The Effects of Climate Change on Labor and Capital Reallocation: Evidence from Brazil

Christoph Albert[1], Paula Bustos[2] and Jacopo Ponticelli[3]

[1]Collegio Carlo Alberto

[2]UPF and CEPR

[3]Northwestern University, CEPR and NBER

Motivation

- Economic effects of climate change
  - ↑ frequency and intensity of extreme weather events
  - Heterogeneous changes in average precipitation [IPCC, 2021]
    - General drying expected in subtropical regions
  - Fall in future agricultural productivity in these regions (Conte et al., 2021) Map
- Developing economies particularly exposed
  - Large agricultural employment share
  - Capital and labor market frictions
- Our focus:
  - Labor and capital reallocation across sectors/regions
  - Spillover effects on connected regions

This paper

- Setting: Brazil 2000-2018
  - → Warming trends accelerated since 1980
  - → Increasing frequency of droughts (new data on natural disaster reports)
  - → Increasing average dryness relative to historical average (SPEI)

- Study effects of differential changes in dryness across regions
  1. Direct: local economy
  2. Indirect: economy of regions integrated with affected regions through
     - Capital markets
     - Labor markets

- Track factor flows across sectors, regions and firms
  - → K: Bank branch balance-sheet data (ESTBAN)
  - → L: Census and social security data (RAIS)

Main Findings

Effects of excess dryness relative to historical averages:

1. Capital
   - Short run (yearly): ↑ agri loans in affected regions, ↓ agri loans in connected regions
   - Long run (decade): ↓ loans to *all* sectors

2. Labor
   - Reallocation away from agriculture and services in directly affected areas
   - Within regions: → manufacturing
   - Across regions: → agriculture, services, but not in manufacturing

→ Explore mechanisms using firm-level exposure to climate migrants
- Manufacturing firms: (i) less connected to "drying" regions via migrant networks
  (ii) if connected, respond less to climate-driven L supply ↑

Related Literature

- Effects of weather and climate on local economic activity and migration.

  [Jayachandran, 2006; Schlenker and Roberts 2006; Deschenes and Greenstone 2007; Dell et al. 2012; Hornbeck, 2012; Burke and Emerick, 2016; Henderson et al. 2017; Addoum et al., 2019; Colmer, 2021]

→ Capital, spillovers on destination regions, firm exposure to climate migrants

- Climate finance

  [Giglio et al. (2021), Kacperczyk and Peydrò (2022), Collier et al. (2020), Brown et al. (2021), Aguilar-Gomez et al. (2022), de Roux (2021)]

→ Spatial reallocation, temporary vs permanent shocks

- Quantitative models on impact of climate on allocation of economic activity

  [Desmet and Rossi-Hansberg, 2015; Costinot et al. 2016; Balboni 2021; Conte et al. 2021.]

→ Evidence on past changes in climate can inform relevant margins of adjustment

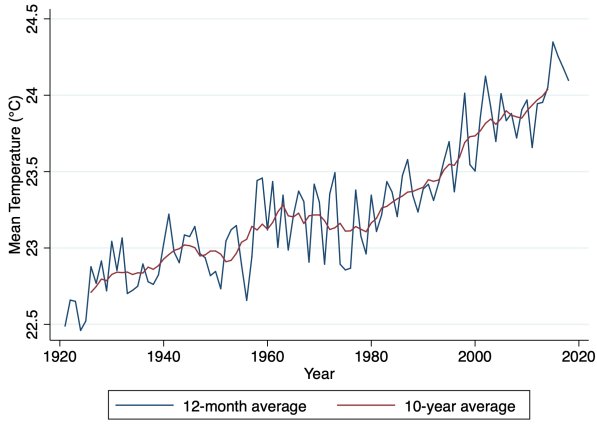
Structure of the Talk

1. Background, Data and Empirical Strategy
    - Climate change in Brazil
    - Natural disaster reports
    - Meteorological measure of excess dryness: SPEI
2. Results:
    - Agriculture
    - Direct and indirect effects on capital and labor markets
    - Firm-level evidence

Background, Data, and Empirical Strategy

Background: Climate Change in Brazil

Figure: Average temperature in Brazil since 1920

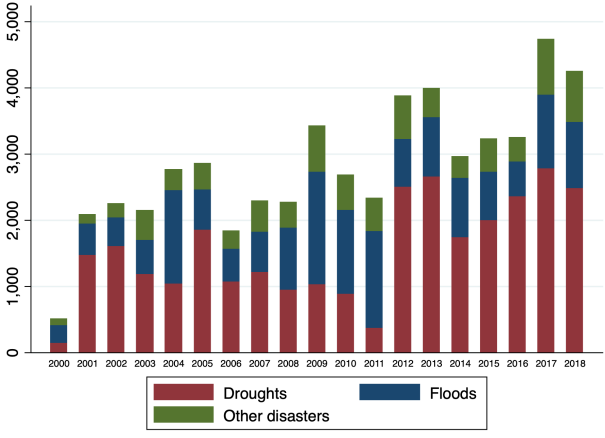


Notes: Data from Climatic Research Unit - University of East Anglia (`https://www.uea.ac.uk/groups-and-centres/climatic-research-unit`)

By macro-region

Data: Reports on Natural Disaster

- Digitized reports on natural disasters filed by municipalities to the federal government



Notes: Data from Sistema Nacional de Proteção e Defesa Civil (SINPDEC)

urban vs rural

Data: SPEI

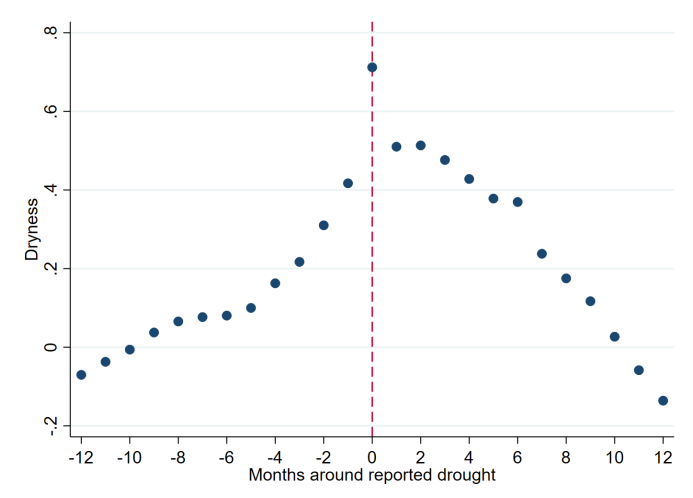
- Challenge: potential bias in propensity to report across municipalities or over time
- Solution: measure of dryness based on meteorological variables
  [Vicente-Serrano et al. (2010)]

