The Influence of Climate Variability on Internal Migration Flows in South Africa

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FEEM Seminar

Background

- Migration: One possible response to climate change
  - Internal vs international
    (Henry et al, 2003; Bohra-Mishra et al, 2014; Cai et al, 2014)
  - Rural to urban
  - Immobility (Gray and Mueller, 2012)
- Possible effects of climate on migration (Marchiori et al, 2012)
  - Direct: well-being, health
  - Indirect: agriculture, income, other economic channels
- Consequences on:
  - Migrants
  - Sending & receiving regions (Licker and Oppenheimer, 2013)

Research questions

1. *Did climate variability influence internal migration flows in South Africa in recent history?*
2. *If so, is agriculture one of the possible channels through which adverse climate conditions enhance out-migration?*
3. *Does the effect of climate on migration vary by migrant characteristics?*

Why South Africa?

- High internal migration rates

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  - 2007-2011: 12% of SA population moved ($\sim$ 6m people)
  - 0.3% international, 11.7% internal, 5% across districts (StatsSA, 2011)

Why South Africa?

- High internal migration rates
- High inter-racial inequality and poverty ratio
  - Share of population below national poverty line: **53.8%** (in 2010)
  - Income Gini coefficient: **63.4%** (in 2011)

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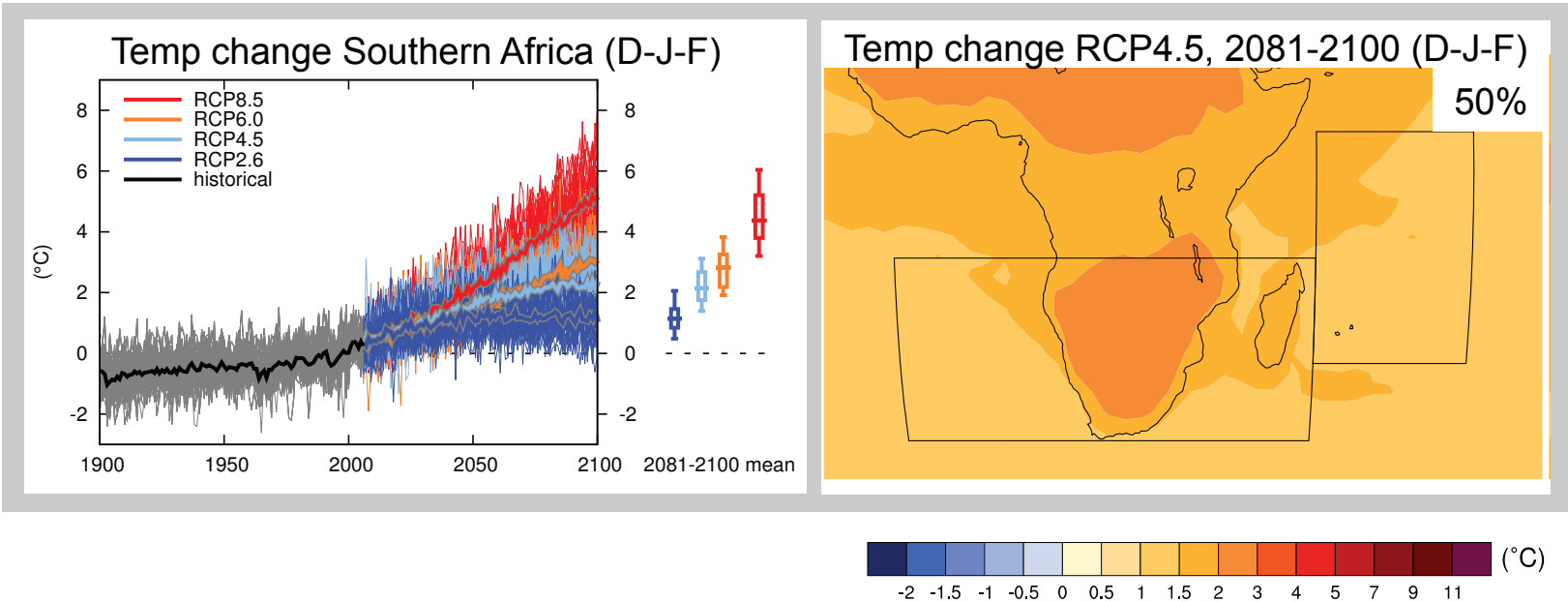

