Short and long-term impacts of drought: Evidence from Brazilian municipalities*
PRELIMINARY

Paulo Bastos† Matias Busso‡ Sebastian Miller§

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Abstract

This paper examines short and long run impacts of drought on local development. Drawing on uncommonly rich panel data for Brazilian municipalities, we build drought indexes based on contemporaneous and historical rainfall patterns, and show that they are a strong predictor of emergency declarations associated with drought in 2003-2008. Using these weather-based measures to account for potential endogeneity of drought declarations in an IV approach, we find that a drought leads to a 40% decline in agricultural value added and detracts 30% of local GDP, on average. In the longer-term, the occurrence of drought induces migration away from the areas most frequently affected. Hence the increased occurrence of extreme weather events associated with emissions of greenhouse gases is a potentially important driver of long-run urbanization patterns in developing nations.

Keywords: Climate change; drought; migration; urbanization; Brazil.
JEL classification:

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†Research Department, The World Bank. E-mail: pbastos@worldbank.org.
‡Research Department, Inter-American Development Bank. E-mail: mbusso@iadb.org.
§Research Department, Inter-American Development Bank. E-mail: smiller@iadb.org.

1 Introduction

There is a growing consensus that, in addition to raising the levels of temperature and precipitation, emissions of greenhouse gases due to human activity lead to more volatile weather conditions, and hence to a more frequent incidence of extreme events such as droughts, storms and floods (IPCC, 2007a, b, c). How does the increased occurrence of drought impact on local economic and social development both in the short and medium term? Empirical evidence on this issue is relatively scarce, but highly relevant to support policy makers in developing effective instruments to assist the local communities most severely affected (Verner, 2010, 2011).

In this paper, we examine short and long-term impacts of drought on local development, drawing uncommonly rich data for municipalities in Brazil. We first estimate the short-run impact of these extreme events on agricultural value added and local income, using panel data on the universe of emergency declarations, municipal GDP and its composition from 2003-2008. To account for the potential endogeneity of emergency declarations, we construct drought indexes based on contemporaneous and historical rainfall patterns. We show that these weather-based measures are a strong predictor of emergency declarations associated with drought, and use them to estimate the causal impacts of drought on local income in an instrumental-variable approach. We find that a drought leads to a 40% decline in agricultural value added and lowers local GDP by 30%, on average.

We then turn to estimating the longer term impacts of drought on population growth and migration patterns across minimum comparable areas (AMCs). For this purpose, we link the aforementioned weather-based drought measures for 1970-2010 with population data for the same period from five census waves. We look not only at effects on overall population levels, but also to impacts on the age and skill composition of the population. We find that the occurrence of drought induces migration away from the areas most frequently affected. These results suggest that population movements within developing nations countries are a potentially important form of adaptation to the increased occurrence of extreme weather events associated with emissions of greenhouse gases; and hence that climate change is a potentially important driver of their long-term urbanization patterns.

This paper builds on and contributes to the emerging literature seeking to quantify the economic and social impacts of weather shocks at the local level, including influential work by Deschenes and Greenstone (2007), Maccini and Yang (2009) and Burgess et al. (2012).[1] A common approach in this literature has been to use changes in levels of temperature or

[1] Our paper is also broadly related to research using cross-national panel data to estimate the impact of changing weather conditions on aggregate GDP and exports, including recent work by Dell et al. (2012) and Jones and Olken (2010).

rainfall to identify the impacts of changing weather conditions on agricultural productivity and other economic and social indicators. A key distinguishing feature of our paper is the ability to construct detailed weather-based measures of drought and to link them to administrative panel data on emergency declarations in order to pin down the short-term effects of these extreme weather events on agricultural production and income.

We also add to this literature by estimating, to our knowledge for the first time, the long-term impacts of drought on the evolution of population in rural and urban areas. In doing so, our paper is also related to recent work by Michaels et al. (2012), who find that structural transformation shifting employment away from agriculture is an important driver of long-term patterns of urbanization, both in the US and in Brazil. We contribute to this body of research by showing that the increased occurrence of extreme weather events has the ability to affect both agricultural GDP and the level and composition of population movements within countries, and thereby the potential to influence future patterns of urbanization.

