Out of the Frying Pan

Climate Change and Internal Migration in Brazil

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Climate migration

- Temperature and precipitation changes affect productivity in climate-sensitive activities, such as agriculture.

- Households whose income depends on agricultural output will experience income shocks.

- Adaptation mechanisms:
  - Switch to planting climate-resilient crops.
  - Relocate to areas less affected by climate and continue planting the same crops.
  - Move into the manufacturing or service sector.

Current and Future Problem

CNN World • LIVE TV

Climate crisis could displace 1.2 billion people by 2050, report warns

By Jessie Yeung, CNN

Updated 4:36 AM ET, Thu September 10, 2020

The New York Times https://nyti.ms/32IqvSg

TIMES INSIDER

Capturing the Faces of Climate Migration

A Times Magazine series examines how climate change will force millions worldwide to move. Recently, Meridith Kohut photographed people on the front lines of this shift. In America.

By Libby Peterson

Sept. 19, 2020

THE GREAT CLIMATE MIGRATION

By Abrahm Lustgarten | Photographs by Meridith Kohut

Opinion Climate change

Americans are becoming climate migrants before our eyes

Alex Domash

While the US closes the doors on climate migrants from abroad, it must acknowledge that the problem has already come home

Fri 2 Oct 2020 08.05 EDT

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CITYLAB

Cities That Were Poised to Absorb Climate Migrants Face a New Challenge

As hurricanes and wildfires accelerate climate migration, U.S. cities that were dubbed "climate havens" face drastic financial shortfalls after Covid-19.

By Linda Poon

October 5, 2020, 8:07 AM EDT

Existing evidence

- Relatively recent but growing fast: natural disasters (e.g. Fussell et al., 2014) or gradual changes (e.g. Cai et al., 2014)
- Aburn and Wesselbaum (2017): costs $>$ temperature changes $>$ income or political freedom
- Cattaneo and Peri (JDE 2016) finds that warming leads to more emigration from middle-income countries but less emigration from low-income countries.
  - International migration and internal through urbanization rate (no tracking of internal migrants)
  - Possibly due to poverty trap
- Suggests that migration costs matter.
  - Climate shocks cannot be insured through traditional means and possibly more permanent/recurrent.

This paper

- Aim to provide evidence of:
  - Whether time-varying costs prevent households from adapting to the changing climate through migration
  - Accounting for travel costs, what are the effects of temperature and precipitation changes on internal migration?
- Focus on Brazil from 1981 to 2010 – long-run:
  - 5th largest agricultural producer in the world
  - Share of the agricultural sector in total employment still 16% in 2010, 5% of GDP.
  - Internal migration prevalent
  - Significantly affected by climate change
  - Road connectivity significantly improved

Migration data

- Decennial census data for 1991, 2000, and 2010 sourced from the Integrated Public Use Microdata Series (IPUMS).
  - Covers between 1.3 and 2.9 million households, or 5.8 to 10.1 million individuals.
- Aggregate data at the state level: 24 states + Brasilia D.F.
  - Information on previous state of residence and length of stay in current residence
  - Goais-Tocantins, Mato Grosso-Mato Grosso do Sul
- Calculate 5-year bilateral migrant flows between state pairs.

Migration data

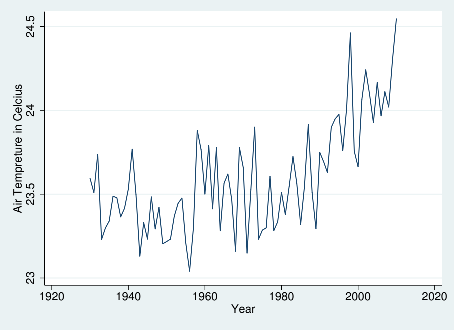
Table: Cross-state migrants by five year period

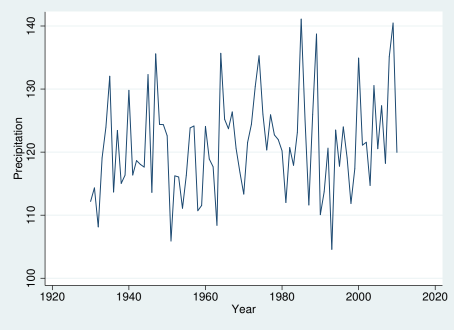
Year	Total	Male	Female	Lbfc	Agr.
1981-1985	2,531,338	1,262,495	1,268,843	1,008,936	204,855
1986-1990	5,290,004	2,657,986	2,632,018	1,784,064	345,060
1991-1995	4,475,337	2,241,107	2,234,231	1,397,093	240,594
1996-2000	6,557,345	3,254,798	3,302,547	2,047,343	329,443
2001-2005	3,281,974	1,617,173	1,664,801	1,052,745	172,038
2006-2010	6,010,912	3,052,305	2,958,607	1,823,847	280,250