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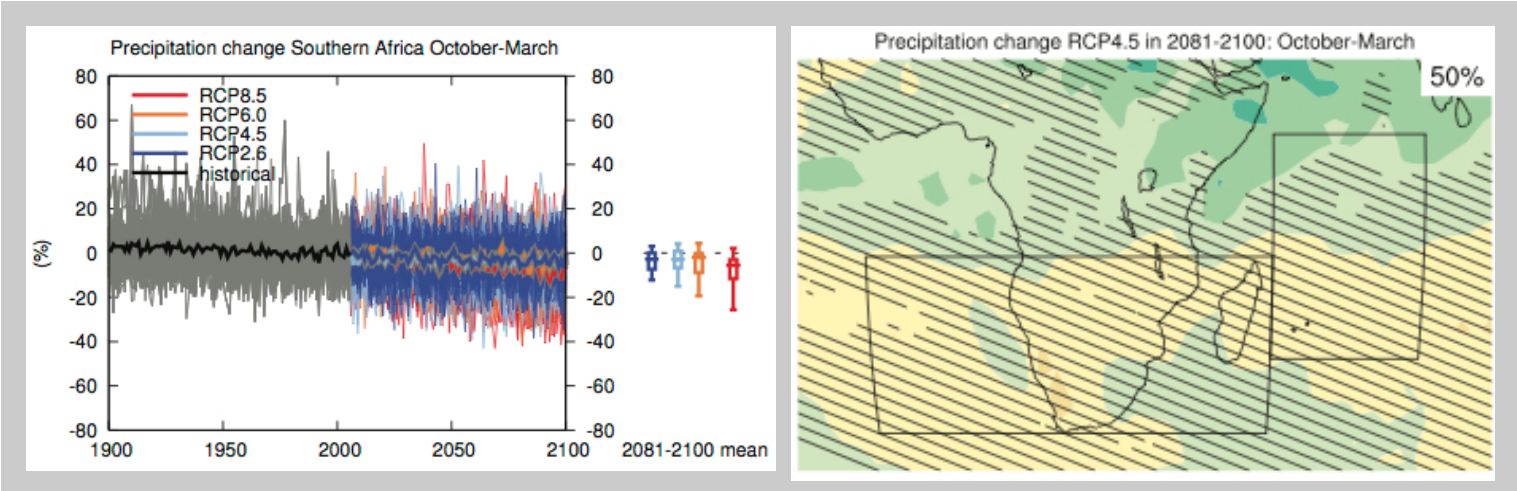

IPCC WGI AR5, 2013

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- High inter-racial inequality and poverty ratio
- Widespread and significant climate change projected
- Relevance of agricultural sector
  - 5-10% of formal employment; 20% of hh involved (2.9 m)
  - SA among top 10 world producers of maize and cereals
  - Large share of arid land, strong impact of climate change

Why South Africa?

- High internal migration rates
- High inter-racial inequality and poverty ratio
- Widespread and significant climate change projected
- Relevance of agricultural sector
- No studies considering the effect of climate on migration in SA

Data

- **Population Censuses**
  - SA Census 1996, 2001, 2011; Community Survey 2007
  - Information on : demographics, health, education, employment, households and services, **migration** (previous residence – year of move)

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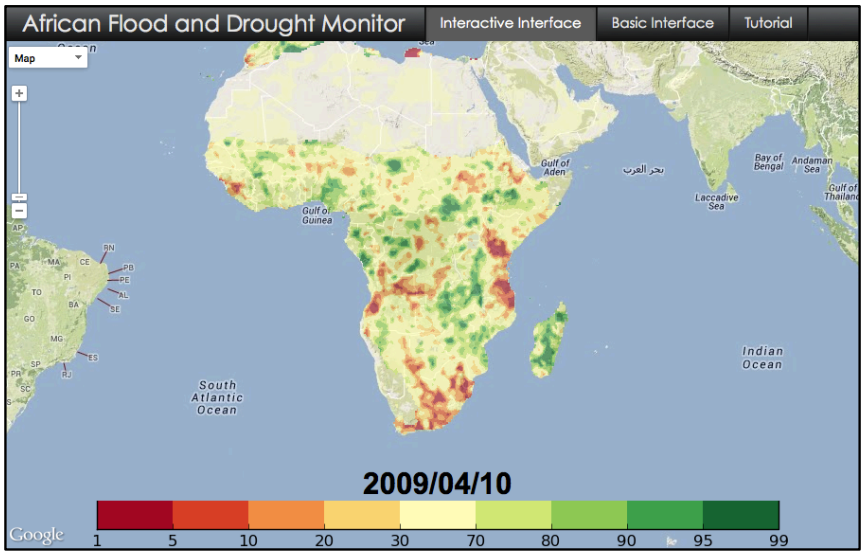
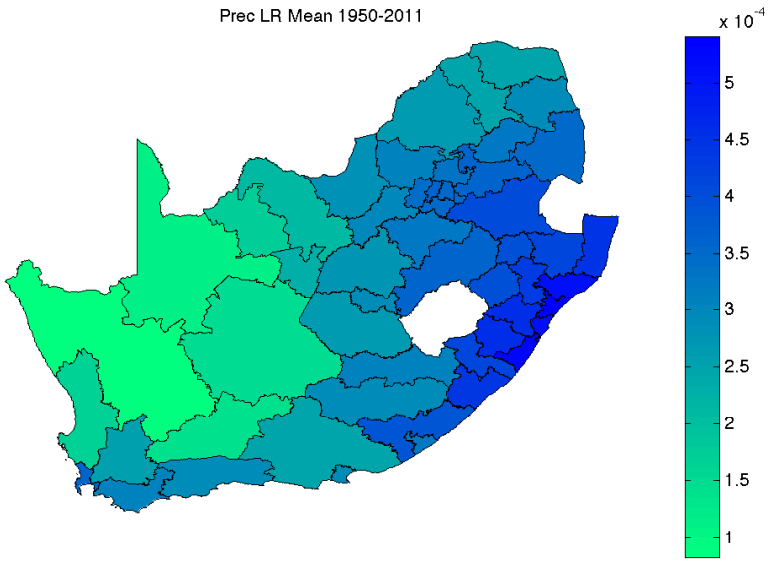
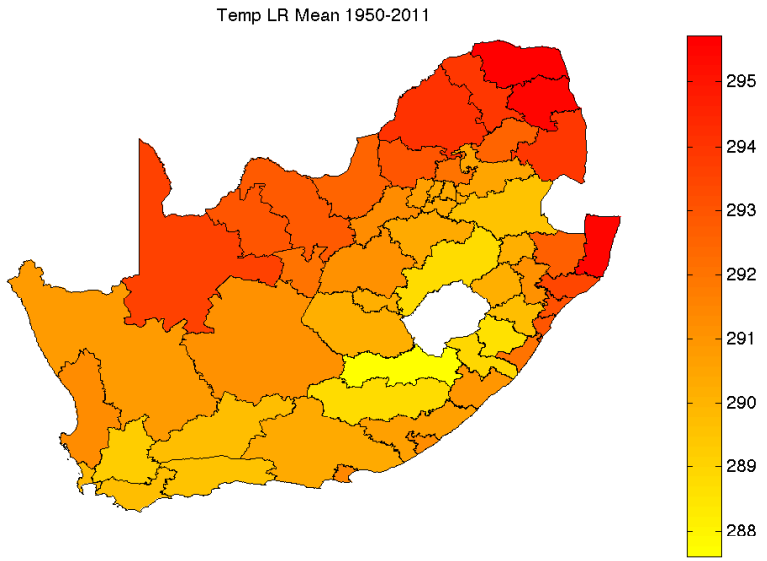
- **Climate Data**
  - Gridded data at 0.25 degree resolution
  - Monthly, annual data on precipitation, T_{min}, T_{max}, soil moisture (Sheffield et al, 2014)