→ SPEI: Standardized Precipitation and Evapotranspiration Index

  - Measures standard deviations of dryness from long-term average (1905-2018)
  - Inputs: rainfall, temperature, sun hours

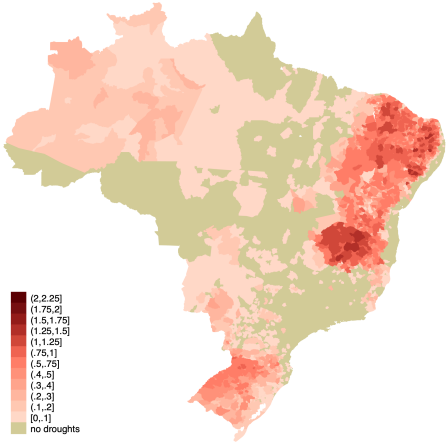
Dryness vs reported droughts

Figure: Average excess dryness index around drought events

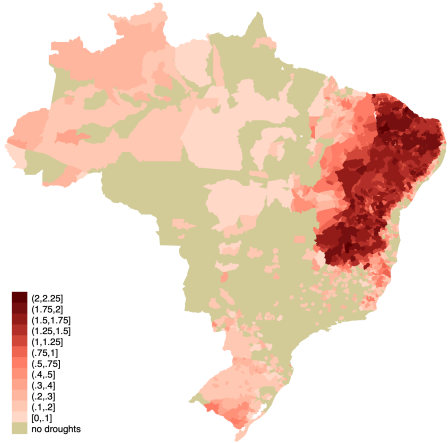


Reported Droughts

(a) 2000-2010

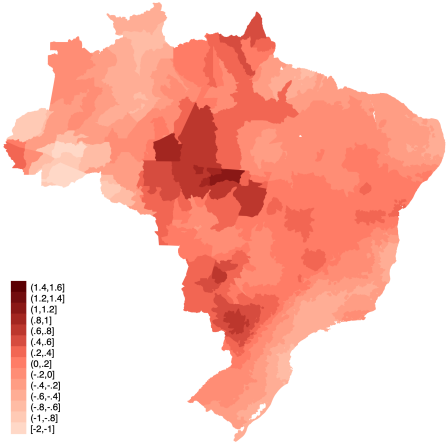


(b) 2011-2018

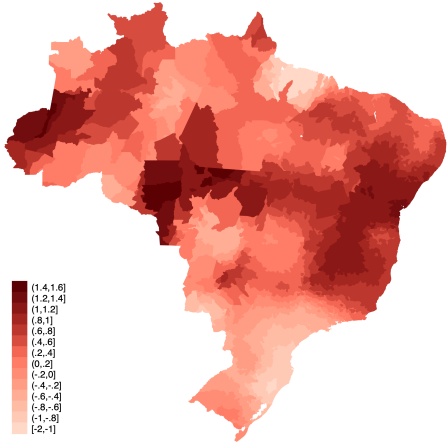


Dryness relative to historical average

(a) 2000-2010 "normal" decade

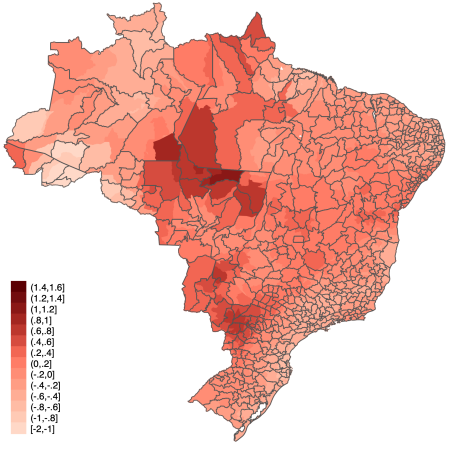


(b) 2011-2018 "dry" decade

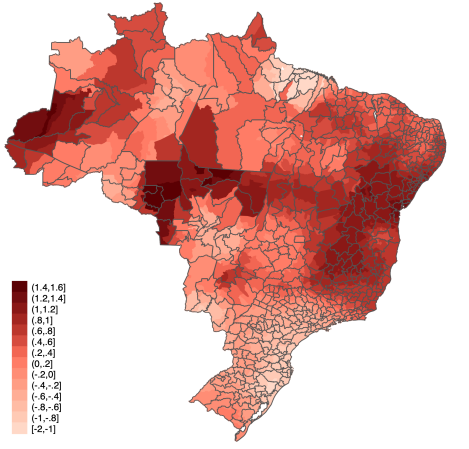


Dryness relative to historical average

(a) 2000-2010 "normal" decade

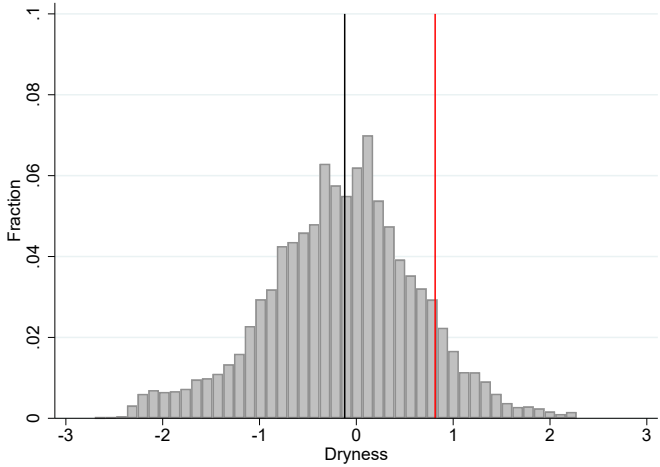


(b) 2011-2018 "dry" decade



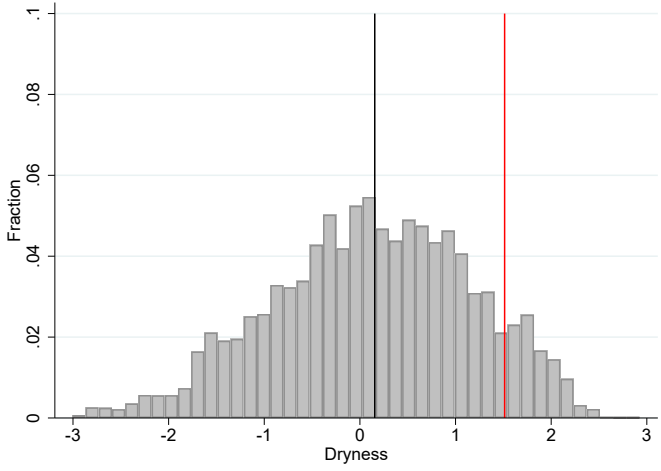
→ Standard errors clustered at micro-region level in all specifications