The remainder of the paper proceeds as follows. Section 2 provides background and describes the data employed. Section 3 presents the empirical strategy for examining the short-term effects of drought on agricultural production and income, and then reports the corresponding results. Section 4 outlines the empirical strategy used to examine the long-term impacts of drought on the evolution of population ... Section 5 concludes the paper.

2 Background and data

2.1 Emergency declarations in Brazil

The Brazilian Federal Union has a population of about 192 million over 8.5 million Km2. It is comprised of 26 states, 1 federal district and over 5500 municipalities. Municipalities are run by an elected mayor and an elected city council. The procedures to declare an emergency are as follows. In the 10 days after the disaster has struck, the mayor or state governor makes a formal request to the Ministry of National Integration. The request describes the nature of the disaster and its main effects, including estimates of damages, casualties, injuries, services being affected, etc. The ministry then declares an emergency or state of public calamity for a period of up to 180 days, which may be renewed. It may also reject the request if it considers that it does not comply with a set of pre-established conditions. The federal government may unilaterally – and preemptively – declare a state of emergency to accelerate the process of distributing disaster relief, while it receives the formal request from local authorities. Disaster relief is coordinated by Civil Defence, but each of the corresponding Ministries (eg. Agriculture, Health, Finance, etc) is responsible

for its own relief activities.

2.2 Data

The empirical analysis in this paper draws on the following sets of data:

1. *Drought declarations.* We draw on administrative data on emergency declarations from the National Secretariat of Civil Defense from 2003-2008. This data set comprises information by municipality on: the type of extreme event (flood, drought, rain, storms, wind, etc.), type of emergency declared (state of emergency or state of public calamity), starting date and duration of the declaration. We construct two different variables: the number of droughts declared in each year by the municipality and a dummy variable that takes the value of one if at least one drought was declared in that municipality-year (and zero otherwise).

2. *Rainfall and droughts.* We use data on monthly rainfall at the municipality level covering the period 1900-2009. Data for 1900-2002 come from the University of East Anglia's Climate Research Unit (dataset CRU TS 3.0). We complement this information with data from the National Environmental Data System (*Sistema Nacional de Dados Ambientais*) for the period 2002-2009. Using a kriging procedure we compute rainfall for each municipality on a monthly basis for the whole sample period.

3. *Local income.* Annual data on the size and functional composition of municipal public spending come from the National Treasury through the FINBRA data set. For each year in the period 2000-2008, this data set contains information on municipal spending by functional category. Annual data on municipal GDP and its composition, and on local population come from the National Institute of Geography and Statistics (IBGE).

4. *Population.* Data on population cover the period 1970-2010 and come from the corresponding waves of the decennial population census.

3 Estimation Framework

3.1 Descriptive Statistics

Droughts can be defined as instances of a severe reduction in soil moisture with respect to the average moisture that could be find in that same area in the last decades. Unfortunately, information on soil moisture is typically not available and therefore droughts are

difficult to observe. We use two alternative measures of droughts. In Figure 1 we compare the spatial distribution of these two measures. On the left, we map the annual frequency, over the period 2003-2008, with which each municipality declared and was granted a state of emergency due to a severe drought. We denote this measure D_{it}^1. The figure on the right shows the spatial distribution of droughts based on weather data. In this case, we consider a drought occured if the amount of rainfall in the last three months falls below the percentile 20 of the typical rainfall received in the region in which the municipality is located. We denote this second measure D_{it}^2 .The first measure has the advantage that it allows us observe droughts directly but could, in principle, be contaminated by political factors. The second measure is a more objective measure of droughts but it is imperfect. This can be seen, for instance, in the high number of droughts identified in the northwest part of the country located in the Amazonas states characterized by a tropical climate.

Figure 2 shows the percentage of municipalities that had a drought according to D_{it}^1 and D_{it}^2. Both measures are highly correlated. Around 50% of the municipalities in Brazil never declare an emergency in 2003-2008, between 10%-20% had one drought, and 20% had more than one drought in the five year period.

Table 1 shows basic descriptives statistics comparing areas that declared emergencies over the period under analysis and areas that did not. It can be observed that typically areas with no emergency declaration are less populated and have higher GDP, higher fiscal revenues and expenditure.