http://hydrology.princeton.edu/monitor

Precipitation and temperature





- Long run average precipitation per km^2 (1950–2011)
- Long run average temperature in K degrees (1950–2011)

Research design

- **Bilateral** (origin-destination) flows

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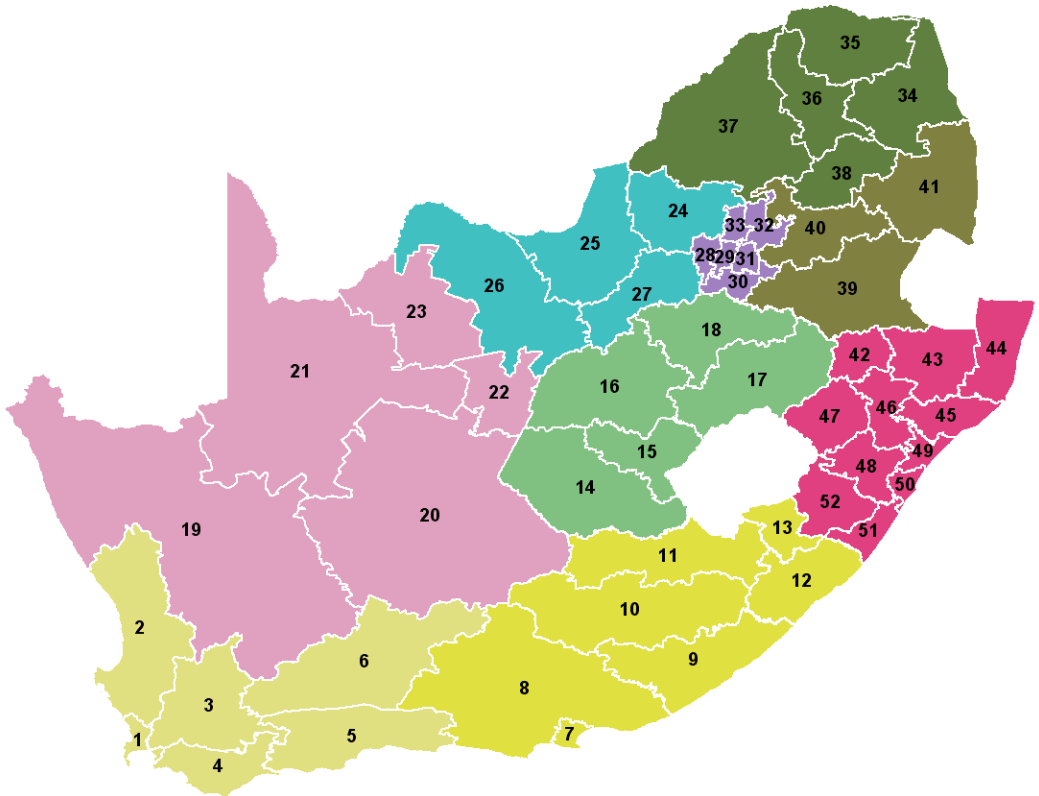
- **Inter-district** migration
  - 52 districts (either metropolitan or district municipalities)