Distribution of Dryness: 2000 to 2010 ("normal" decade)



- municipality moving $50^{th} \rightarrow 90^{th}$ percentile of Dryness $\approx$ 1 St.Dev

Distribution of Dryness: 2011 to 2018 ("dry" decade)



- municipality moving $50^{th} \rightarrow 90^{th}$ percentile of Dryness $\approx$ 1.36 St.Dev First Stage

Balance test

	Number of reported droughts				
	1(# Droughts =0)	1(# Droughts > 0)	Difference		t-stat
share of rural population	0.387	0.536	0.148	***	7.50
log income per capita	4.719	4.309	-0.410	***	3.88
alphabetization rate	0.768	0.661	-0.107	***	3.13
soy soil suitability	0.271	0.334	0.064	***	2.86
maize soil suitability	0.859	1.132	0.272	***	4.31
	Dryness index				
	1(Dryness $\leq$ median)	1(Dryness > median)	Difference		t-stat
share of rural population	0.440	0.477	0.037		1.47
log income per capita	4.570	4.478	-0.092		0.93
alphabetization rate	0.734	0.700	-0.035		1.24
soy soil suitability	0.285	0.317	0.031		1.33
maize soil suitability	0.951	1.028	0.078		1.05

Notes: Observable characteristics observed in 1991 (pop census), except soy and maize productivity, which are theoretical soy and maize yields under low inputs as defined in Bustos, Caprettini and Ponticelli (2016).

Empirical Results

Empirical results

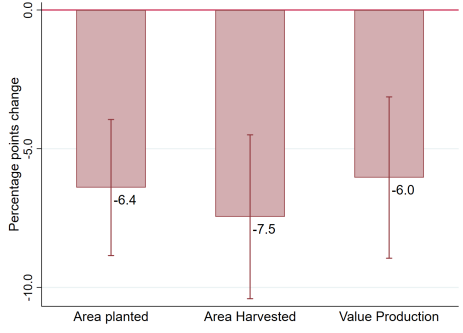
1. Agriculture
2. Capital
3. Labor

Agriculture

Agriculture

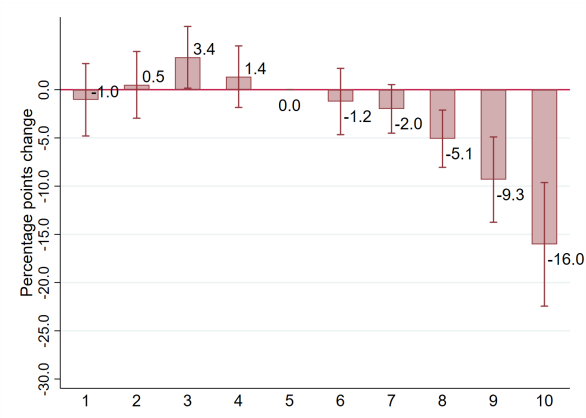
$$y_{mrt} = \alpha_m + \alpha_t + \alpha_{rt} + \beta Dryness_{mt} + \gamma X_{mrt} + u_{mrt}$$

m: municipality (4,248)
r: region (5)
t: time (2000-2018)



Notes: Effects for a municipality going from 50th→ 90th pct of *Dryness*.

Dryness and Value of Agricultural Production



Notes: Effects by decile of *Dryness* (wettest to driest), relative to 5th decile.

Area planted and harvested | Yields by Crop | Table

Capital

Capital: Specification

$$y_{mrt} = \alpha_m + \alpha_t + \alpha_{rt} + \beta_1 \underbrace{Dryness_{mt}}_{\text{Direct effect}} + \beta_2 \underbrace{ExposureDryness_{mt}}_{\text{Indirect effect}} + \gamma X_{mrt} + u_{mrt}$$

- Outcomes: local loans, deposits, capital net flows (ESTBAN - Central Bank)
- Steps to compute *ExposureDryness*:

1.

$$BankExposure_{bt} = \sum_{o \in O_b} \omega_{bo} Dryness_{ot}$$

O_b: set of origin municipalities o in which bank b was present at baseline
ω_{bo}: share of deposits in bank b originating in municipality o

2.

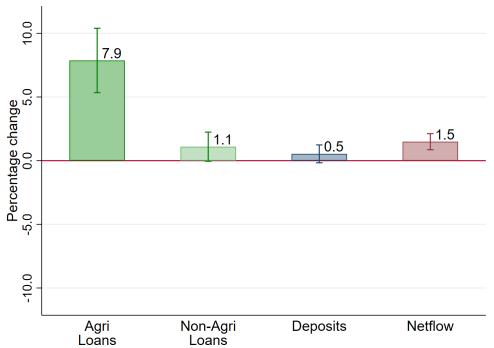
$$ExposureDryness_{mt} = \sum_{b \in B_m} w_{bm} BankExposure_{bt}$$

B_m: set of banks operating in municipality m
w_{bm}: market share of bank b in m

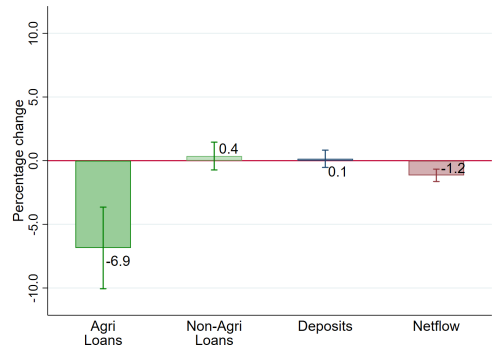
Year-to-year effect of Dryness on Capital Outcomes

$$y_{mrt} = \alpha_m + \alpha_t + \alpha_{rt} + \beta_1 \underbrace{Dryness_{mt}}_{\text{Direct effect}} + \beta_2 \underbrace{ExposureDryness_{mt}}_{\text{Indirect effect}} + \gamma X_{mrt} + u_{mrt}$$

(a) Direct effect



(b) Indirect effect



Notes: Effects for a municipality going from 50th→ 90th pct of *Dryness*, *ExposureDryness*.