3.2 Estimation

We are interested in estimating the effect of droughts D_{it}, that affected municipality i at time t, on a set of economic outcomes that we can generally denote y_{it}

$$y_{it} = \alpha + \theta D_{it} + \mu_i + \nu_t + \epsilon_{it}$$

where μ_i is a municipality fixed effect and ν_t is an year fixed effect. Droughts are self-declared by the municipality when they asked the federal government for emergency funding.

First we study the short run effect of droughts by estimating a model using annual data of emergencies declaration over the period 2003-2008. Table 2 present the results. In column 1 we show the OLS impacts using the measure D_{it}^1. Having a drought reduces the product of the municipality by 1.2% and the agricultural product by 5.8%. In principle, these estimates could be biased because emergency declaration could have been granted to municipalities with declining economies. In column 2 we estimate the same model measuring droughts using weather data D_{it}^2. Again, we find reductions of GDP and agricultural GDP of about 1.3-1.7%. Using an IV approach, instrumenting D_{it}^1 with D_{it}^2 we

find that the results increase substantially. Effect of a drought on agriculture GDP are of 40%, while municipal output falls 30% with a drought. Population also decreases with a drought, with an estimate of about 4% over the 2000-2010 period, using the IV approach.

We also look at fiscal variables, where the results are less than robust. We do find some evidence that droughts tend to decrease revenue and expenditure at the municipal level, but the results are not conclusive. Educational and social outcomes appear also less than conclusive.

In Table 3 we investigate the long run impact of droughts on population using census data for the period 1970-2000. We only have information on D_{it}^2 so we estimate an OLS model of log population on the number of droughts idenified in that municipality ($\sum_{t=1970}^{2000} 1\left(D_{it}^2 = 1\right)$). We can see that drought not only have an immediate effect on product but also it reduces population by 0.8%.

4 Concluding remarks

Evidence is mounting that emissions of greenhouse gases due to human activity lead to a more frequent occurrence of extreme weather events such as droughts. We have examined short and long-run impacts of these extreme events on local economic and social development, drawing on uncommonly rich data for municipalities in Brazil. We have first estimated short-run effects on agricultural value added and local income, using panel data on the universe of emergency declarations and municipal GDP from 2003-2008. We have constructed detailed drought indexes at the local level based on contemporaneous and historical rainfall patterns. These weather-based measures are shown to be a strong predictor of emergency declarations associated with drought, and are then used to estimate the causal effects of drought on local income. Instumental-variable estimates reveal that the occurrence of drought leads to a 40% decline in agricultural value added, thereby reducing local income by 30%, on average.

We have them examined the longer term impacts of drought on population growth and migration, linking the aforementioned weather-based drought measures with population data from various census waves spanning the period 1970-2010. We have found that the occurrence of drought induces migration away from the areas most frequently affected. These results suggest that the increased occurrence of extreme weather events associated with emissions of greenhouse gases is a potentially important driver of long-run urbanization patterns in developing nations.

