Weather Variability, Agriculture and Rural Migration: Evidence from India

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Structure

• Context
  – Climate Change Impacts on Agriculture
  – Migration as an adaptation/coping option

• Objectives

• Migration Patterns in India

• Data and Methodology

• Results-State level and District Level

• Conclusions
# Climate Change Impacts - Agriculture

### Daily per-capita Calorie Availability

![Bar chart showing daily per-capita calorie availability across regions.](chart)

- **South Asia and the Pacific**: 2000, No Climate Change, CSIRO, NCAR
- **East Asia**: 2000, No Climate Change, CSIRO, NCAR
- **Europe and Central Asia**: 2000, No Climate Change, CSIRO, NCAR
- **Latin America and the Caribbean**: 2000, No Climate Change, CSIRO, NCAR
- **Middle East and North Africa**: 2000, No Climate Change, CSIRO, NCAR
- **Sub-Saharan Africa**: 2000, No Climate Change, CSIRO, NCAR
- **Developing countries**: 2000, No Climate Change, CSIRO, NCAR

### Economy-wide Impacts of Climate Change on Indian Agriculture

![Table showing impacts of climate change on Indian agriculture.](table)

<table>
<thead>
<tr>
<th>Scenario (ΔT/ΔP)</th>
<th>Without Spatial Autocorrelation</th>
<th>With Spatial Autocorrelation</th>
<th>GDP (%)</th>
<th>Cal per cap (%)</th>
<th>Pop. prop. in bottom two expenditure classes - rural (base 0.183)</th>
<th>Pop. prop. in bottom three expenditure classes – urban (base 0.145)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000</td>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+2°C/7%</td>
<td>-81.2</td>
<td>14.2</td>
<td>-22.9</td>
<td>-2.6</td>
<td>0.283</td>
<td>0.208</td>
</tr>
<tr>
<td>India Specific CC Scenario</td>
<td>-195.1</td>
<td>43.4</td>
<td>-2.1</td>
<td>-0.23</td>
<td>0.294</td>
<td>0.214</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>0.311</td>
<td></td>
</tr>
</tbody>
</table>

### Source
- Daily per-capita Calorie Availability (source: Nelson et al., 2009)
- Economy-wide Impacts of Climate Change on Indian Agriculture (source: Kumar and Parikh, 2001, Kumar, 2011)
Understanding Triggers of Migration

• Migration from rural to urban areas as gradual development process – ongoing, albeit at a relatively lower pace in South Asia than rest of the world

• Migration in response to shocks – e.g., extreme weather events like cyclones, droughts, floods

• Migration due to distress in agriculture and rural livelihoods
Climate-Change and Migration

• Growing recognition for migration as an adaptation strategy in climate change context (McLeman and Smit, 2006; Byravan and Chella Rajan, 2009; McLeman and Hunter 2010; Massey et al., 2010)

• Migration as a response to multiple stresses including climate stress (Black et al., 2011)

• Migration could include within country and cross-country movement – both are relevant from climate perspective

• Migration (within and cross-country) could be both planned and autonomous
Climate-Change and Migration

• Crop productivity-climate change -migration
  – Provided three-way connection between climate change, maize/wheat yields and for emigration from Mexico to the USA (Feng et al., 2010)
  – Feng et al. (2012) applied similar approach to study internal migration in the US to find climate change induced crop productivity changes on migration

• Weather anomalies and migration
  – rural to urban migration (economic geography) and emigration (amenity channel) for countries in sub-Saharan Africa Marchiori et al. (2012)
Climate-Change and Migration

- Linkage between migration, agricultural risk and weather variability is observed for Nigeria based on primary data (Dillon et al., 2011)

- Barbieri et al. (2010) use simulation techniques to study the impact of climate change on Brazilian agriculture which in turn influences migration

- Hassani-Mahmoooei and Parris (2012) based on agent-based modelling analyse the effects of climate change on internal migration in Bangladesh.
  - Predict that depending on the severity of various climate extremes there could be between 3 to 10 million internal migrants over next 40 years.
Objectives

• Acknowledging that migration can take place due to several reasons, this study for India focuses on
  – weather variability induced migration,
  – operating through the channel of agricultural productivity changes.

• Specific objectives of the study are:
  – What is the evidence of inter-state migration rate in India caused by weather (variability) induced agricultural yield changes?
  – How significant is the impact on migration rate to crop yield changes at intra-state level?
  – Does migration rate depend on the agricultural crop under consideration?
Defining a Migrant

• Definition based on place of Last Residence obtained from the population census
  – “Is the place of enumeration different from the place of last residence?”