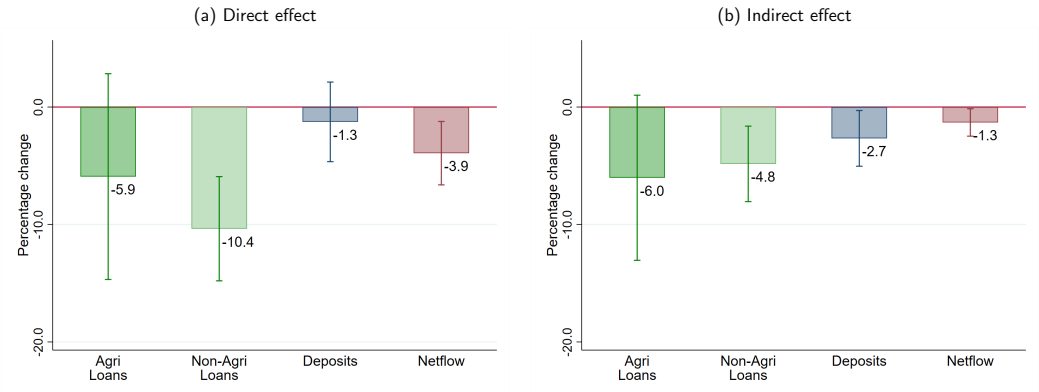
Table

Year-to-year effects: Discussion

- Affected regions borrow from connected but non-directly affected regions
  - Consistent with **risk sharing**
- Connected regions adjust by reducing agricultural lending
  - Mandated lending to rural sector (25% of deposits): banks keep to minimum
- Small and non-significant effects on **deposits**

Decadal effect of Dryness on Capital Outcomes

$$\Delta y_{mr,2000-2010} = \alpha_r + \beta_1 \underbrace{Dryness_{m,2001-2010}}_{\text{Direct effect}} + \beta_2 \underbrace{ExposureDryness_{m,2001-2010}}_{\text{Indirect effect}} + \gamma X_{mr} + u_{mr}$$



Notes: Effects for a municipality going from 50th→ 90th pct of *Dryness*, *ExposureDryness*.

Table

Decadal effects: Discussion

- Decade of drier climate: $\downarrow$ local loans
  - $\downarrow$ expected future income and thus lower credit demand
  - $\downarrow$ repayment and thus lower approval rate of loan applications
- Connected regions also suffer
  - Consistent with increase in non-performing loans in regions served by same banks (Aguilar-Gomez et al. 2022)

Labor

Labor: Specification

- Data on migration flows and employment: Population Census 2000 and 2010

$$y_{mr,2000-2010} = \alpha_r + \beta_1 \underbrace{Dryness_{m,2001-2010}}_{\text{Direct effect}} + \beta_2 \underbrace{ExposureDryness_{m,2001-2010}}_{\text{Indirect effect}} + \gamma X_{mr} + \varepsilon_{mr},$$

$$ExposureDryness_{m,2001-2010} = \sum_{o \neq m} \alpha_{om} Dryness_{o,2001-2010},$$

$$\alpha_{om} = \frac{\text{Migrants}_{o \to m}}{\text{Migrants}_{m}} \text{ in 2000 Census}$$

o: origin municipality, m: destination municipality

Migration

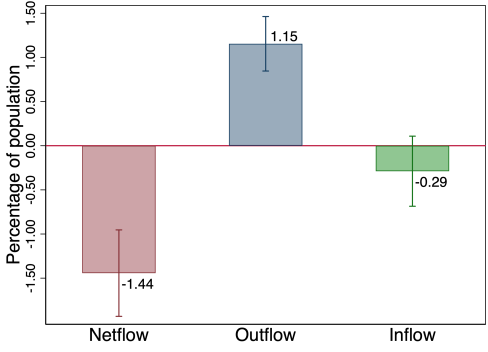
$$\left(\frac{inflow - outflow}{pop}\right)_{mr,2005-2010} = \alpha_r + \beta_1 \underbrace{Dryness_{m,2001-2010}}_{\text{Direct effect}} + \beta_2 \underbrace{ExposureDryness_{m,2001-2010}}_{\text{Indirect effect}} + \gamma X_{mr} + \varepsilon_{mr},$$

- Geographical correlation:
  - *ExposureDryness* excluding municipalities within 55km radius (robust to 111km) Diagnostics
  - SE clustered at microregion level (558)
- Control for exposure via road distance
  - Market access approach (Donaldson and Hornbeck, 2016)

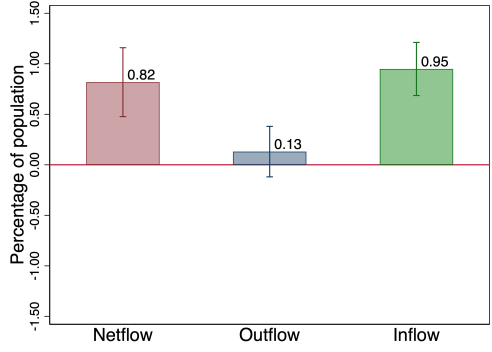
Migration

$$\left(\frac{inflow - outflow}{pop}\right)_{mr,2005-2010} = \alpha_r + \beta_1 \underbrace{Dryness_{m,2001-2010}}_{\text{Direct effect}} + \beta_2 \underbrace{ExposureDryness_{m,2001-2010}}_{\text{Indirect effect}} + \gamma X_{mr} + \varepsilon_{mr},$$

(a) Direct effect

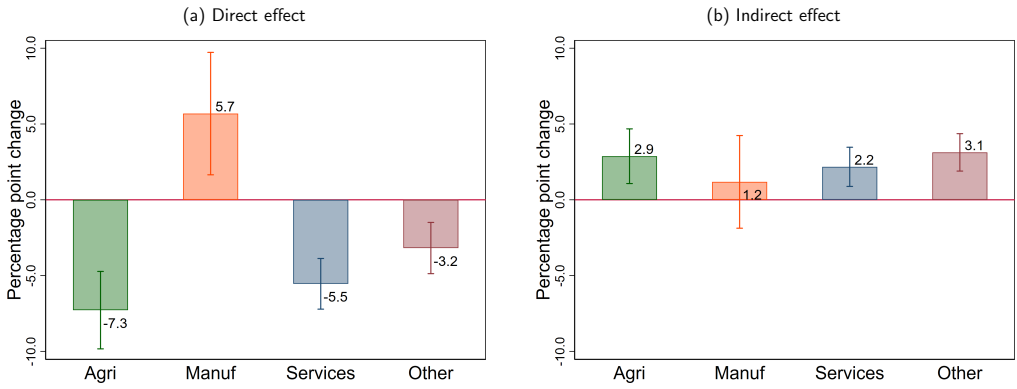


(b) Indirect effect



Sectoral structure of the economy

$$\Delta \log L^{sector}_{m,2000-2010} = \beta_1 \underbrace{Dryness_{m,2001-2010}}_{\text{Direct effect}} + \beta_2 \underbrace{ExposureDryness_{mr,2001-2010}}_{\text{Indirect effect}} + \alpha_r + \gamma X_{mr} + \varepsilon_{mr},$$



Notes: Effects for a municipality going from 50th→ 90th pct of *Dryness*, *ExposureDryness*.