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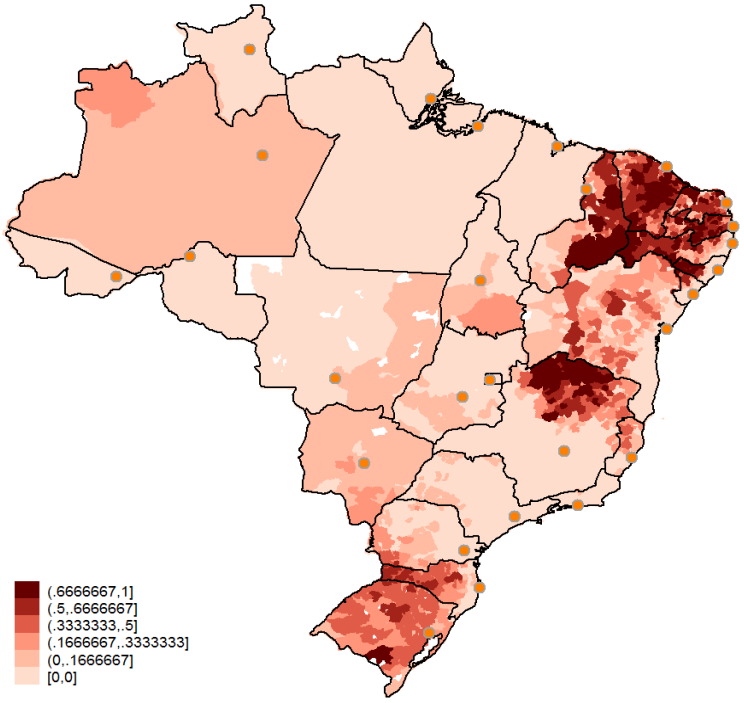
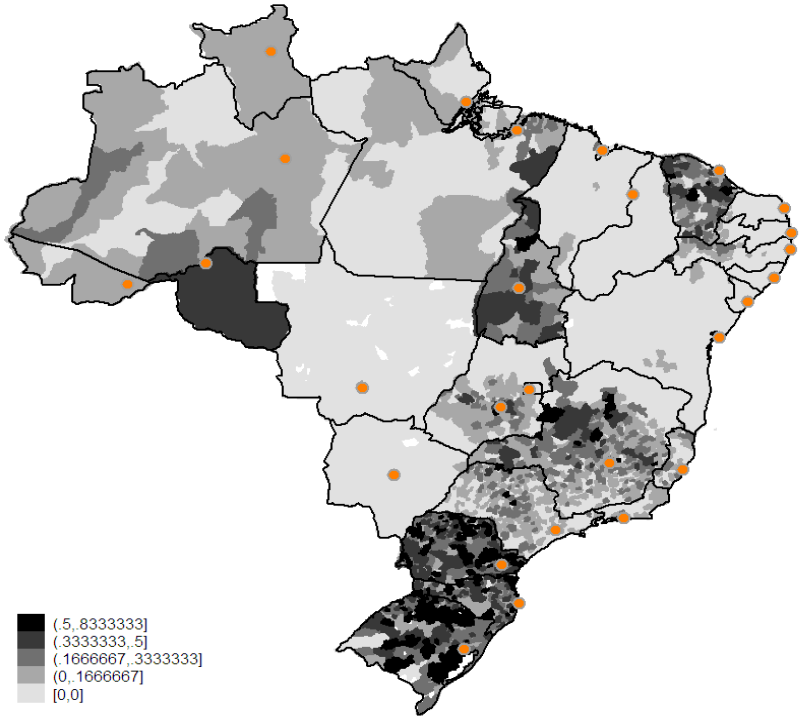
Figure 1 Maps of emergencies declaration and droughts (2003-2008)

Emergencies



Droughts (3 Months, Region comparison)



Source: Author's calculations.

Table 1 Descriptive Statistics

Average 2003-2008

		Mean		
Type	**Variable**	**Total**	**No emergencies**	**At least one**
Population	Log Population	9.72	9.70	9.80
Economy	Log GDP	11.50	11.54	11.24
	Log Agricultural GDP	9.63	9.65	9.51
	Agricultural GDP / Total GDP	0.24	0.24	0.22
Fiscal	Log revenue	16.56	16.56	16.52
	Log expenditure	16.54	16.54	16.51
	Log expenditure in education	15.33	15.32	15.37
	Log expenditure in health	15.06	15.06	15.03
	Log other expenditure	14.37	14.38	14.27
Education	Distortion age-grade	0.19	0.18	0.23
	Class size	27.67	27.72	27.36

Source: Author's calculations.