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- **Migrant**: an individual (15-64) who in year $t = 2001, 2011$ was living in district j and moved there from district $i \neq j$ within the 5 years before t (included)

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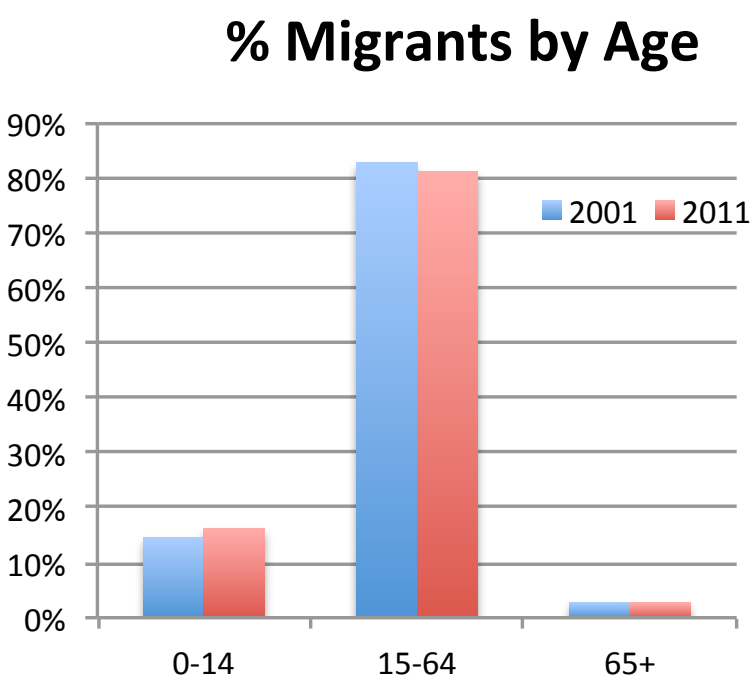
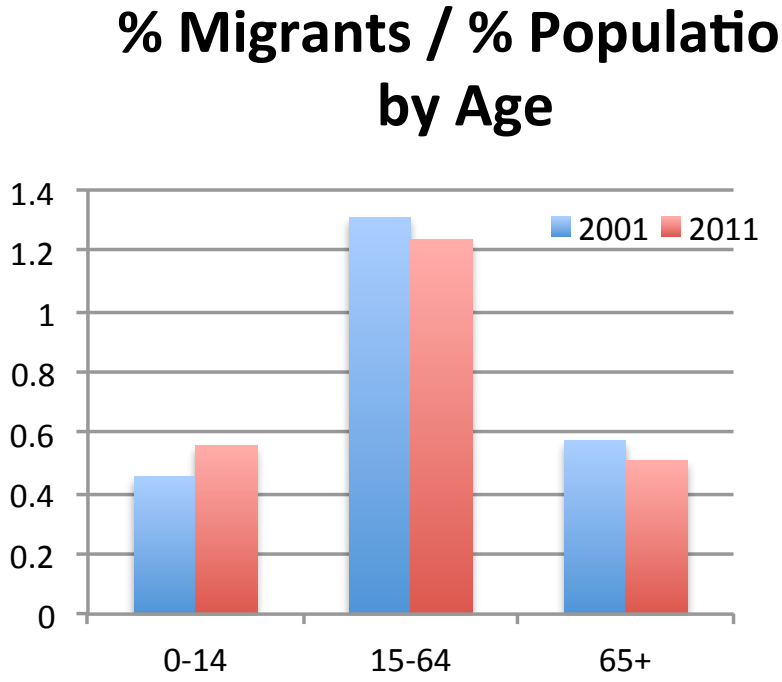
- **Migrant**: an individual (15-64) who in year $t = 2001, 2011$ was living in district j and moved there from district $i \neq j$ within the 5 years before t (included)
- **Bilateral migration flows**: number of people (15-64) moving from district i ($i = 1 \ldots 52$) to district $j \neq i$ during the 5 years before the Census year t (included)