Table: Decadal Effect of Dryness on Employment: 2000-2010

outcomes:	Δ log Employment						
sector:	all	all	all	agriculture	manufacturing	services	other
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Avg Dryness, 2001-2010	-0.0150**	-0.0278***	-0.0289***	-0.0728***	0.0570**	-0.0554***	-0.0318***
	(0.00708)	(0.00815)	(0.00817)	(0.0155)	(0.0246)	(0.0101)	(0.0103)
Exposure to Dryness via migrants		0.0192***	0.0210***	0.0287***	0.0118	0.0217***	0.0312***
		(0.00607)	(0.00609)	(0.0109)	(0.0185)	(0.00783)	(0.00748)
Exposure to Dryness via banks			-0.0134***	0.0139	-0.0940***	-0.00269	-0.0136**
			(0.00462)	(0.00891)	(0.0174)	(0.00619)	(0.00686)
Observations	4,248	4,248	4,248	4,248	4,241	4,248	4,248
R-squared	0.128	0.132	0.134	0.071	0.099	0.093	0.049
Macro-region FE	y	y	y	y	y	y	y
Controls	y	y	y	y	y	y	y

Notes: Standard errors clustered at the microregion level (558) reported in parenthesis. Coefficient estimates refer to a municipality moving from the 50th to the 90th percentile of the distribution of dryness or exposure to dryness. Controls include: the share of population living in rural areas, log income per capita, literacy rate, population density, changes in soy and maize potential yields and exposure to Dryness via trade links.

Correlation between measures of exposure | Table with exposure via trade coefficients

Margins of adjustment

- Effects for a municipality going from 50th→ 90th pct of *Dryness*

  → 3.7% of individuals aged 18-64 leave employment in agriculture and services.

  Of these:

  1/3 relocate locally to the manufacturing sector

  50% emigrate to other municipalities

- No direct/indirect effects on average wages Wages
  - Suggestive evidence that migrants from dry areas earn less than average worker at destination Individual-level results

Effects on Destination Firms

- Analysis at firm level:
  1. Explore mechanisms:
     - Why lack of reallocation into manufacturing at destination?
  2. Identification:
     - Municipalities more exposed to *Dryness* via migrant flows might also be more connected via other channels (e.g. trade links)

     $\rightarrow$ Exploit variation *within* destination regions

To measure workers' flows across locations and firms we use data from RAIS:

- Employer-employee dataset, covering all formal workers

Firm exposure

- Firm exposure to past migration from municipality o:

$$\alpha_{oi(m)} = \frac{L_{i(m),o \to m}}{L_{i(m)}}$$

- Share of workers employed in firm i whose last move was $o \to m$

  (baseline year: 2005, reference period 1998 to 2005)

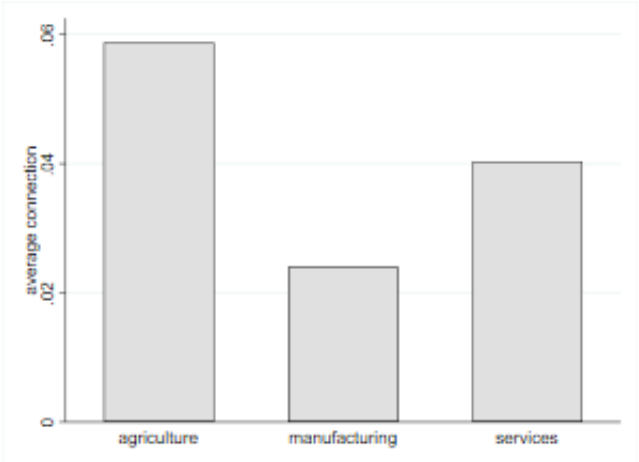
$\to$ Rationale: migrant workers follow similar employment trajectories as previous migrants from same area (e.g. referrals)

Firm-origin level specification

$$\underbrace{\frac{L_{oi(m),2006-2010}}{L_{i(m)}}}_{\substack{\text{worker flow}\\ \text{from origin } o\\ \text{to firm } i}} = \alpha_i + \beta_1 \alpha_{oi(m)} + \beta_2 \underbrace{\alpha_{oi(m)}}_{\substack{\text{firm initial}\\ \text{exposure to } o}} \times \underbrace{1(Dry)_o}_{\substack{=1 \text{ if } o\\ \text{top quartile}\\ \text{of } Dryness}} + \gamma 1(Dry)_o + \varepsilon_{oi(m)}$$

i: plant
m: destination municipality
o: origin municipality

Figure: Average firm-level initial connections to "very dry" municipalities



- Agriculture and services: more connected to dry regions via past migrant networks
- Manufacturing: least connected

Firm exposure and employment growth

outcome:	(1) $\frac{L_{oi(m)2006-2010}}{Lavg_i}$	(2)	(3)
firm connection to origin $\times$ 1(Dry)		0.209***	0.322***
		(0.0560)	(0.0570)
firm connection to origin	0.621***	0.424***	0.506***
	(0.0189)	(0.0202)	(0.0271)
Observations	1,415,758	1,415,758	1,415,758
R-squared	0.257	0.356	0.663
mean Y	.13	.13	.13
destination AMC FE	y	y	y
firm FE	n	n	y

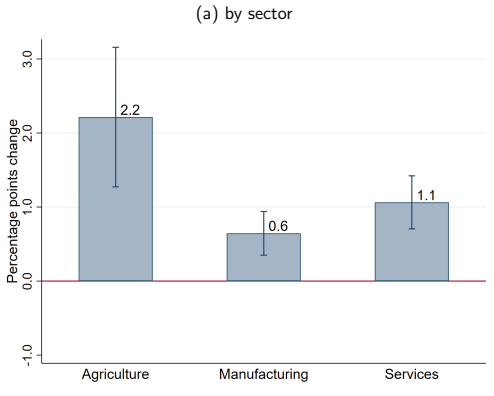
Notes: 1(Dry) included in all specifications. Standard errors clustered at meso-region (115) reported in parenthesis.