Figure 3 Emergencies and droughts distribution

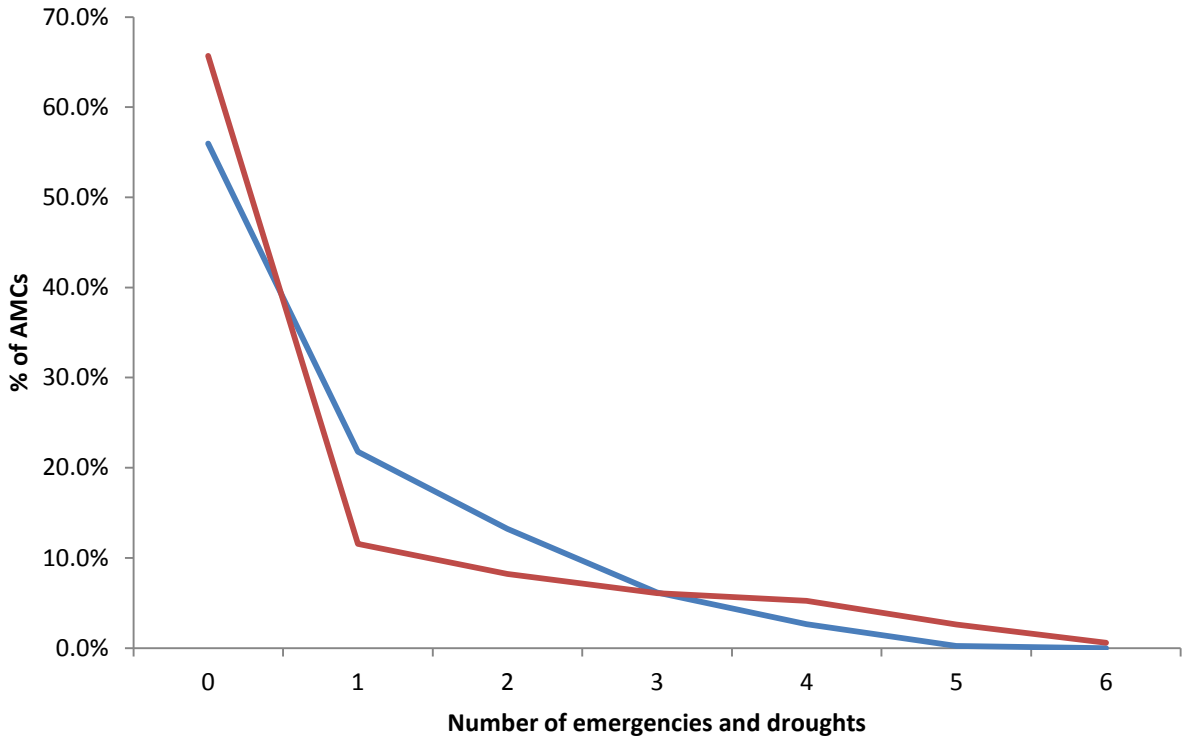


Table 2 Regressions results (2003-2008)

	OLS	Reduced Form	IV (1)
Log GDP	-0.012	-0.013	-0.303
	[0.003]***	[0.003]***	[0.083]***
Log agricultural GDP	-0.058	-0.017	-0.408
	[0.006]***	[0.005]***	[0.139]***
Log population	0.001	-0.002	-0.039
	[0.001]	[0.001]***	[0.015]***
Log revenue	0.002	-0.005	-0.129
	[0.003]	[0.003]*	[0.073]*
Log expenditure	0.009	-0.007	-0.168
	[0.006]	[0.003]**	[0.081]**
Log expenditure in education	0.014	-0.005	-0.117
	[0.007]**	[0.005]	[0.106]
Log expenditure in health	0.024	0.002	0.045
	[0.009]***	[0.006]	[0.131]
Log other expenditure	0.012	-0.029	-0.684
	[0.014]	[0.012]**	[0.300]**
Distortion age-grade	0.003	0.001	0.023
	[0.001]**	[0.001]	[0.021]
Class size	-0.537	-0.042	-1.022
	[0.097]***	[0.065]	[1.551]

Notes

All regressions include year dummies

(1) Emergencies are instrumented by droughts variable.

* p<0.1 ** p<0.05 *** p<0.01

Table 3 Regressions without instruments (1970-2009)

Logarithm of population as dependent variable	Coefficient
Droughts by year	0.003 [0.002]**
Total droughts in a decade	-0.008 [0.001]***

Source: Author's calculations.

Notes

All regressions include year dummies.

Standard errors in parentheses

* p<0.1 ** p<0.05 *** p<0.01

Table 4 Regressions using change in 2000-2010 population as dependent variable (in logs)

Variable	Coefficient
Number of emergencies / droughts	
Emergencies (1) - OLS	-0.008
	[0.001]***
Droughts - RF (2)(3)	-0.005
	[0.001]***
Emergencies - IV	-0.074
	[0.030]**
Had one or more emergencies / droughts	
Emergencies (1) - OLS	-0.031
	[0.004]***
Droughts - RF (2)(3)	-0.009
	[0.004]**
Emergencies - IV	-0.902
	[1.522]

(1) Reduced form

(2) Consider the number of emergencies from 2003 to 2008

(3) Consider the number of droughts from 2000 to 2010

* p<0.1 ** p<0.05 *** p<0.01