The Effects of Climate Change on Labor and Capital Reallocation

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Abstract

I Introduction

The speed of observed climate change is one of the major challenges of our time. As average temperatures rise in many regions around the globe, the frequency and intensity of extreme weather events, such as droughts and floods, is expected to increase (Hsiang and Kopp, 2018). Developing economies are particularly exposed to these events because they tend to be located in tropical areas and a significant share of their population is still employed in agriculture (Mani et al., 2018). Empirical evidence shows that increases in temperature and extreme weather events have negative effects on local economic activity and can generate migration away from affected areas (Dell et al., 2014). However, we lack a clear understanding of how the process of reallocation of economic activity away from areas affected by climate change can mitigate its effects. In particular, there is scarce empirical evidence on the effects of factor reallocation originated by climate change on destination regions.

In this paper, we use new data on extreme weather events that occurred in Brazil during the last two decades to estimate their effects on the local economy of the affected areas, on the magnitude and direction of labor and capital movements that they generate, and on the allocation of factors across sectors and firms in destination regions.

To measure extreme weather events, such as droughts, we digitized administrative data from the National System of Civil Protection in Brazil (Sistema Nacional de Protecao e Defesa Civil - SINPDEC), which records every reported natural disaster at the municipality-level. These data are based on requests of aid from the federal government and, thus, might be subject to reporting bias. To overcome this concern, we use a meteorological measure of droughts, the Standardized Precipitation Evapotranspiration Index (SPEI). This index measures the moisture deficit in a given location relative to its 100 year average and is based on local precipitation and temperature data. It is used by climatologists to predict droughts, including those caused by climate change (Vicente-Serrano et al., 2010). Indeed, we find that this index is a strong predictor of the drought events reported in the SINPDEC data. The SPEI also shows an increase in abnormally dry conditions across Brazilian regions during the last twenty years relative to historical averages, consistent with the increase in average temperatures. We complement these data with information from the Population Census, which records the municipality of origin of all internal migrants in Brazil; social security data from the Annual Social Information System (RAIS), which permits to track workers across regions, sectors and firms; and balance sheet data from all bank branches in Brazil (ESTBAN), which permits to track capital flows across regions.

First, we document that regions subject to dry meteorological conditions in a given year experience a sharp reduction in agricultural output but receive capital inflows: local bank deposits contract, while bank loans expand. Funds are partly drawn from areas connected to affected regions through bank branch networks, which experience capital outflows. This suggests that local economies are able to partially insure themselves against negative weather shocks by being financially integrated with other regions. However, when we analyze the impact of a full decade of unusually dry meteorological conditions, we find that affected regions experience capital outflows, driven by a reduction in loans to these areas. More specifically, a region experiencing unusual dryness during a decade (defined as an increase in average decadal dryness of about 0.5 of a standard deviation relative to its 100 year mean), suffers a 13.3 percent decline in lending originated by local branches. This is consistent with the idea that a full decade of unusually dry meteorological conditions has (or is perceived to have) permanent negative effects on local productivity.

Second, we find that areas with a higher incidence of droughts during the decade 2000-2010 experienced a sharp reduction in population and agricultural employment. This led to a change in the structure of the local economy, where manufacturing employment expanded while the service sector contracted. These findings suggest that the fall in agricultural productivity reduced the demand for local non-traded goods such as services, while it generated an expansion in local traded goods such as manufacturing by reducing the price of labor. However, not all displaced workers were absorbed locally: we document large out-migration flows from both rural and urban areas affected by droughts. In particular, a region experiencing unusual dryness during a decade (defined as an increase in average decadal dryness of 0.5 of a standard deviation relative to its 100 year mean), suffers a population loss of 5.7 percent.

Next, we track the destination of climate migrants. For this purpose, we use the fact that workers who migrate are more likely to relocate towards regions where they have social networks, measured by historical migration links. Then, we construct a measure of indirect exposure of each destination to droughts by summing the droughts that occurred in each potential origin, weighted by the share of all migrants in that destination who came from that particular origin in previous waves of the decadal Population Census. We find that regions receiving climate migrants expand employment in agriculture and services, but not in manufacturing. In particular, a region where 10 percent of historical migrants came from areas affected by unusual dryness during the present decade, experiences an increase in agricultural employment of 0.85 percent and a reduction in manufacturing employment of 0.53 percent.

