Weather Variability, Agriculture and Rural Migration: Evidence from India

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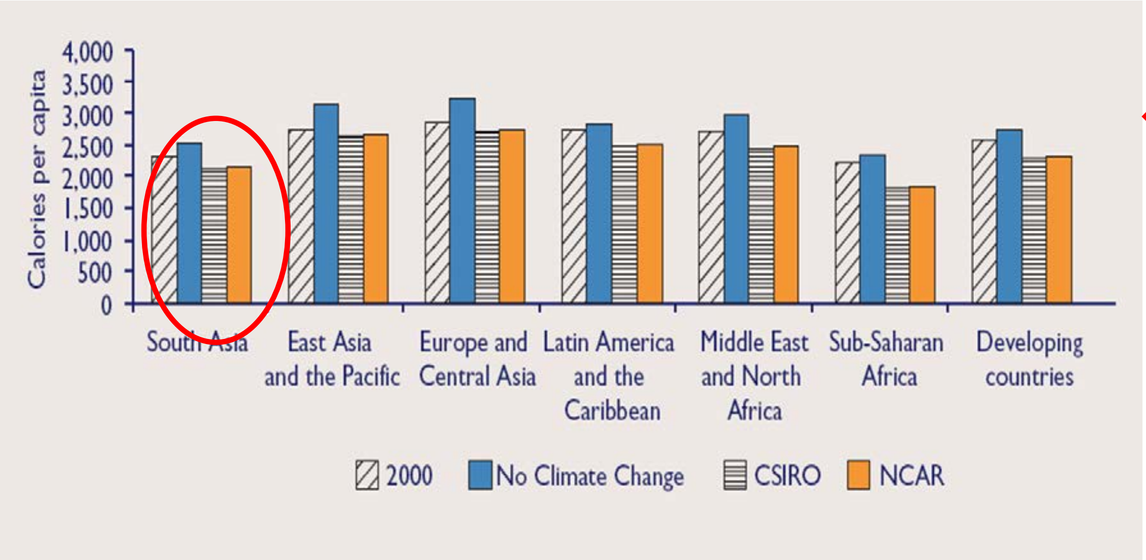
Structure

- 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 (source: Nelson et al., 2009)

Economy-wide Impacts of Climate Change on Indian Agriculture (source: Kumar and Parikh, 2001, Kumar, 2011)

Scenario (ΔT/ΔP)	Without Spatial Autocorrelation		With Spatial Autocorrelation			
			Spatial Lag Model		Spatial Error Model	
	Impacts	% of 1990 Net Revenue	Impacts	% of 1990 Net Revenue	Impacts	% of 1990 Net Revenue
+2°C/7%	-81.2	-9.17	14.2	1.6	-22.9	-2.6
India Specific CC Scenario	-195.1	-22.1	43.4	4.9	-2.1	-0.23

	GFDL	GISS	UKMO
GDP (%)	-1.8	-2.5	-3.4
Cal per cap (%)	-18.2	-19.5	-21.6
Pop. prop. in bottom two expenditure classes - rural (base 0.183)	0.283	0.294	0.311
Pop. prop. in bottom three expenditure classes – urban (base 0.145)	0.208	0.214	0.226

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-Mahmooei 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

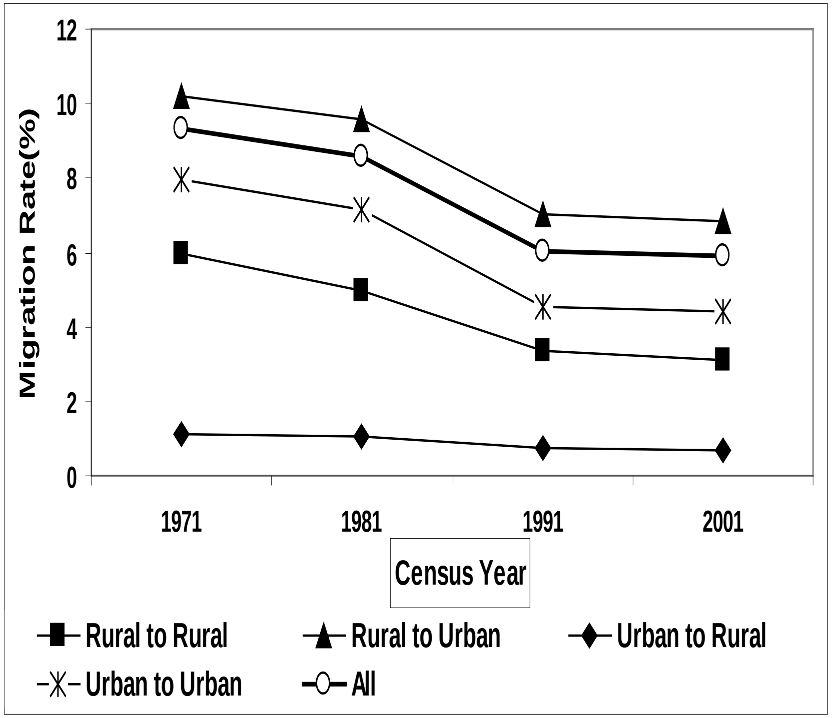
- Acknowledging that migration can take place due to several reasons, this study for India focuses on
  - weather variability induced migration,
  - operating through the channel of agricultural productivity changes.
- Specific objectives of the study are:
  - What is the evidence of inter-state migration 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?