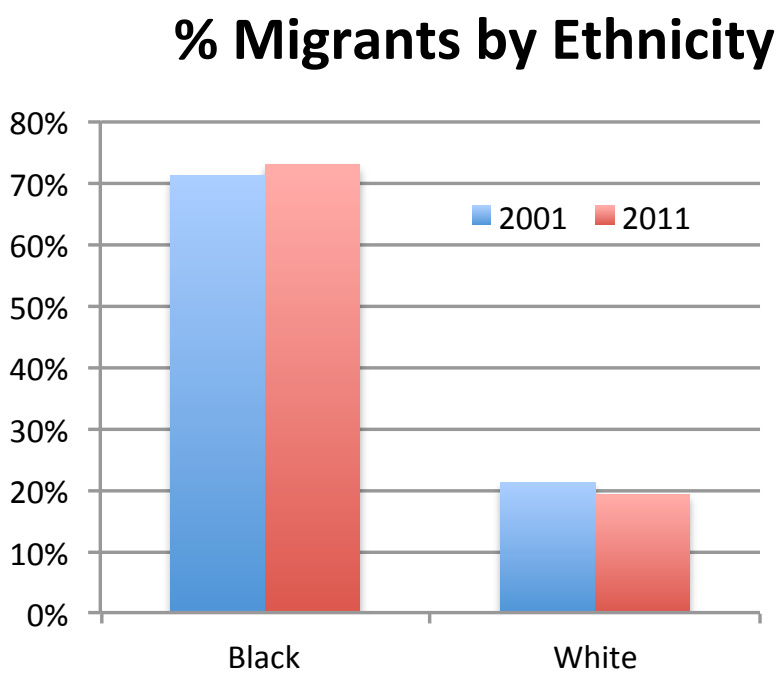
Characteristics of migrants: age

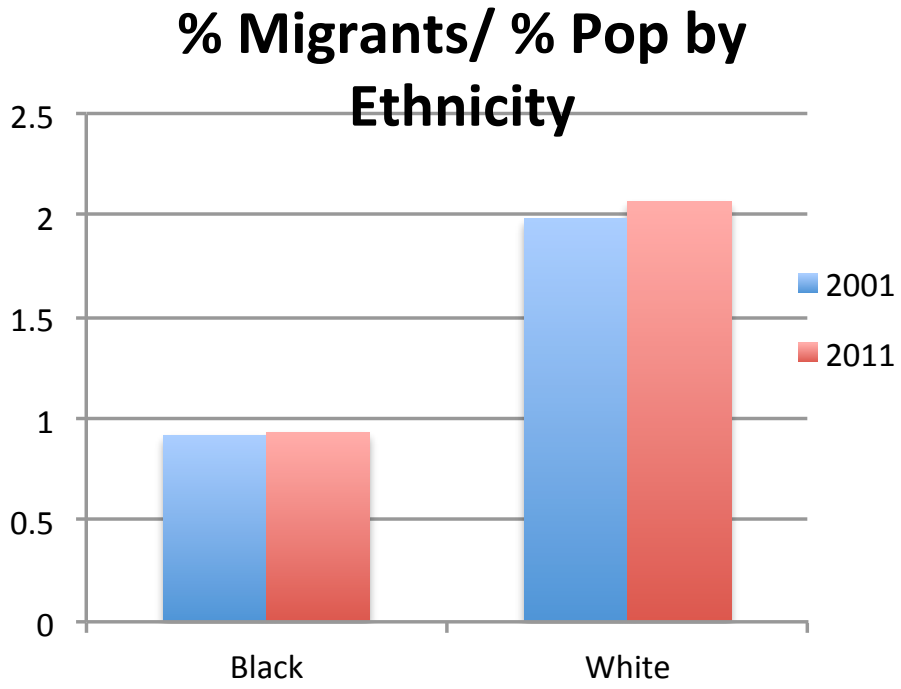




People among 15-64 years old cover 80% of migrants and are over-represented among migrants as compared to population