This finding might be driven by the fact that climate migrants lack the skills required for employment in manufacturing in urban areas. In this case, the absence of migrant reallocation into manufacturing would reflect an optimal allocation of labor at destination. Alternatively, this finding could also be driven by the fact that migrants' social networks are disconnected from manufacturing firms at destination. This asymmetry in labor market frictions across sectors would result in labor misallocation. We turn to explore these explanations next.

To shed some light on the assignment process of climate migrants to jobs at destination, we use the social security data to bring the analysis to the firm-level. For each firm, we construct a measure of exposure to climate migrants. First, we measure whether a firm is connected to regions experiencing droughts through social networks by the baseline share of workers in the firm coming from origins with high exposure to droughts. We find that workers from drought areas tend to reallocate towards firms which already had a large share of migrants from those origins. This implies that climate migrants do not amount to a symmetric increase in labor supply for all firms. Instead, labor market frictions direct migrants to connected firms. This has important implications for the composition of economic activity in destination regions.

First, we document that the manufacturing sector is the least connected to drought areas through past migrant networks: only 2 percent of its workers come from those areas compared to 4 percent in services and 6 percent in agriculture. This might reflect the fact that manufacturing is geographically concentrated due to agglomeration economies. Second, in a given destination, the estimated elasticity of worker inflows from connected origins experiencing droughts are three times larger for firms in the agricultural sector than for firms in manufacturing. This implies that even in the presence of referral networks, manufacturing firms are less prone to employ workers coming from drought areas. This might be due to the fact that manufacturing firms require specialized skills that are sourced in thick local labor markets. Indeed, we find that migrants from drought areas have lower levels of education and earnings than comparable workers at destination.[1] Third, we find that the estimated elasticity of worker inflows from connected origins experiencing droughts is twice as large for small than for large firms. Hence, climate migrants affect the shape of the firm-size distribution, increasing the weight of small firms, which tend to pay lower wages and display lower productivity.[2]

Let us emphasize that a higher incidence of droughts in some locations can have effects in other locations through several channels other than migration flows. For example, goods trade can generate demand or supply linkages across regions. Similarly, droughts can generate capital flows across regions, as we discussed above. If regions with larger labor market integration are also more linked through goods or capital markets, then our measure of labor market integration, namely migrant networks, could capture these other channels. We address this concern by exploiting the fact that we can track workers across regions and firms in the social security data. This permits to absorb aggregate firm growth at each destination municipality, which controls for any general equilibrium effects of droughts in connected areas through labor, product and capital market linkages. In

[1] In contrast, migrants from areas with average weather tend to have a similar level of education as

addition, we can compare worker flows from drought origins with worker flows from other areas at the firm-level in each destination. This permits to separate the labor market effects of droughts on connected firms from other effects taking place through the goods or capital markets. This is because product demand or capital supply linkages affecting firm growth should affect labor demand from all origins. In particular, we check whether our estimated elasticity of firm labor flows from drought origins is affected by the inclusion of firm fixed effects. We find that this elasticity increases by 50 percent when we control for firm-fixed effects, suggesting that the positive effects of labor market linkages on the level of employment might be partly reduced by negative effects of goods market linkages. This would be the case if firms more connected to a particular origin through migrant networks are also more connected through commercial networks and suffer from a lower demand for their products or lower supply (higher prices) for their inputs.

When we control for both destination municipality and firm fixed effects to absorb the capital and goods market channels, our estimates indicate that a firm in agriculture with average connection to areas highly affected by droughts experience a 7 percent larger flow of workers from such regions when the number of droughts at origin increases by 2.62 { the difference between the average number of droughts in the top quartile and the rest of the distribution { in the 2006-2010 period. This effect is about three times larger than the one observed for firms in manufacturing (2.3 percent), while the effect on firms in services is 1.2 percent.