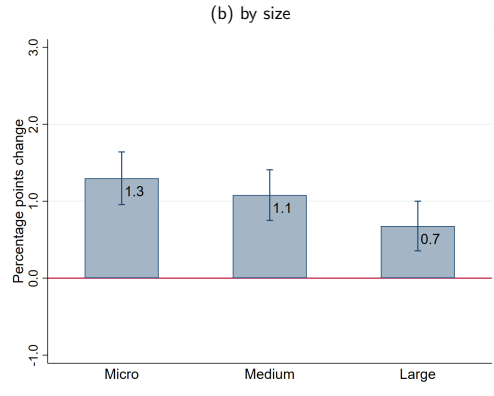
- Firms receive more migrant workers from regions with which initially connected
- This effect is larger for origins exposed to abnormal dryness
- Connections have larger effects when exploiting only *within-firm* variation: trade links might attenuate firm-level estimates

Reported droughts 2011-2017

Firm exposure and employment growth

- Effect for firms with average connection to areas with excess dryness, for 0.76 st.dev. ↑ *Dryness*





Concluding Remarks

- A full decade of excess dryness relative to historical averages generates:

  1. Reallocation of capital and labor away from affected regions

  $\rightarrow$ Capital 3 to 4 times **more elastic** than labor to decadal changes in dryness

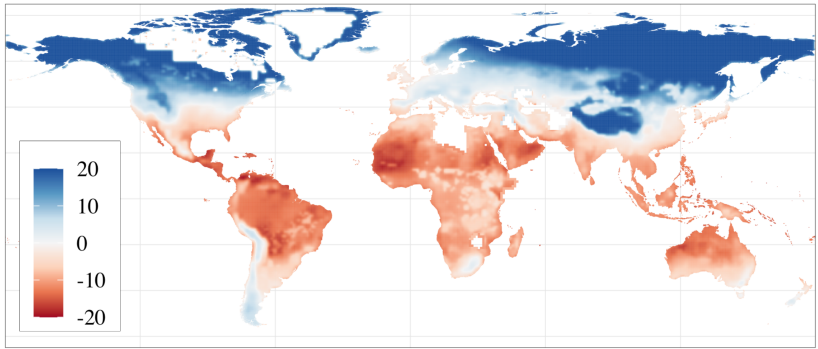
  2. Capital: short-run insurance vs long-run outflows

  3. Labor: net-outmigration, changes in the structure of the economy

Thank you!

Climate change and future agricultural output

Figure: Agricultural output loss in 2200 due to climate change

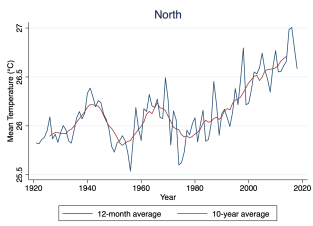


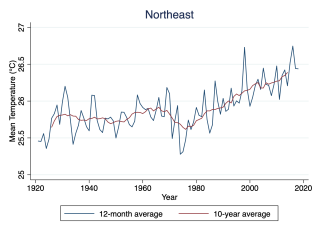
Notes: Figure 8d) from Conte et al. (2021)

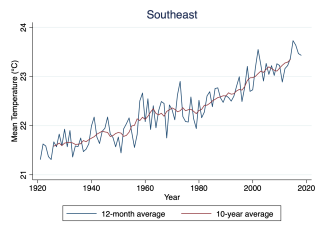
Back

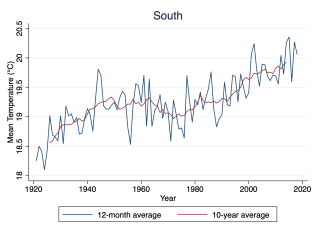
Background

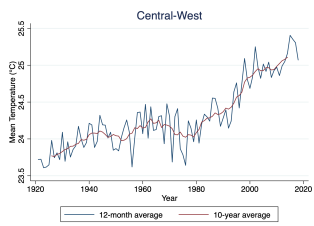
Figure: Average temperature by macro-region since 1920









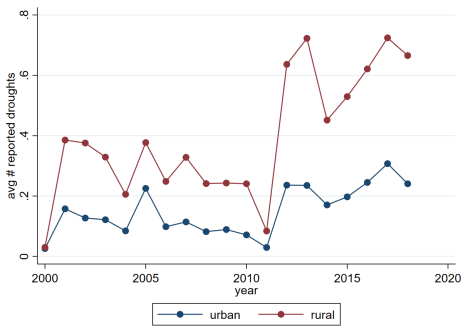


Back

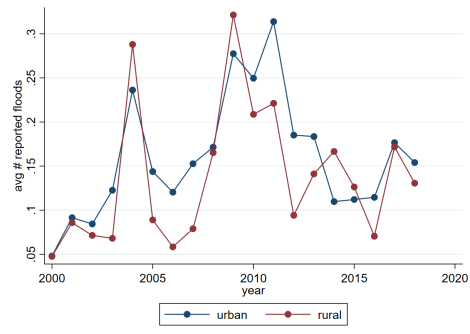
Natural Disasters Affecting Rural vs Urban Areas

- Droughts mostly affect rural areas, while floods similarly affect rural and urban areas

(a) Avg. yearly reported droughts



(b) Avg. yearly reported floods



Notes: Rural municipalities = share of rural adult population above median in 1991 Population Census (47%).

Back

Individual Level Effects

Individual Level Regressions: Specification

- Objective: study selection and labor market outcomes of "climate" migrants vs
  - other migrants
  - non-migrants
- Data: male workers aged 18-64 in 2010 Census
- Specification:

$$y_{iod,2010} = \beta_d + \beta_1 Migrant_{iod} + \beta_2 Migrant_{iod} \times Dryness_{io,2001-2010} + \Lambda Age_{iod} + u_{iod},$$

i: individual

o: municipality of residence in 2005

d: municipality of residence in 2010

$Migrant_{iod}$: dummy indicating $o \neq d$

$Dryness_{io,2001-2010}$: average SPEI in o between 2001 and 2010

Estimate both with β_d and with β_o

Individual Level Regressions: Results

$$y_{iod,2010} = \beta_d + \beta_1 Migrant_{iod} + \beta_2 Migrant_{iod} \times Dryness_{io,2001-2010} + \Lambda Age_{iod} + u_{iod},$$

VARIABLES	(1) High-school grad	(2) Employed	(3) log Income
Migrant	0.00132	0.0307***	0.123***
	(0.00601)	(0.00250)	(0.00910)
Migrant × SPEI-12 ×(−1)	-0.0943***	0.0397***	-0.139***
	(0.0126)	(0.00445)	(0.0261)
Observations	5,243,677	6,273,292	4,607,486
R-squared	0.094	0.103	0.254
Fixed effects	destin.	destin.	destin.

Notes: Standard errors clustered at destination municipality are reported in parenthesis.