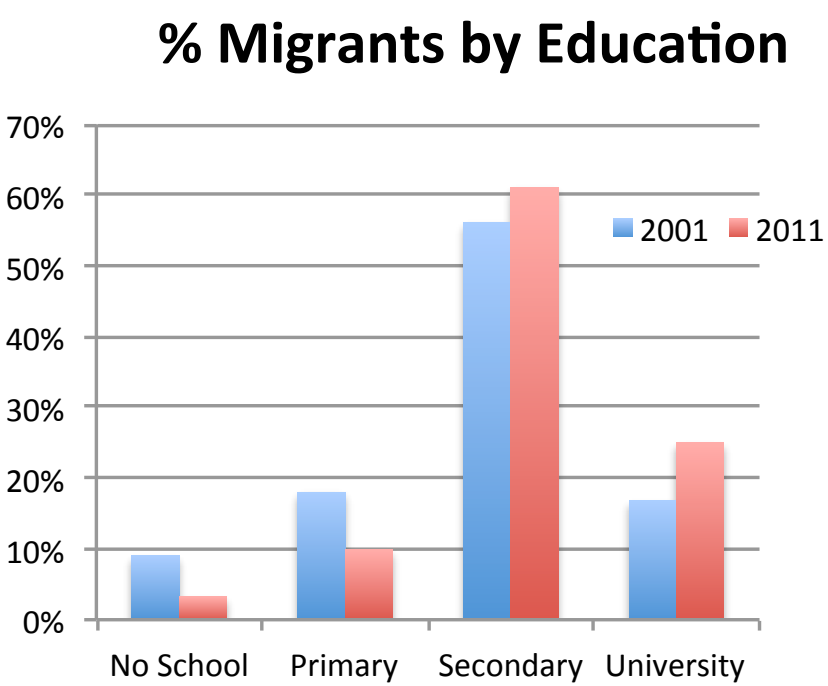
Characteristics of migrants: ethnicity

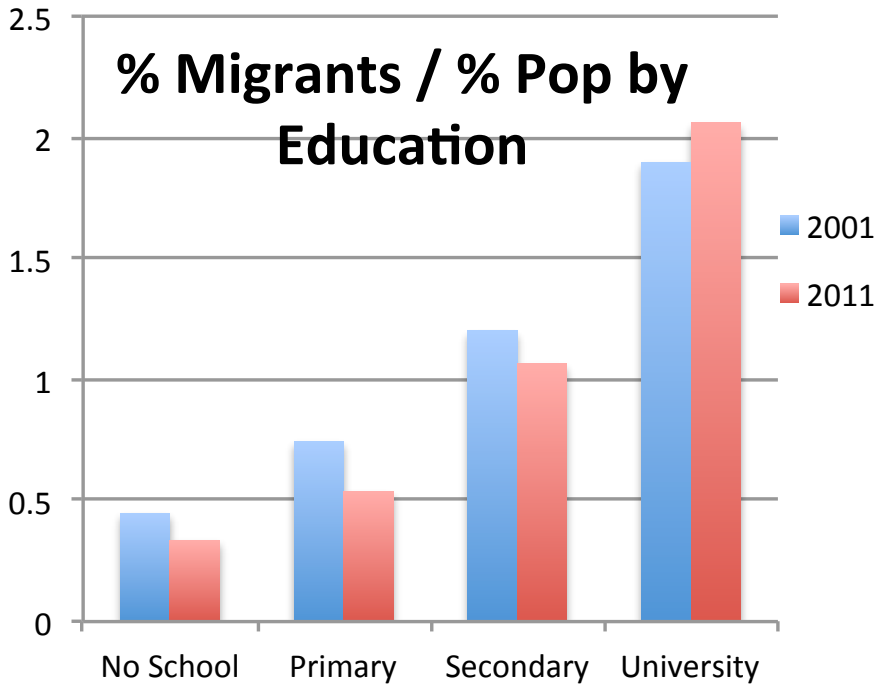




Although black migrants are the majority, white migrants are largely over-represented as compared to population

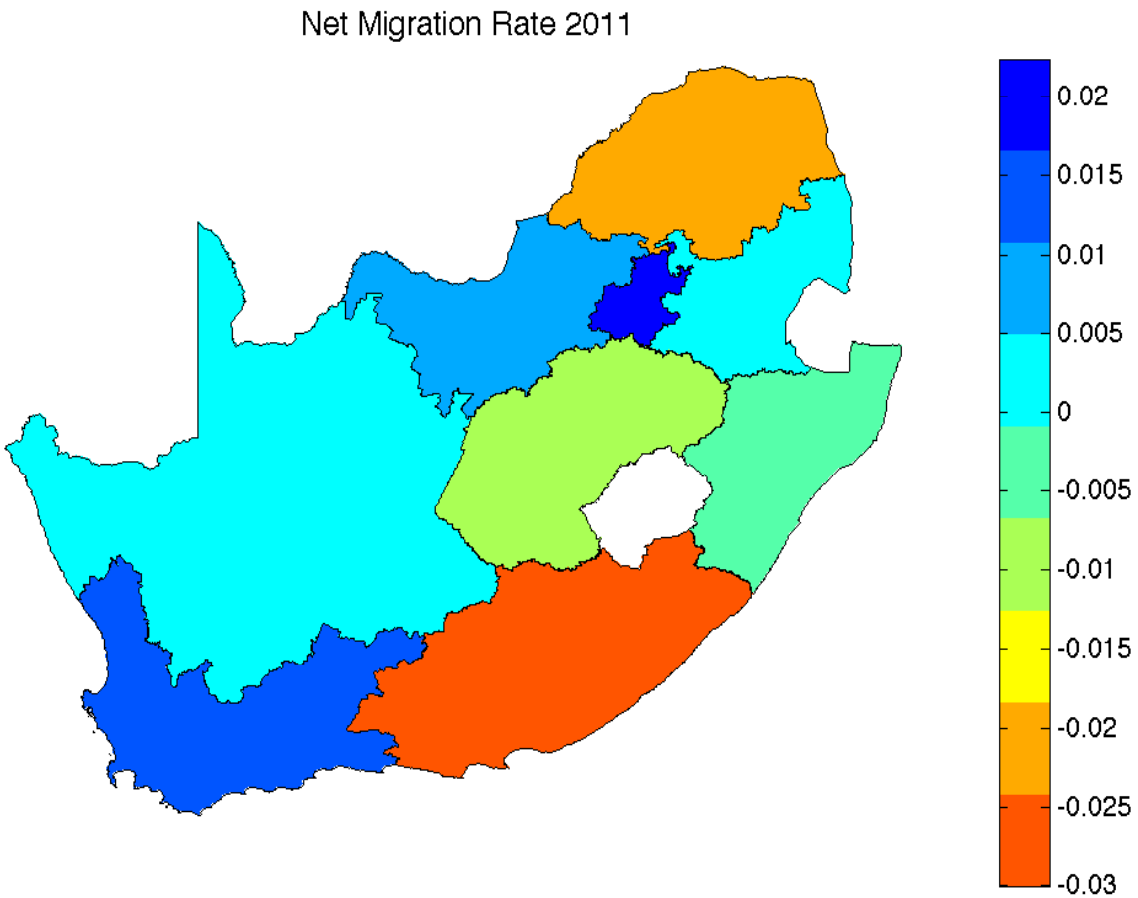
Characteristics of migrants: education





Highly educated migrants are the majority and are over-represented among migrants as compared to population