Warming increases the likelihood of extremely hot days and nights, favours increased atmospheric moisture that may result in more frequent heavy rainfall and snowfall, and leads to evaporation that can exacerbate droughts (National Academies of Sciences, Engineering, and Medicine, 2016).

Temperature increases have been steeper in tropical countries such as Brazil. Figure I use data from the Climatic Research Unit at the University of East Anglia, which shows that the average temperature in Brazil has been steadily increasing since 1920, from 22.5 to 24°C, with an acceleration in the trend since 1980. At the same time, an increase in the frequency and duration of droughts has been documented in Brazil, especially in the 2011-2017 period (Cunha et al., 2019). Many factors contribute to any individual extreme weather event making it challenging to attribute any particular extreme event to human-caused climate change. Still, as climate change makes these events more likely, The index captures deviation in dryness relative to the average observed during the whole 1905-2018 period. A value of SPEI equal to -1 can be interpreted as the di erence between rain and potential evapotranspiration needs being one standard deviation lower than the historical average for a given locality during that period.[4] The gure shows an increase in the incidence of droughts since 2012, con rming the upward trend in reports seen in Figure II. Figure III shows the geographical distribution of SPEI across Brazil in the 2000-2010 period (panel c) and 2011-2018 period (panel d).

To investigate the extent to which reported droughts coincide in terms of timing with dryness measured by the SPEI, we perform an event-study analysis by regressing the SPEI on twelve leads and twelve lags of reported droughts using a monthly panel at the municipality level. More speci cally, we estimate the following equation:

$$SPEI_{jm} = \quad + \sum_{k=\ 12}^{12}$$

data from the population Census. Finally, we track formal worker ows across regions, sectors, and rms using social security data from RAIS.

III.A Agricultural Production

III.A.1 Speci cation

We begin by estimating the e ects of reported droughts and excess dryness as captured by SPEI on agricultural outcomes at the yearly level with the following speci cation:

$$y_{ot} = \ {}_{o} + \ {}_{t} + \ {}_{1} Dryness + \ Controls_{ot} \quad t + u_{ot}; \qquad (2)$$

where o indexes municipalities, and $Dryness$ is either the number of droughts reported in SINPDEC or SPEI. To ease the comparison between the speci cations with reported droughts and SPEI, we henceforth always use the latter multiplied with -1, so that an increase in either measure is associated with higher dryness. We will interchangeably refer to SPEI (1) as \excess dryness".

The vector of controls includes the share of adults living in rural areas in 1991, lludess in either n of droughts in the second period, we find more negative effects and also a significant decrease in the area planted of almost 6 percent when considering the 2011-2018 sample in the final three columns. The losses in harvested area and production value are 8.8 and 13.5 percent, respectively.

In Panel B, we estimate equation (2) using SPEI as a measure of dryness. We find that an increase in excess dryness by one standard deviation (i.e. an increase in the SPEI $\times(-1)$ by 1) decreases the area planted by 1.6 percent and the area harvested by 2.7 percent during 2000-2010. Consistent with the results in Panel A, the effect on the production value is around twice as large as the effect on the harvested area (5.2 percent). During the 2011-2018, the negative impact of dryness is again much stronger for all three outcome variables, with the loss of harvested area being 7 percent and the loss of production value being 7.4 percent.

Overall, these estimates suggest that higher dryness, both when reported and measured using weather data, is associated with sizable output losses in the agricultural sector. This holds true during both periods we consider, with the negative impact of dryness being significantly stronger during the 2010s.

III.B Capital Reallocation

III.B.1 Specification

In this section, we study the impact of climate change on capital reallocation. For this analysis, we use data on bank deposits, loans and assets from the Central Bank of Brazil's ESTBAN dataset, which reports balance sheet information at branch level for all commercial banks operating in the country at the yearly level.