- Cross-state migration about 4-6% of total census population
- 17% of labor force migrants work in agriculture

Climate data

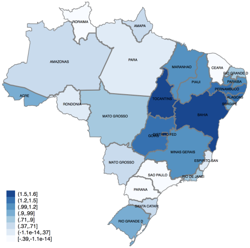
- Sourced from Willmott and Matsuura (2015): worldwide (terrestrial) monthly mean temperature and precipitation data.
  - At 0.5 x 0.5 degree resolution (approximately 56km x 56km at the equator)
  - Aggregate weather data to the state level by taking the average of weather data from all grids within each state.



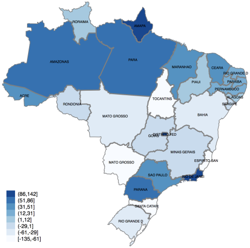


Climate data - regional variations

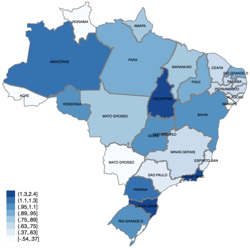
Air Temp. in December, 2010 minus 1980



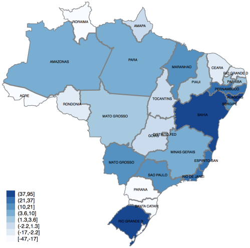
Precipitation in December, 2010 minus 1980



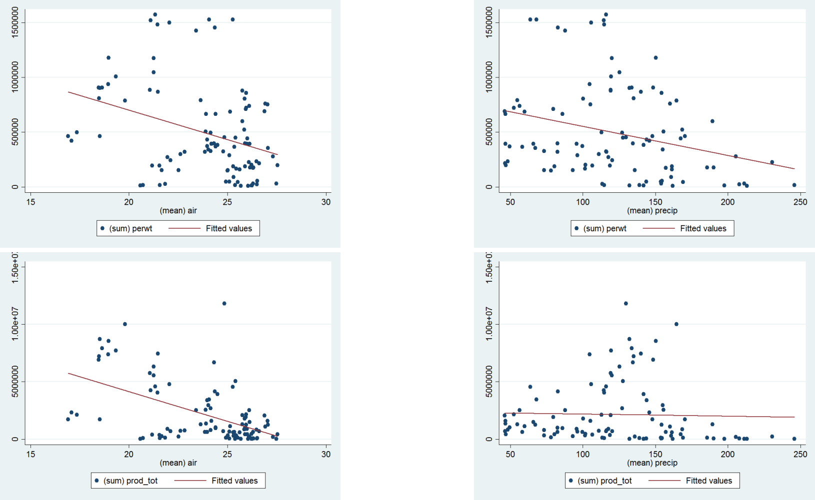
Air Temp. in July, 2010 minus 1980



Precipitation in July, 2010 minus 1980



Climate data - Links to agricultural sector



table

Migration costs - Road data

- Obtained maps of road networks from OpenStreetMap and the Brazilian Statistical Office:
  - For 1986, 1990, 1995, 2000, 2005, and 2010.

- Constructed a dataset of the evolution of the road infrastructure in Brazil by digitizing the maps using geospatial software.

- Used Network Analysis to calculate the shortest travel distance between two state pairs taking into account distance and speed.
  - On average, shortest travel time between two states decreased 21% between in 1986 and 2010.

Migration costs - Road data

Figure: 1986

Figure: 2010

Estimation - "push" and "pull" factors

$$
\begin{aligned}
m_{ijt} = & \exp[\omega_{ij} + \psi_{it} + \eta_{jt} + \beta_1 \cdot lnRoadDist_{ijt} \\
& + \beta_2 \cdot lnRoadDist_{ijt} * lnTemp_{it} + \beta_3 \cdot lnRoadDist_{ijt} * lnPrecip_{it} \\
& + \beta_4 \cdot lnRoadDist_{ijt} * lnTemp_{jt} + \beta_5 \cdot lnRoadDist_{ijt} * lnPrecip_{jt} \\
& + \delta \cdot \mathbf{Z}_{ijt}] + \epsilon_{ijt}
\end{aligned}
$$

- Gravity model estimated using PPML
  - State-pair: common border, geographic, cultural and economic distance
  - Origin-time and destination-time: climate, income, education, industrial composition, state policies