• Classification of Migrants by
  – Durations of Stay
  – Males and Females
  – Origin and Destination: Rural/Urban; inter-state/inter-district/intra-district
  – Purpose of migration- Marriage/Employment/Family (associated)/Studies/Others
Trend in Male and Female Migration Rates: India 1971-2001

Migration rates (ratio of migrants to total population in a region) in general have declined over time since the early 1970s to 2000.
Trends in Number of Male and Female Migrants

Male Migrants
- RU increases but RR drops
- Inter-State migrants increase for both RU and UU more so between 1991-2001

Female Migrants
- Only RR is dominant and increases
- Inter-state migrants increase marginally
Migration: Long-term versus Short-term, 2007-08

Source: NSSO

Long-term migrants

Short-term Migrants
Migration Patterns in India

• Given these patterns, it could be challenging to isolate weather induced migration in India
  – either through agriculture channel
  – or through amenity angle as explored in the literature (e.g., Feng et al., 2010, 2012; Marchiori et al., 2012)
Data: In-Migration Variables

• State level
  – Rural inter-state out-Migration rate using three Censuses: 1981, 1991 and 2001 and two durations of stay-1 to 4 years and 5 to 9 years
  – Covering 15 States
  – Excludes marriage and place of birth as reason for migration

• District level
  – Rural in-migration rate including inter-district and intra-district migrants for two durations of stay-1 to 4 years and 5 to 9 years from 2001 census
  – Covering 15 states
  – Male and Total migration rates are considered separately
Data: Weather

• Temperature and Rainfall
  – generated for the year 1970 to 2001 using gridded data (1°x1° lat/lon resolution)
  – published recently by India Meteorological Department
  – Mean temperatures and rainfall are used for the corresponding periods

(Acknowledge Chandrakiran Krishnamurthy for sharing the district level weather summaries)
Data: Agriculture Variables

• Yield data for two main cereal crops rice and wheat
• Per Capita Net State Domestic Product for Agriculture

  • State level annual date for 1961 to 2010
  • Mean values for the periods under consideration
  • The data sources include: India Agriculture and Climate Dataset (Sanghi et al.); Indiastat; Indian Harvest (CMIE)
Econometric Methodology

• The econometric estimation is based on the simultaneous equation model specified below (Feng et al., 2010).

\[(1) \quad M_{it} = \alpha + \beta \ln(Y_{it}) + d_i + r_t + \varepsilon_{it}, \text{ and}\]
\[(2) \quad \ln(Y_{it}) = \gamma + \delta T_{it} + p_i + c_t + \nu_{it}\]

\(M_{it}\) - out-migration (in-migration) rate from (to) region ‘i’ at period ‘t’ for a given state (district),

\(Y_{it}\) - agriculture variable: wheat yield or rice yield for states as well as districts or per capita net state domestic product of agriculture for region ‘i’ at period ‘t’ for states

\(T_{it}\) - set of weather variables for region ‘i’ at period ‘t’

\(d_i\) and \(p_i\) - coefficients for the regional (fixed) effects;

\(r_t\) and \(c_t\) - coefficients to capture time (fixed) effects

These fixed effects are included to capture the omitted variables that could be correlated with the variables (yield and weather) included in the equations (1) and (2).
State-level Results based on per-capita NSDP-Ag

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>p-value</th>
<th>Coefficient</th>
<th>p-value</th>
<th>Coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2SLS</td>
<td>OLS-1</td>
<td>OLS-2</td>
<td></td>
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<tr>
<td><strong>Agriculture Equation</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Average Temperature</td>
<td>0.1569</td>
<td>0.142</td>
<td>0.157</td>
<td>0.156</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Total Rainfall</td>
<td>0.0004*</td>
<td>0.016</td>
<td>0.0004**</td>
<td>0.016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>-3.260</td>
<td>0.274</td>
<td>-3.260</td>
<td>0.289</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.9189</td>
<td></td>
<td>0.9189</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Migration Equation</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>logarithm of per-capita NSDP-Ag</td>
<td>0.00023</td>
<td>0.942</td>
<td>-0.003***</td>
<td>0.001</td>
<td>-0.003***</td>
<td>0.001</td>
</tr>
<tr>
<td>Annual Average Temperature</td>
<td></td>
<td></td>
<td>0.000520</td>
<td>0.563</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Total Rainfall</td>
<td></td>
<td></td>
<td>0.000001</td>
<td>0.271</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>0.0018</td>
<td>0.676</td>
<td>0.006***</td>
<td>0.000</td>
<td>-0.009</td>
<td>0.730</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.8248</td>
<td></td>
<td>0.8102</td>
<td></td>
<td>0.8081</td>
<td></td>
</tr>
<tr>
<td><strong>Test Statistic for Joint Significance of Weather Variables</strong></td>
<td></td>
<td></td>
<td>(F(2,68) = 3.31^{**})</td>
<td>0.0426</td>
<td>(F(2,67) = 0.64)</td>
<td>0.5325</td>
</tr>
<tr>
<td><strong>Test for Endogeneity</strong></td>
<td>(\chi^2(19) = 1.225)</td>
<td>0.268</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of Observations</strong></td>
<td>90</td>
<td></td>
<td>90</td>
<td></td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>
State-level Results Inter-State-Out Migration Rate using per-capita NSDP of Agriculture

