161</td>
<td>0.0120**</td>
<td>0.00179</td>
<td>0.00703</td>
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<td>(0.00453)</td>
<td>(0.00300)</td>
<td>(0.00506)</td>
<td>(0.00557)</td>
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<tr>
<td>l2_ % affected*kharif</td>
<td>-0.00628</td>
<td>0.00785*</td>
<td>0.00577**</td>
<td>0.00241</td>
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<td>l3_ % affected*kharif</td>
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<td>0.00401</td>
<td>0.00671</td>
<td>0.00661**</td>
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<td>l4_ % affected*kharif</td>
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<td>l5_ % affected*kharif</td>
<td>0.00507</td>
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</table>

**Joint sig ls (pvalue):**

- (1) 0.689
- (2) 0.313
- (3) 0.0456
- (4) 0.462
- (5) 0.0255
<table>
<thead>
<tr>
<th>LHS in ln</th>
<th>(1) rev maize</th>
<th>(2) rev cotton</th>
<th>(3) rev gnut</th>
<th>(4) rev wheat</th>
<th>(5) rev gram</th>
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<tr>
<td>CROP TYPE</td>
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<td>Kharif</td>
<td>Kharif</td>
<td>Rabi</td>
<td>Rabi</td>
</tr>
<tr>
<td>% affected*rabi</td>
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<td>l1_% affected*rabi</td>
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<td>-0.0146**</td>
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<td>l2_% affected*rabi</td>
<td>-0.0138**</td>
<td>-0.0124*</td>
<td>-0.00268</td>
<td>-0.00704**</td>
<td>-0.00424</td>
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<td>l3_% affected*rabi</td>
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<td>l5_c% affected*rabi</td>
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<td>joint sig ls (pvalue)</td>
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<td>0.0641</td>
<td>0.0761</td>
<td>0.382</td>
<td>0.677</td>
</tr>
</tbody>
</table>
Additional specifications:

- Test identifying assumption by doing an event study analysis
  \[\implies\] need to show that leads are jointly insignificant
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  ⇒ need to show that leads are jointly insignificant

- Adaptation regressions:
  - Include measure for shocks within past five to ten years
  - Include measure for shock to neighboring district
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- Test identifying assumption by doing an event study analysis → need to show that leads are jointly insignificant

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  - Include measure for shocks w/in past five-ten years
  - Include measure for shock to neighboring district

- Differential effect: interact cyclone variables with
  - Distance to sea
  - State-level characteristics:
    - Income
    - Financial Development
    - Government responsiveness
Additional datasets:

- Use district-level growing schedules to improve on Kharif vs. Rabi classification
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- Use district-level growing schedules to improve on Kharif vs. Rabi classification
- Analysis of consumption & employment data
  - Advantage: complements above analysis of the income channel

- Analysis of the manufacturing sector
  - Test “creative destruction” (Gilchrist & Williams 2004) vs. “large temporary shock” hypothesis (Davis & Weinstein 2002, Miguel & Roland 2006)
  - Construct a measure of productivity (following Olley & Pakes 1996 & Pavcnik 2002)
  - Two possible datasets:
    - PROWESS dataset (1989-2003): only medium & large ﬁrms
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- Use district-level growing schedules to improve on Kharif vs. Rabi classification.
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  - Advantage: complements above analysis of the income channel.
- Analysis of the manufacturing sector
  - Test "creative destruction" (Gilchrist & Williams 2004) vs. "large temporary shock" hypothesis (Davis & Weinstein 2002, Miguel & Roland 2006).
  - Construct a measure of productivity (following Olley & Pakes 1996 & Pavcnik 2002).
  - Two possible datasets:
Summary

- This paper uses a new digital dataset of cyclone tracks to estimate the direct cost of natural disasters on the primary sector in India at the district level.
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- Preliminary findings suggest that:
  - The elasticity of total revenue to cyclone shocks is -0.128.
  - For a median level of destruction of 49% total revenue drops by 7.6% (Note that these numbers are lower bound estimates).
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- This paper uses a new digital dataset of cyclone tracks to estimate the direct cost of natural disasters on the primary sector in India at the district level.

- Preliminary findings suggest that:
  - The elasticity of total revenue to cyclone shocks is -0.128.
  - For a median level of destruction of 49% total revenue drops by 7.6% (Note that these numbers are lower bound estimates).
  - This effect does not persist over time.
  - However, the capital stock remains significantly lower even 5 years after the shock suggesting the presence of liquidity constraints.
Summary

- This paper uses a new digital dataset of cyclone tracks to estimate the direct cost of natural disasters on the primary sector in India at the district level.

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  - The elasticity of total revenue to cyclone shocks is -0.128.
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  - This effect does not persist over time.
  - However, the capital stock remains significantly lower even 5 years after the shock suggesting the presence of liquidity constraints.
  - There is some income smoothing/risk diversification across crop types.