- Bilateral travel measure
  - More roads make it easier to move ⇒ facilitate migration
  - More roads imply better connectivity to goods networks ⇒ reduces need to migrate

Endogeneity

- Reverse causality: it is possible that the roads are built due to migratory pressure.
- Morten and Oliveira (2017): exogenous highway expansion in 1960 due to the creation of Brasilia.
  - Euclidean Minimum Spanning Tree (EMST) network to predict the least costly way to connect Brasilia to all state capitals. map
  - Entirely new network: capital city was new so new roads did not replace existing ones, and completion of the city happened in less than 4 years.
  - Cannot reject that municipalities on the EMST network are similar to those not on the network.
  - Pair fixed effects control for other factors that influence the connectivity and migration between two states.
  - Control function approach first-stage

By migrant type

	PPML	PPML-CF				
	All	All	Ag	Non-ag	Male	Female
$\ln RoadDist_{ijt}$	-4.269	-3.192	-11.868	-2.31	-3.416	-3.024
	(1.480)***	(1.392)**	(3.147)***	(1.408)	(1.496)**	(1.330)**
$\ln RoadDist_{ijt}$ * $\ln Temp_{it}$	1.015	0.881	1.727	0.81	0.985	0.787
	(0.424)**	(0.416)**	(0.833)**	(0.435)*	(0.454)**	(0.391)**
$\ln RoadDist_{ijt}$ * $\ln Precip_{it}$	0.043	0.01	0.187	0.029	0.03	-0.009
	(0.070)	(0.070)	(0.142)	(0.074)	(0.077)	(0.067)
$\ln RoadDist_{ijt}$ * $\ln Temp_{jt}$	0.373	0.255	1.234	0.256	0.22	0.291
	(0.420)	(0.410)	(0.963)	(0.430)	(0.441)	(0.396)
$\ln RoadDist_{ijt}$ * $\ln Precip_{jt}$	-0.036	-0.066	0.409	-0.224	-0.084	-0.045
	(0.062)	(0.063)	(0.160)**	(0.071)***	(0.070)	(0.060)
N	3,594	3,594	3,330	3,582	3,588	3,594

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Ag/non-ag status based on post-migration data

Magnitudes

- Improved road network increases migrant flows
  - With an average air temperature of 25°C, a 10% decrease in travel time is associated with a 3.6% increase in migrant flows on average.
- An increase in origin temperature makes travel costs less inhibitive to migration
  - Facing higher temperature, more emigration despite the travel cost
  - A 10% increase in air temperature is associated with an 8.8% increase in migrant flows compared to a scenario with the same improvements in road connectivity but no change in temperature.

Agricultural states

	Ag (1)	Ag (2)
$\ln RoadDist_{ijt}$	-3.386 (1.603)**	-3.401 (1.385)**
$\ln RoadDist_{ijt}$ * $\ln Temp_{it}$ * $Daghigh_{it}$	-0.424 (0.163)***	
$\ln RoadDist_{ijt}$ * $\ln Precip_{it}$ * $Daghigh_{it}$	0.256 (0.119)**	
$\ln RoadDist_{ijt}$ * $\ln Temp_{jt}$ * $Daghigh_{jt}$	-0.081 (0.149)	
$\ln RoadDist_{ijt}$ * $\ln Precip_{jt}$ * $Daghigh_{jt}$	0.024 (0.106)	
$\ln RoadDist_{ijt}$ * $\ln Temp_{it}$ * $Daglow_{it}$		0.374 (0.195)*
$\ln RoadDist_{ijt}$ * $\ln Precip_{it}$ * $Daglow_{it}$		-0.260 (0.137)*
$\ln RoadDist_{ijt}$ * $\ln Temp_{jt}$ * $Daglow_{jt}$		0.311 (0.209)
$\ln RoadDist_{ijt}$ * $\ln Precip_{jt}$ * $Daglow_{jt}$		-0.177 (0.142)
N	3,594	3,594

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

- Agriculture-intensive ("High" $>$ 20% empl.) states: 5 from NE (Paraiba, Alagoas, Piaui, Maranhao, Bahia) and Rondonia
- Generally have lower average income: possibly a povery trap story, or an adaptation story.