Net migration rates 2007–2011



- In blue, Gauteng and Western Cape
- In orange and red, Limpopo and Eastern Cape

Econometric framework: Gravity model

$$m_{ij}^t = \kappa \cdot \exp\{\varphi_i + \phi_j^t + \boldsymbol{\beta}\mathbf{Z}_{ij} + \boldsymbol{\mu}\mathbf{C}_i^{t-5,t} + \boldsymbol{\theta}\mathbf{X}_i^{\tau}\} \cdot \varepsilon_{ij}^t$$

i : origin district; j : destination district; t : 2001, 2011

m_{ij}^t : bilateral migration flows

φ_i, ϕ_j^t : origin and time-destination fixed effects

$\mathbf{Z}_{ij}$: bilateral variables (log of distance and contiguity dummy)

$\mathbf{C}_i^{t-5,t}$: climate variables at origin (pos. max and neg. min temperature anomalies, pos. and neg. precipitation anomalies, soil moisture)

$\mathbf{X}_i^{\tau}$: origin controls (e.g., population, ethnicity, education, unemployment rate); $\tau = 1996, 2007$

Estimation technique: PPML vs OLS

Determinants of migration flows

Variables		Sign
Demographic :	• Population	+
	• Share of white individuals	+
Geographic (bilateral variables):	• Origin-destination distance	-
	• Contiguity	+
Socio – economic :	• Unemployment rate	+
	• Share of population with at most primary education	-
Climatic :	• Pos max temperature anomalies	+
	• (Abs) neg min temperature anomalies	NS
	• Pos precipitation anomalies	+
	• (Abs) neg precipitation anomalies	+
	• Soil moisture	-

Main results

- **Results on climate are robust to**:
  - Alternative definition of migration flows (1 year flows)
  - Lagged climatic variables (92-96 for 2001 and 02-06 for 2011)
  - Alternative specifications of climatic variables
  - Alternative setups as to the way **push** and **pull** factors are modeled
    - Positive maximum temperature anomalies and soil moisture are not significant pull factors
    - Increase in rainfall anomalies at destination reduces migration towards those areas

Conditioning flows to migrant characteristics

Does climate affect unevenly South African migrants?

- By age (0-14; 15-30; 31-45; 46-64; 65+)
  - Inverse U-shaped relationship between age and the climate-migration coefficient
- By gender
  - No significant differences
- By marital status
  - No significant differences
- By ethnicity (black vs white)
  - Smaller impact on white migrants
- By income (below vs above median income)
  - Much smaller impact on richest migrants

Interactions with agriculture

Is the impact of climate on migration stronger in more agriculture-dependent districts?

$$m_{ij}^t = \kappa \cdot \exp\{\psi_i + \phi_j^t + \boldsymbol{\beta}\mathbf{Z}_{ij} + \boldsymbol{\theta}\mathbf{X}_i^\tau + \mu\mathbf{C}_i^{t-5,t} + \alpha A_i^\tau + \gamma A_i^\tau \cdot \mathbf{C}_i^{t-5,t}\} \cdot \varepsilon_{ij}^t.$$

A_i^τ: Agriculture employment rate

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A_i^τ: Agriculture employment rate

- Increases in max temp anomalies and reduction in soil moisture enhance migration **more strongly** in agriculture-dependent districts (significant interaction terms)
- The relationship between employment in agriculture and the effect of precipitation on migration is less clearcut
- Positive effect of agriculture on migration (holding climate constant)

Indirect effects

Is agriculture a channel through which climate impacts migration?

1. We regress the agricultural var A_i^τ against climate

$$\boxed{A_i^\tau = \kappa + \varphi_i + \zeta_\tau + \mu \mathbf{C}_i^{\tau^*} + \epsilon_i^\tau}$$

- $\uparrow$ pos temp anom / $\uparrow$ prec anom / $\downarrow$ soil moist $\Rightarrow \downarrow A_i^\tau$

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2. We regress migration against the predicted agricultural var $\hat{A}_i^\tau$

$$\boxed{m_{ij}^t = \kappa \cdot \exp\{\psi_i + \phi_j^t + \boldsymbol{\beta}\mathbf{Z}_{ij} + \boldsymbol{\theta}\mathbf{X}_i^\tau + \alpha\hat{A}_i^\tau\} \cdot \varepsilon_{ij}^t}$$

   - $\downarrow \hat{A}_i^\tau \Rightarrow \uparrow m_{ij}^t$

Summing Up

- First study on climate as a determinant of internal migration in SA

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- First study on climate as a determinant of internal migration in SA
- Consistent impact of climate on migration
- Strong impact of climate on black and low-income South African migrants; weak impact on white and high-income migrants
- The effect of temperature anomalies and soil moisture is stronger in more agriculture-dependent districts
- Adverse climatic conditions seem to affect migration through agriculture

Future work

1. Providing consistent estimates of the climate/migration relationship at a global scale
    - Harmonization of definitions of migration, of socio-economic and demographic controls and of climatic variables
    - Identification of a family of micro- and macro-econometric models

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   - Harmonization of definitions of migration, of socio-economic and demographic controls and of climatic variables
   - Identification of a family of micro- and macro-econometric models
2. Modeling migration behavior through an Agent-based Model (ABM)
   - Agents are provided with a utility function, a set of network linkages and some knowledge of opportunities in other areas
   - Decision is some bounded-rational expected utility maximization scheme
   - Income diversification and migration might compete as strategies

THANK YOU!