• No evidence of endogeneity for per-capita NSDPAg in the migration equation

• OLS estimation of Agriculture equation shows
  – per-capita NSDPAg increases with better weather conditions (higher rainfall), and

• OLS estimation of migration equation shows
  – larger per-capita NSDPAg reduces out-migration
  – A ten percent increase in per-capita NSDPAg could decrease migration rate by 0.03 percent.

• Inter-state out-migration is mainly through agricultural channel no evidence for amenity channel as
  – OLS estimates of weather variables in a model with both agriculture and weather are statistically insignificant
## State-Level Estimates for Inter-State-Out-Migration Rate

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>p-value</th>
<th>Coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield Equation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June-September Temp.</td>
<td>0.328**</td>
<td>0.027</td>
<td></td>
<td></td>
</tr>
<tr>
<td>October-November Temp.</td>
<td>-0.169</td>
<td>0.136</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std. Dev. of Jan-Mar Rainfall</td>
<td>-0.002**</td>
<td>0.041</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Annual Temp.</td>
<td>-1.467</td>
<td>0.135</td>
<td>0.028</td>
<td>0.136</td>
</tr>
<tr>
<td>(Average Annual Temp.)²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joint Significance of Weather Variables</td>
<td>F(3,58)=3.20*</td>
<td>0.0299</td>
<td>F(2,68)= 1.14</td>
<td>0.3249</td>
</tr>
<tr>
<td><strong>Migration Equation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>logarithm of Yield</td>
<td>-0.0036**</td>
<td>0.054</td>
<td>-0.0074*</td>
<td>0.094</td>
</tr>
<tr>
<td><strong>Test for Endogeneity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robust score $\chi^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi^2 (1)=2.75*$</td>
<td>0.097</td>
<td></td>
<td>$\chi^2(1)=5.70**$</td>
<td>0.0166</td>
</tr>
</tbody>
</table>

- Evidence for endogeneity of wheat and rice yields in the respective migration equation
- A ten percent decrease in yield could lead to 0.036 and 0.074 percent increase in out-migration rate for wheat and rice, respectively
- Higher semi-elasticity values for rice yield may be due to larger population growing rice compared to wheat
District-level Results based on Wheat & Rice Yields

• Moving on to District level migration data as
  – Inter-state out-migration rates are very small compared to within state movements
  – Lesser variability in yields when considered at the state level
• Only ‘in-migration’ data at district level from the census
  – which includes both inter-district and intra-district movements
• An increase in crop yield in a district could lead to increase in-migration of people from other districts into the district, and
  – Decrease the intra-district mobility
• The overall sign of the crop yield in the migration equation could thus depend on the relative strength of these two opposing effects
## District-Level Estimates for In-migration Rates Using Wheat Yield

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>p-value</th>
<th>Coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield Equation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male Migrants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June-Sep Temp.</td>
<td>0.264*</td>
<td>0.090</td>
<td>0.264*</td>
<td>0.090</td>
</tr>
<tr>
<td>Jan-Mar Temp.</td>
<td>-0.333</td>
<td>0.105</td>
<td>-0.333</td>
<td>0.105</td>
</tr>
<tr>
<td>Annl Total Rainfall</td>
<td>0.0001</td>
<td>0.416</td>
<td>0.0001</td>
<td>0.416</td>
</tr>
<tr>
<td>F-statistic for overall</td>
<td>F(4,333)=</td>
<td>0.000</td>
<td>F(4,333)=</td>
<td>0.000</td>
</tr>
<tr>
<td>Model significance</td>
<td>908.96***</td>
<td></td>
<td>908.96***</td>
<td></td>
</tr>
<tr>
<td><strong>Migration Equation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>logarithm of Yield</td>
<td>0.046***</td>
<td>0.012</td>
<td>0.037***</td>
<td>0.020</td>
</tr>
<tr>
<td><strong>Test for Endogeneity</strong></td>
<td></td>
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</tr>
<tr>
<td>Robust Score $\chi^2$</td>
<td>F(1,396)=11.3***</td>
<td>0.001</td>
<td>F(1,396)=7.4***</td>
<td>0.006</td>
</tr>
</tbody>
</table>
### District-Level Estimates for In-migration Rates Using Rice Yield