- Reference group: workers in the same destination municipality of migrants
- "climate" migrants:
  - negatively selected in terms of education
  - higher probability of employment
  - lower income than other migrants

Back

Individual Level Regressions: Results

$$y_{iod,2010} = \beta_o + \beta_1 Migrant_{iod} + \beta_2 Migrant_{iod} \times Dryness_{io,2001-2010} + \Lambda Age_{iod} + u_{iod},$$

VARIABLES	(1) High-school grad	(2) Employed	(3) log Income
Migrant	0.0292***	0.0591***	0.289***
	(0.00655)	(0.00435)	(0.0226)
Migrant × SPEI-12 ×(−1)	0.0101	0.0754***	0.178***
	(0.0105)	(0.00640)	(0.0189)
Observations	5,243,677	6,273,292	4,607,486
R-squared	0.095	0.098	0.248
Fixed effects	origin	origin	origin

Notes: Standard errors clustered at destination municipality are reported in parenthesis.

- Reference group: workers in municipality of origin of migrants
- "climate" migrants:
  - positively selected in terms of education (at origin)
  - higher probability of employment
  - higher income than other migrants / non migrants

Reported droughts Back

Table: Reported Droughts and Excess Dryness

outcomes:	Number of droughts		
sample:	2000-2010	2011-2018	2000-2018
	(1)	(2)	(3)
Dryness	0.0796***	0.0730***	0.0699***
	(0.00915)	(0.0101)	(0.00736)
Observations	46,739	33,992	80,731
R-squared	0.507	0.738	0.620
Year and AMC FE	y	y	y
Macro-region x year FE	y	y	y
Controls x year FE	y	y	y
F-stat	480.4	223.4	567.6

Notes: Standard errors clustered at the microregion level (558) reported in parenthesis. F-stat is the Cragg-Donald Wald F statistic. Coefficient estimates refer to a municipality moving from the 50th to the 90th percentile of the distribution of dryness. The controls interacted with year dummies are the share of population living in rural areas, log income per capita, literacy rate, population density and changes in soy and maize potential yield.

Back

Coefficients on Exposure to Dryness via Trade Links

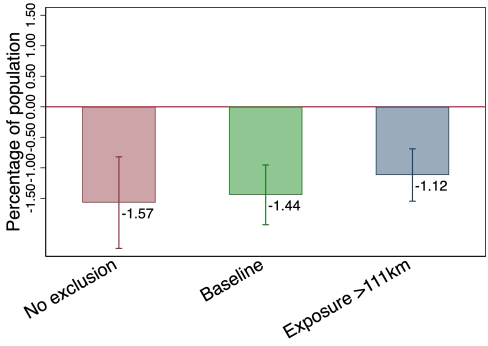
outcomes:	Capital net flows	Δ log loans	Migration net flows	Δ log L	Δ log wage
	(1)	(2)	(3)	(4)	(5)
Exposure to Dryness via banks	-0.0404*	-0.217***	-0.000532	-0.0134***	0.00639
	(0.0214)	(0.0562)	(0.00162)	(0.00462)	(0.00542)
Exposure to Dryness via migrants	0.0290*	0.107***	0.00824***	0.0210***	0.0133**
	(0.0174)	(0.0312)	(0.00207)	(0.00609)	(0.00668)
Exposure to Dryness via trade links	0.0601*	-0.0241	-0.00983***	0.00123	-0.00532
	(0.0309)	(0.0544)	(0.00352)	(0.0112)	(0.0116)
Observations	2,795	2,795	4,248	4,248	4,248
R-squared	0.066	0.172	0.229	0.134	0.165
Macro-region FE	y	y	y	y	y
Controls	y	y	y	y	y

Notes: Standard errors clustered at the microregion level (558) reported in parenthesis.

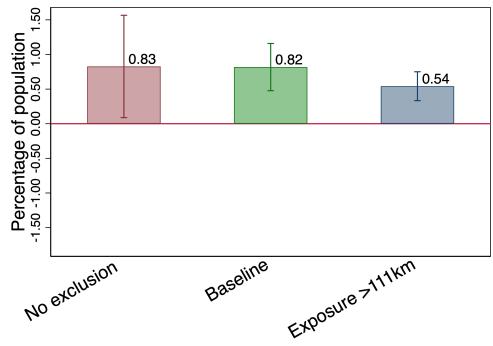
Back

Effects of Excess Dryness on the net migration rate
Diagnostics on Spatial Correlation

(a) Direct effect



(b) Indirect effect



Back

Correlation between Exposure Measures

	Dryness	Exposure via banks	Exposure via migrants	Exposure via trade links
Dryness	1.000			
Exposure via banks	0.110 0.000	1.000		
Exposure via migrants	0.643 0.000	0.157 0.000	1.000	
Exposure via trade links	0.438 0.000	0.364 0.000	0.303 0.000	1.000

Notes: All measures of exposure are computed excluding 55km area around focal AMC

Back

Year-to-year effect of Dryness on Capital Outcomes

$$y_{mrt} = \alpha_m + \alpha_t + \alpha_{rt} + \beta_1 \underbrace{Dryness_{mrt}}_{\text{Direct effect}} + \beta_2 \underbrace{ExposureDryness_{mrt}}_{\text{Indirect effect}} + \Lambda Controls_{mr} \times t + u_{mrt}$$

outcomes:		log loans		log deposits	net capital flows
	all	agri	non-agri		
	(1)	(2)	(3)	(4)	(5)
Dryness	0.0354***	0.0787***	0.0110	0.00535	0.0149***
	(0.00729)	(0.0153)	(0.00695)	(0.00426)	(0.00384)
Exposure to Dryness via banks	-0.0142*	-0.0685***	0.00364	0.00149	-0.0115***
	(0.00760)	(0.0195)	(0.00662)	(0.00412)	(0.00295)
Observations	58,124	50,606	58,124	58,124	58,124
R-squared	0.960	0.878	0.966	0.979	0.795
Year and AMC FE	y	y	y	y	y
Macro-Region x year FE	y	y	y	y	y
Controls x year FE	y	y	y	y	y

Notes: Standard errors clustered at microregion level.

back

Decadal effect of Dryness on Capital Outcomes

$$\Delta y_{m,2000-2010} = \beta_1 \underbrace{Dryness_{m,2001-2010}}_{\text{Direct effect}} + \beta_2 \underbrace{ExposureDryness_{m,2001-2010}}_{\text{Indirect effect}} + \Lambda Controls_{m,2000} + u_m$$

outcomes:	all	log loans agri	non-agri	log deposits	net capital flows
	(1)	(2)	(3)	(4)	(5)
Avg Dryness, 2001-2010	-0.118***	-0.0593	-0.104***	-0.0126	-0.0393**
	(0.0291)	(0.0532)	(0.0269)	(0.0206)	(0.0164)
Exposure to Dryness via banks	-0.0691***	-0.0603	-0.0484**	-0.0267*	-0.0132*
	(0.0187)	(0.0427)	(0.0195)	(0.0144)	(0.00708)
Observations	2,795	2,334	2,795	2,795	2,795
R-squared	0.167	0.158	0.168	0.185	0.062
Macro FE	y	y	y	y	y
Controls	y	y	y	y	y

Notes: Robust standard errors reported in parenthesis. Controls: share of population living in rural areas, log income per capita, literacy rate, population density, changes in soy and maize potential yields.