Climatic Variables

- **Positive maximum temperature anomalies**: Positive values of maximum temperature in the 5 years before the Census minus long-run mean divided by long-run standard deviation (long run = 1950-2011)
- **Positive precipitation anomalies in the rainy season**: Positive values of average precipitation in the 5 years before the Census (rainy season) minus long-run mean divided by long-run standard deviation
- **Negative precipitation anomalies in the rainy season**: Negative values of average precipitation in the 5 years before the Census (rainy season) minus long-run mean divided by long-run standard deviation
- **Soil Moisture**: Relative soil moisture of the top layer (0-10 cm) calculated from the land surface model output (average over the 5 years before the Census) – Sheffield et al. (2004)

Table : **Gravity model estimation**

	(1)	(2)	(3)	(4)	(5)
Distance	-0.9395***	-0.9403***	-0.9395***	-0.9399***	-0.9387***
Contiguity	0.5321***	0.5318***	0.5317***	0.5315***	0.5328***
Population	0.5451***	0.3927***	0.5612***	0.4000***	0.3541***
Primary	-8.1961***	-8.5314***	-6.7194***	-7.1336***	-6.7911***
White	3.4994***	0.9692	4.9012***	2.1328**	0.7318
Unemployment	1.0105***	0.4826*	0.4097*	0.0475	-0.0875
Pos T_{max} anom	0.5212***		0.4975***		
Neg Precip anom	0.6274***	0.5667***			
Neg T_{min} anom		-0.1678		-0.0624	
Pos Precip anom			0.1341*	0.0557	
Soil moisture					-0.1055***
N	5050	5050	5050	5050	5050
Pseudo R^2	0.8395	0.8385	0.8388	0.8378	0.8386

Poisson Pseudo Maximum-Likelihood (PPML) estimates.
Dependent variable: 5-year district-to-district migration flows of 15-64 year-old people.
Constant, time-invariant origin and time-destination fixed effects included.

Effects of climate on migration

$$d\% \text{ increase in } C_0 \Rightarrow \frac{(m_1 - m_0)}{m_0} = \exp(\beta d C_0) - 1$$

		% change in migration flows, C_0 =mean of distr.				
Variables	**d%**	**(I)**	**(II)**	**(III)**	**(IV)**	**(V)**
Pos max temp anomalies	10%	1.87		1.79		
(Abs) neg prec anomalies	10%	2.23	2.02			
(Abs) neg min temp anomalies	10%		-0.67		-0.25	
Pos prec anomalies	10%			0.97	0.39	
Soil moisture	1%					-5.20

Table : **Conditioning bilateral flows to migrant characteristics**

	(1)		(2)		(3)
	Pos T_{max} anom	Neg Precip anom	Pos T_{max} anom	Pos Precip anom	Soil moisture
Age					
0-14	0.490***	0.433***	0.587***	0.338***	-0.075**
15-30	0.610***	0.661***	0.603***	0.143*	-0.128***
31-45	0.433***	0.597***	0.366***	0.077	-0.098***
46-64	0.377***	0.612***	0.355***	0.192**	-0.028
65+	0.201*	0.110	0.289***	0.221***	-0.019
Ethnicity					
Black	0.685***	0.841***	0.666***	0.146*	-0.135***
White	0.213*	0.081	0.287*	0.179*	-0.033
Income					
Low	0.553***	0.663***	0.522***	0.123	-0.113***
High	0.217*	0.004	0.181	-0.070	-0.095**

Table : **Interaction effects between climate and agriculture**

	(1)	(2)	(3)	(4)
Pos T_{max} anom	0.378***			
Pos T_{max} anom $\times$ A	3.915**			
Neg Precip anom		0.316		
Neg Precip anom $\times$ A		3.132		
Pos Precip anom			0.234**	
Pos Precip anom $\times$ A			-6.554***	
Soil moisture				-0.093***
Soil moisture $\times$ A				-0.209**
A	4.643***	4.545***	11.444***	15.720***
Pseudo R^2	0.839	0.838	0.840	0.840

Table : **Links between climate, agriculture, and migration**

	(1)	(2)	(3)
Dependent Variable: A			
Pos T_{max} anom	-0.027***	-0.027***	
Neg Precip anom	-0.005***		
Pos Precip anom		0.003	
Soil moisture			0.002***
R^2	0.836	0.835	0.820
Dependent Variable: Migration			
Predicted A	-13.448***	-15.307***	-23.371***
Pseudo R^2	0.838	0.839	0.838