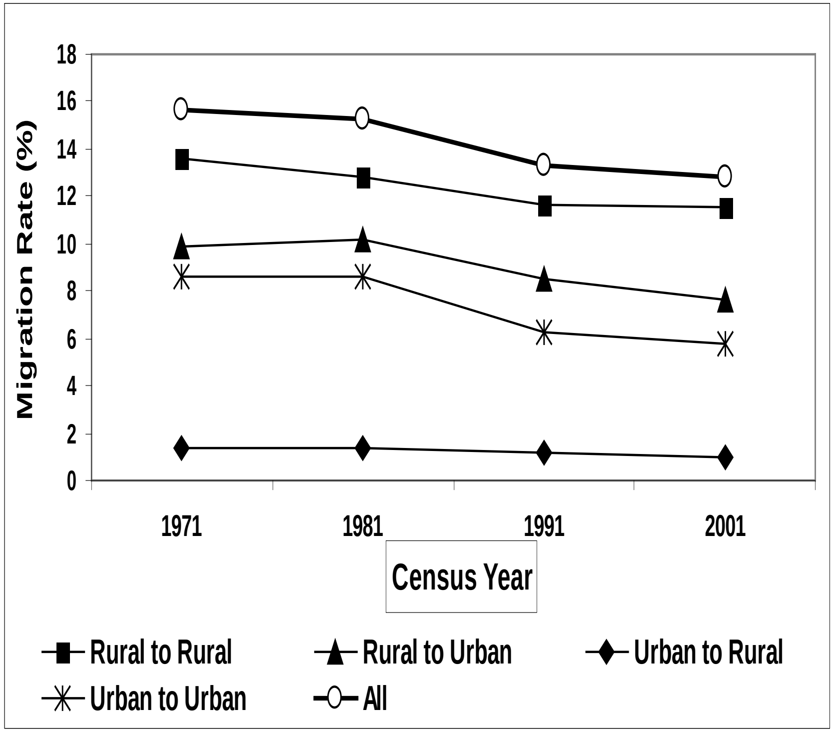
Defining a Migrant

- 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

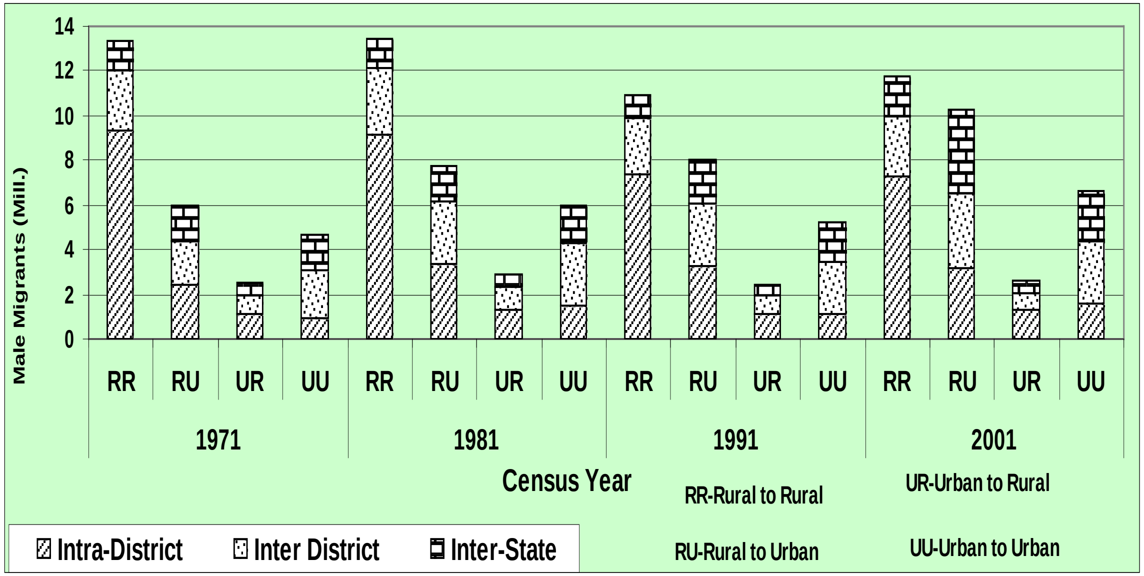




(a) Male Migration Rates **(b) Female Migration Rates**

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

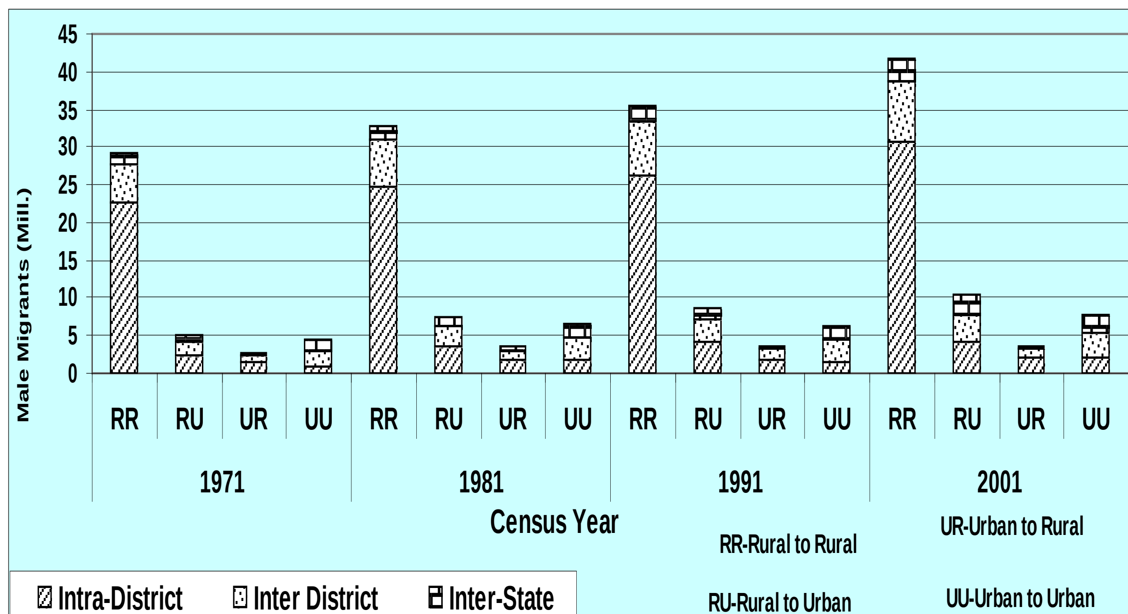


Male Migrants

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

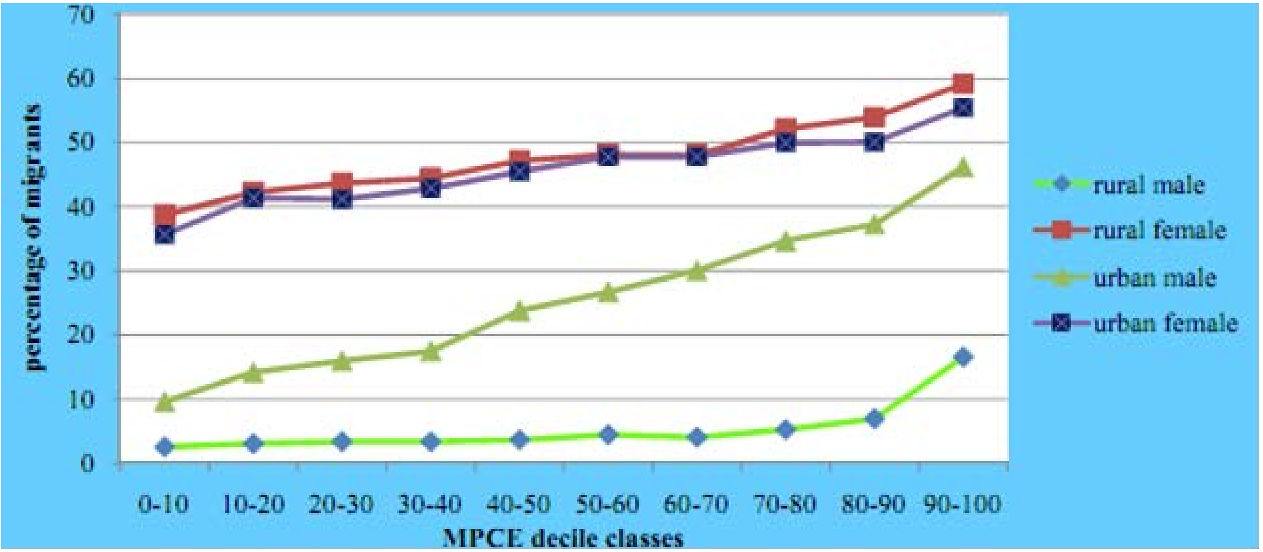
Female Migrants

- Only RR is dominant and increases
- Inter-state migrants increase marginally



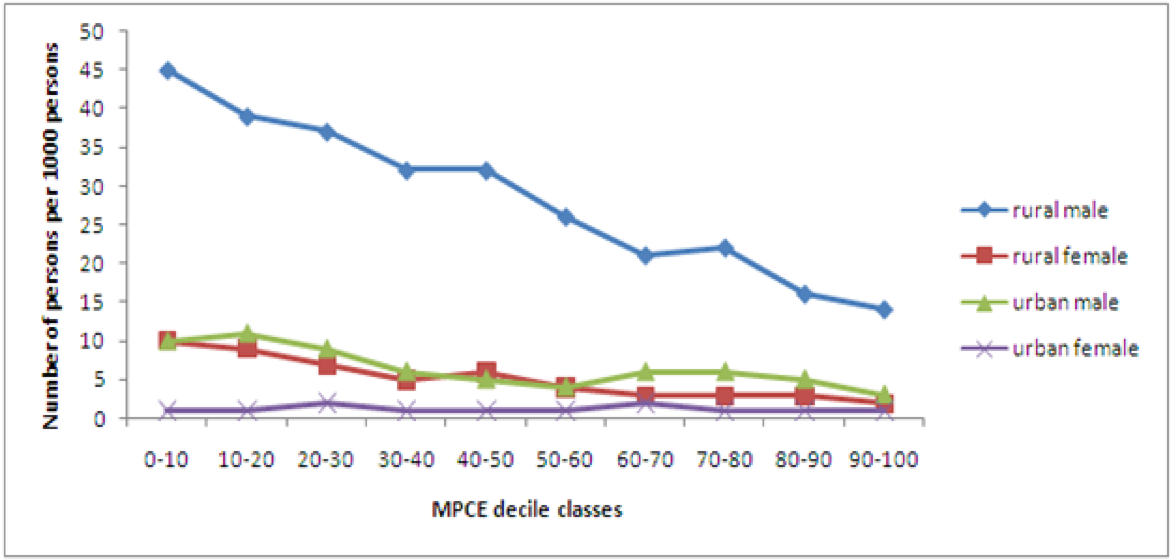
Migration: Long-term versus Short-term, 2007-08

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
  - Overall 6 Time periods: 1972-1976, 1977-1981, 1982-1986, 1987-1991, 1992-1996, 1997-2001
  - 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
  - Overall 2 Time periods 1992-1996, 1997-2001
  - 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 ($1^o x 1^o$ 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) $M_{it} = \alpha + \beta \ln(Y_{it}) + d_i + r_t + \varepsilon_{it}$, and