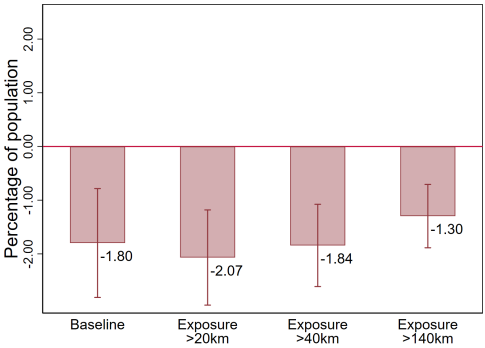
Back

Migration: 2005-2010

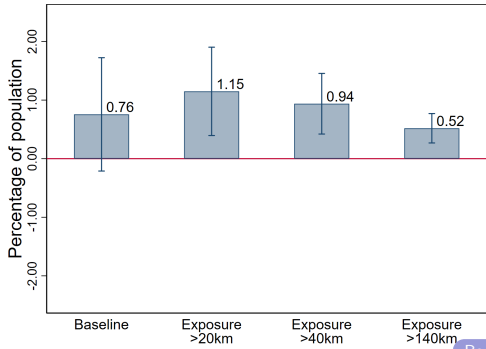
$$netflow_{mr,2005-2010} = \beta_1 \underbrace{Dryness_{mr,2001-2010}}_{\text{Direct effect}} + \beta_2 \underbrace{ExposureDryness_{mr,2001-2010}}_{\text{Indirect effect}} + \alpha_r + \gamma X_{mr} + \varepsilon_{mr},$$

- *ExposureDryness* excluding municipalities within: 20km radius (10th pct migration)
  40km radius (25th pct migration)
  140km radius (50th pct migration)

(a) Direct effect



(b) Indirect effect



Panel A: Reported droughts, year-to-year effects

outcomes:	log area planted	log area harvested	log value production
	(1)	(2)	(3)
# droughts	-0.0259***	-0.0535***	-0.107***
	(0.00949)	(0.0126)	(0.0119)
Observations	79,758	79,758	79,758
R-squared	0.934	0.919	0.923

Panel B: Excess dryness, year-to-year effects

outcomes:	log area planted	log area harvested	log value production
	(1)	(2)	(3)
Dryness	-0.0639***	-0.0747***	-0.0604***
	(0.00997)	(0.0110)	(0.0111)
Observations	79,758	79,758	79,758
R-squared	0.934	0.919	0.923

Panel C: Excess dryness, long run effects (2000 to 2018)

outcomes:	Δ log area planted	Δ log area harvested	Δ log value production
	(1)	(2)	(3)
Avg Dryness, 2001-2018	-0.142***	-0.171***	-0.225***
	(0.0439)	(0.0447)	(0.0494)
Observations	4,187	4,187	4,187
R-squared	0.235	0.254	0.238

Notes: Standard errors are clustered at the microregion level. Controls: share of population living in rural areas, log income per capita, alphabetization rate, population density, changes in soy and maize potential yields, and distance to the cast interacted with year dummies.

Example of Report on Drought

Municipality of Maravilha (state of Santa Catarina) reported a drought in February 2014

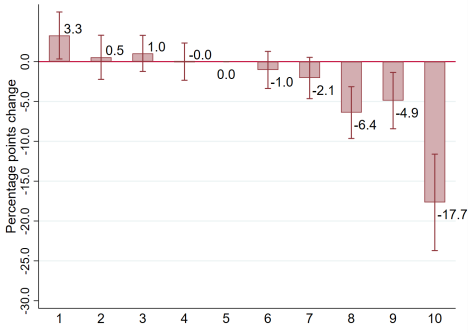
- Reported losses: 30% corn, 40% soy, 15% milk.
- Farmers unable to cover planting investments



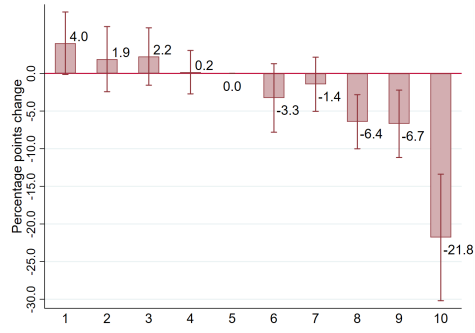

Back

Additional Agricultural Outcomes

(a) Area Planted



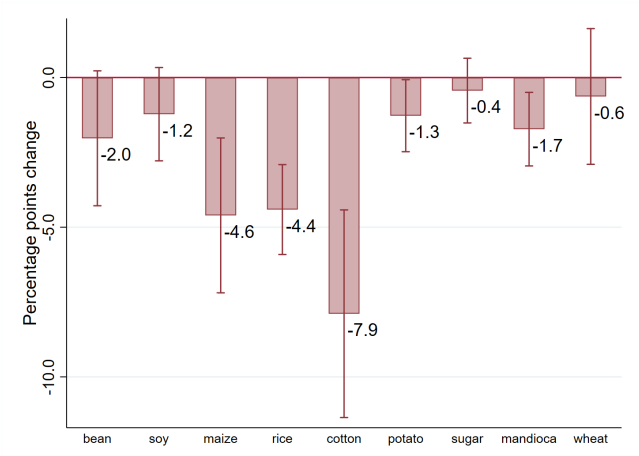
(b) Area Harvested



Notes: Effects by decile of *Dryness* (wettest to driest), relative to 5th decile.

Back

Yields of Main Temporary Crops



Notes: Effects for a municipality going from 50th→ 90th pct of *Dryness*.

Back

Decadal Effect of Dryness on Population and Wages

outcomes:	Δ log Population		Δ log Avg Wages	
	(1)	(2)	(3)	(4)
Avg Dryness, 2001-2010	-0.0517***	-0.0525***	0.0120	0.0129
	(0.00692)	(0.00689)	(0.00817)	(0.00831)
Exposure to Dryness via migrants	0.0217***	0.0230***	0.0118*	0.0104
	(0.00455)	(0.00459)	(0.00665)	(0.00679)
Exposure to Dryness via banks		-0.0100***		0.00868
		(0.00363)		(0.00533)
Observations	4,248	4,248	4,248	4,248
R-squared	0.208	0.210	0.166	0.167
Macro-region FE	y	y	y	y
Controls	y	y	y	y

Notes: Standard errors are clustered at micro region level level.

Back