Regional variation

	East⇒West	Sugar⇒Non Sugar	NE⇒Non NE
	All	Ag	Ag
	(1)	(2)	(3)
$\ln RoadDist_{ijt}$	-43.549	-9.391	-37.41
	(6.267)***	(5.680)*	(25.644)
$\ln RoadDist_{ijt}$ * $\ln Temp_{it}$	-2.015	-2.245	7.098
	(1.214)*	(1.764)	(6.983)
$\ln RoadDist_{ijt}$ * $\ln Precip_{it}$	0.018	-0.128	-2.171
	(0.247)	(0.321)	(0.747)***
$\ln RoadDist_{ijt}$ * $\ln Temp_{jt}$	14.633	4.993	2.109
	(2.220)***	(2.404)**	(5.976)
$\ln RoadDist_{ijt}$ * $\ln Precip_{jt}$	0.502	0.231	3.629
	(0.887)	(0.305)	(1.438)**
N	816	627	779

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

By age group and family status

	15-54 yo	0-14 yo	55+ yo	w. child	no child	child<5yo	no child<5yo	HH head	not HH head
	All	All	All	All	All	All	All	All	All
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\ln RoadDist_{ijt}$	-3.759	-3.987	-5.465	-4.268	-4.571	-3.872	-4.612	-3.188	-4.838
	(1.392)***	(1.702)**	(1.592)***	(1.434)***	(1.479)***	(1.673)**	(1.446)***	(1.350)**	(1.508)***
$\ln RoadDist_{ijt}$ * $\ln Temp_{it}$	0.999	0.968	1.193	1.159	0.985	0.746	1.122	0.847	1.113
	(0.406)**	(0.487)**	(0.561)**	(0.420)***	(0.437)**	(0.438)*	(0.435)***	(0.397)**	(0.443)**
$\ln RoadDist_{ijt}$* $\ln Precip_{it}$	0.032	0.079	-0.090	0.059	0.043	0.077	0.040	0.012	0.062
	(0.069)	(0.086)	(0.087)	(0.069)	(0.074)	(0.085)	(0.071)	(0.070)	(0.072)
$\ln RoadDist_{ijt}$ * $\ln Temp_{jt}$	0.347	0.192	0.311	0.195	0.510	0.547	0.351	0.330	0.392
	(0.401)	(0.463)	(0.542)	(0.415)	(0.420)	(0.439)	(0.419)	(0.407)	(0.421)
$\ln RoadDist_{ijt}$ * $\ln Precip_{jt}$	-0.103	0.018	0.280	-0.028	-0.043	-0.086	-0.017	-0.091	-0.014
	(0.064)	(0.076)	(0.092)***	(0.063)	(0.063)	(0.089)	(0.059)	(0.063)	(0.063)
N	3,582	3,582	3,486	3,576	3,594	3,564	3,594	3,582	3,594

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Alternative climate measures: weights

	Crop All (1)	Agr. Emp. All (2)	Lbfc All (3)
lnRoadDist_{ijt}	-0.343	-3.584	-3.386
	(0.172)**	(1.499)**	(1.434)**
$\text{lnRoadDist}_{ijt} * lnTemp_{it}$	0.291	0.881	0.692
	(0.080)***	(0.382)**	(0.346)**
$\text{lnRoadDist}_{ijt} * lnPrecip_{it}$	-0.036	0.021	0.006
	(0.046)	(0.070)	(0.059)
$\text{lnRoadDist}_{ijt} * lnTemp_{jt}$	0.142	0.372	0.455
	(0.088)	(0.384)	(0.357)
$\text{lnRoadDist}_{ijt} * lnPrecip_{jt}$	-0.040	-0.072	-0.028
	(0.045)	(0.068)	(0.055)
N	3,030	3,594	3,594

$$Climate_{it} = \frac{1}{12} \sum_{m=1}^{12} \sum_{c=1}^{10} growth_{icm} * prodsh_{ic} * climate_{imt}$$

Alternative climate measures: variation

	Mean Ag (1)	SD Ag (2)	Range Ag (3)	Max Ag (4)	Min Ag (5)	Dev. 10 Yr Ag (6)	Anomaly Ag (7)	Extreme Mon. Ag (8)
$\ln RoadDist_{ijt}$	-11.868	-0.570	0.138	-5.987	-1.773	-0.019	0.033	-1.252
	(3.147)***	(0.411)	(0.487)	(3.214)*	(0.795)**	(0.105)	(0.111)	(1.086)
$\ln RoadDist_{ijt}$ * $\ln Temp_{it}$	1.727	0.291	-0.120	1.066	0.622	0.006	0.005	0.139
	(0.833)**	(0.193)	(0.097)	(0.607)*	(0.199)***	(0.008)	(0.006)	(0.080)*
$\ln RoadDist_{ijt}$ * $\ln Precip_{it}$	0.187	0.078	0.042	0.065	-0.002	0.002	0.005	0.101
	(0.142)	(0.089)	(0.049)	(0.050)	(0.013)	(0.008)	(0.009)	(0.162)
$\ln RoadDist_{ijt}$ * $\ln Temp_{jt}$	1.234	-0.217	-0.159	0.588	-0.017	0.024	0.020	0.118
	(0.963)	(0.228)	(0.122)	(1.019)	(0.280)	(0.010)**	(0.007)***	(0.081)
$\ln RoadDist_{ijt}$ * $\ln Precip_{jt}$	0.409	0.041	0.019	0.040	0.002	-0.013	0.002	0.195
	(0.160)**	(0.099)	(0.067)	(0.066)	(0.015)	(0.014)	(0.016)	(0.260)
N	3,330	3,330	3,330	3,330	3,330	3,330	3,330	3,330