(2) $\ln(Y_{it}) = \gamma + \delta \boldsymbol{T}_{it} + p_i + c_t + \nu_{it}$

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

$\boldsymbol{T}_{it}$ *- 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 NSDPAg

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

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

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

- 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

Variable	Coefficient	p-value	Coefficient	p-value
Yield Equation	**Male Migrants**		**Total Migrants**	
June-Sep Temp.	0.264*	0.090	0.264*	0.090
Jan-Mar Temp.	-0.333	0.105	-0.333	0.105
Annl Total Rainfall	0.0001	0.416	0.0001	0.416
F-statistic for overall Model significance	F(4,333)= 908.96***	0.000	F(4,333)= 908.96***	0.000
Migration Equation				
logarithm of Yield	0.046***	0.012	0.037***	0.020
Test for Endogeneity				
Robust Score χ^2	F(1,396)=11.3***	0.001	F(1,396)=7.4***	0.006

District-Level Estimates for In-migration Rates Using Rice Yield

Variable	**Coefficient**	**p-value**	**Coefficient**	**p-value**
Yield Equation	**Male Migrants**		**Total Migrants**	
June-Sep Temp.	-0.639	0.000	-0.639	0.000
Jan-Mar Temp.	0.592	0.000	0.592	0.000
Oct-Nov Temp.	-0.517	0.000	-0.517	0.000
Log (Jun-Sep Tot Rainfall)	0.252	0.098	0.252	0.098
F-statistic: overall Model significance	F(432,365)= 9.35*	0.00	F(432,365)= 9.35*	0.00
Migration Equation				
logarithm of Yield	-0.0038**	0.026	-0.011***	0.000
Test for Endogeneity				
Robust score Chi^2	7.2***	0.007	32.9 ***	0.000

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

	Inter-State Out-Migration	Intra/Inter-District In-Migration
Wheat – Male Migration Rate	-	0.046 (2.78)
Wheat – Total Migration Rate	-0.004 (-0.90)	0.037 (0.90)
Rice – Male Migration Rate	-	-0.007 (-0.40)
Rice – Total Migration Rate	-0.007 (-1.85)	-0.011 (-0.03)

Hind Casting: Inter-State Out Migration Rates

- Using the estimated <u>state-level</u> 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^{o}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^{o}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 anlaysed 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