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>p-value</th>
<th>Coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield Equation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male Migrants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June-Sep Temp.</td>
<td>-0.639</td>
<td>0.000</td>
<td>-0.639</td>
<td>0.000</td>
</tr>
<tr>
<td>Jan-Mar Temp.</td>
<td>0.592</td>
<td>0.000</td>
<td>0.592</td>
<td>0.000</td>
</tr>
<tr>
<td>Oct-Nov Temp.</td>
<td>-0.517</td>
<td>0.000</td>
<td>-0.517</td>
<td>0.000</td>
</tr>
<tr>
<td>Log (Jun-Sep Total Rainfall)</td>
<td>0.252</td>
<td>0.098</td>
<td>0.252</td>
<td>0.098</td>
</tr>
<tr>
<td><strong>F-statistic: overall</strong></td>
<td>F(432,365)=9.35*</td>
<td>0.000</td>
<td>F(432,365)=9.35*</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Model significance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Migration Equation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logarithm of Yield</td>
<td>-0.0038**</td>
<td>0.026</td>
<td>-0.011***</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Test for Endogeneity</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Robust score Chi²</td>
<td>7.2***</td>
<td>0.007</td>
<td>32.9 ***</td>
<td>0.000</td>
</tr>
</tbody>
</table>
District-level Results based on Wheat & Rice Yields

• Results suggest that there is statistically significant evidence for endogeneity of both wheat and rice yields in the migration equation.

• While estimated coefficient of yield in the migration equation is positive in case of wheat, it is negative for rice yield.

• The absolute values of semi-elasticity of migration rate to crop yield are higher at district level than those estimated at state-level.
## Summarizing the Estimates

Semi-elasticity (elasticity) of Migration Rate to Crop Yield Changes

<table>
<thead>
<tr>
<th></th>
<th>Inter-State Out-Migration</th>
<th>Intra/Inter-District In-Migration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat – Male Migration Rate</td>
<td>-</td>
<td>0.046 (2.78)</td>
</tr>
<tr>
<td>Wheat – Total Migration Rate</td>
<td>-0.004 (-0.90)</td>
<td>0.037 (0.90)</td>
</tr>
<tr>
<td>Rice – Male Migration Rate</td>
<td>-</td>
<td>-0.007 (-0.40)</td>
</tr>
<tr>
<td>Rice – Total Migration Rate</td>
<td>-0.007 (-1.85)</td>
<td>-0.011 (-0.03)</td>
</tr>
</tbody>
</table>
Hind Casting: Inter-State Out Migration Rates

• Using the estimated state-level elasticities it is feasible to hind cast migration rates
  – In the period between 1971 to 2001, the average migration rate was 0.4%
• If the annual temperature were 1°C more during this period, the migration rate would have been 0.44% operating through decline in rice yields
• If the October-November temperature were 1°C more during this period, the migration rate would have been 0.46% operating through decline in wheat yields
Summarizing…

• This study has for the first time analysed the three-way linkage for India using secondary data.
• Findings on weather-agriculture-migration linkage appears somewhat weak
  – In terms of ‘endogeneity’ of agriculture
  – Weak instruments
  – Very small magnitude of change in migration rates due to changes in yield triggered by weather impacts
• Nevertheless the results are indicative of possible linkages between weather variability affecting crop yield and in turn migration rates.
Way Forward…

• To understand the puzzle of differences in signs across crop-yields for district level in-migration.
  – Rice is grown in almost all regions of the country
  – Rice is more labour intensive
  – More poverty in rice growing regions

• Implications of the large Rural-Rural Migration

• Distinguishing between the distress and the development angles of migration
  – To incorporate weather shocks alongside weather variability/anomalies.
THANK YOU

We thank SANDEE for the project grant to work on this issue