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Definitions

Summary

- Although road networks could provide an alternative adaptation strategy through a better connected goods market, we find strong evidence that a reduction in travel time is associated with higher levels of cross-state migration.
- Despite travel costs, facing higher temperatures more migrants flow out, especially agricultural migrants if they can afford it.
  - Unclear that migrants appreciate climate in their choice of destination.
- Reducing migration costs through better road connectivity could be key to households being able to adapt to the changing climate by relocating.

The End

EMST travel time as instrument

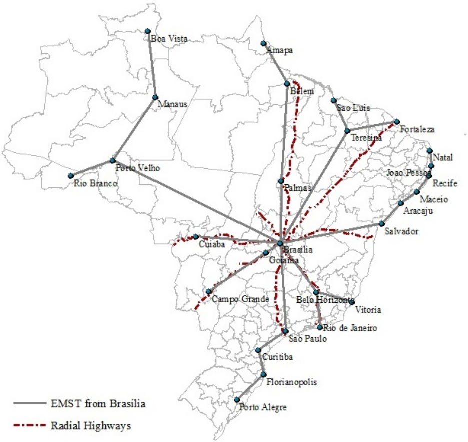


Figure: Morten and Oliveira (2016)

Back to Endogeneity

First stage estimates: migration costs

$$lnRoadDist_{ijt} = \psi_i + \eta_j + \gamma \cdot \delta_t * lnRoadDist_{ij,1960} + \epsilon_{ijt}$$

Year	1981	1986	1991	1996	2001	2006
$\ln\text{RoadDist}_{ij,1960}$	1.021	1.089	1.005	0.994	1.011	1.010
	(0.030)***	(0.032)***	(0.031)***	(0.029)***	(0.030)***	(0.028)***
R^2	0.87	0.87	0.86	0.85	0.87	0.89
N	600	600	600	600	600	600

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Back to Endogeneity

Climate data - Links to agricultural sector

	Income (1)	Production (2)	Employment (3)	Income (4)	Production (5)	Employment (6)
Temp.	-50,562.771	-50,227.422	-76,506.609	-143,211.474	-142,450.446	13,472.379
	(22,934.097)**	(22,588.794)**	(28,068.812)**	(77,418.415)*	(77,148.155)*	(16,636.174)
Precip.	-2,367.286	-2,272.800	-1,683.495	-5,055.226	-5,053.473	-283.401
	(1,158.167)*	(1,159.699)*	(1,343.930)	(4,202.807)	(4,259.608)	(321.298)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
State FE	No	No	No	Yes	Yes	Yes
R^2	0.61	0.61	0.79	0.52	0.52	0.99
N	150	150	150	150	150	150

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Back to Graphs

Alternative climate measures: variation

- Dev10yr: deviation from average of previous ten years.
- Anomaly: standardized deviation from 1930-1980 baseline "norm".
  - Eliminates scale effects
  - Controls for the fact that climatic variations typically greater in more arid regions
  - Beine and Parsons (2015)
- Extreme months: outside the 99% confidence interval standardizing using long-term mean and standard deviation.

Back to Results

First: effect of climate on its own

	All		Ag
	(1)	(2)	(3)
$\ln RoadDist_{ijt}$	0.019	-0.009	-0.034
	(0.056)	(0.042)	(0.080)
$\ln Temp_{it}$	-0.283	-1.902	-4.564
	(1.869)	(1.417)	(2.367)*
$\ln Precip_{it}$	-0.257	-0.281	-0.876
	(0.258)	(0.184)	(0.263)***
$\ln Temp_{jt}$	4.522	0.728	1.870
	(1.511)***	(1.048)	(1.367)
$\ln Precip_{jt}$	0.435	0.058	0.131
	(0.144)***	(0.102)	(0.251)
Additional Controls	No	Yes	Yes
Time	Yes	Yes	Yes
Origin x destination	Yes	Yes	Yes
SE Cluster	Origin	Origin	Origin
N	3,594	3,510	3,289

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$