We begin by estimating a yearly regression as the one described in equation (2). We use this specification to study the contemporaneous effects of dryness conditions on local deposits, loans and capital outflows. We define the latter for each municipality as the difference between total deposits and total loans, normalized by assets.

We also investigate the indirect effects on regions linked to those affected by drought events or excess dryness via bank branch networks. To this end, we construct a measure of municipality-level exposure to dryness in connected regions based on Bustos et al. (2020). This measure is constructed in two steps. First, we define the degree of exposure of each bank to drought events or excess dryness based on the geographical structure of its bank branch network as follows:

$$BankExposure_{bt} = \sum_{o \in O_b} \omega_{bo} \; TA_o Dryness_{ot}. \quad (3)$$

The weights ω_{bo} are the share of national deposits of bank b coming from origin municipality o in the baseline year 2000, O_b is the set of origin municipalities in which bank b

where the coe cient on SPEI-12 (1) indicates that a standard deviation increase in excess dryness corresponds to a decline in local deposits of about 0.5 percent. The result

In the remainder of this section, we investigate the long-run effects of droughts and excess dryness on capital outcomes by running the following regression:

$$y_{dr,2000-2010} = \beta_1 Dryness_{dr,2001-2010} + \alpha_r + \gamma X_{dr} + \varepsilon_{dr}, \quad (5)$$

where α_r denotes macro-region fixed effects and X_{dr} is a set of controls for municipality characteristics. These include the share of population living in rural areas, income per capita, literacy rate, population density as well as the changes in soy and maize productivity.[8]

Table IV reports the results using as dependent variables the changes in deposits, loans and capital outflows between 2000 and 2010. We start by discussing the effects on deposits. As shown, we find that areas with higher incidence of droughts or with higher excess dryness over the 2000-2010 decade relative to their historical averages experience a decline in bank deposits, which is however not statistically significant at standard levels.

Next, in column (2), we focus on the long-run effects on lending. Our main result is that areas with higher excess dryness over the 2000-2010 decade experienced a larger and significant decline in loans originated by local banks. This result, coupled with the results presented in Table III, gives new insights on the role of the banking sector in capital reallocation due to climate change. Our findings indicate that, in the short run, the local financial system favors risk sharing in areas affected by climate shocks with the support of connected areas. However, over the long run, the evidence indicates that the financial system redirects credit destined to finance investment outside of areas affected by abnormal climate. In particular, the magnitude of the coefficient in column (2) of Panel B indicates that a municipality whose average excess dryness in the 2000-2010 period increases from the median level to the 90th percentile (an increase of 0.45 in the index) experienced a 13.3 percent decline in lending originated by local bank branches.

The results in column (3) confirm this intuition, showing that in the long run areas experiencing abnormal dryness over the 2000-2010 decade also experienced larger capital outflows. The magnitude of the coefficient indicates that the direct effect of excess dryness for a municipality moving from the median to the 90th percentile of SPEI-12 (β_1) is a 2.4 percentage points increase in capital outflows as a share of assets. In column (3) we also include the indirect effect of being connected with abnormally dry areas via the bank network. As shown, in the long run, regions connected to those directly affected by abnormally dry climate experience larger capital outflows. The magnitude of the coefficient indicates that a movement from the median to the 90th percentile of municipality-level exposure increases capital outflows by about 3.8 percent of assets. Notice that, in the long

[8] We use changes in soy and maize potential yields from Bustos et al. (2016) to

run, connected regions might be negatively a ected by abnormally dry climate at origin due to an overall decline in local capital supply. Such decline in capital can result from an out-migration of workers (which we document below in section III.C), and a general decline in long-run investment opportunities in the region.

III.C Labor Reallocation across Regions and Sectors

III.C.1 Speci cation

As a next step, we turn to Census data to analyze the impact of drought events on the reallocation of labor across regions and sectors. As in section III.B, we aim to capture two types of e ects. First, due to the local impact of exceptionally dry weather on agricultural productivity, which potentially also a ects other sectors through general equilibrium e ects, droughts directly a ect labor. We estimate this *direct e ect* by using the average yearly number of reported local droughts during 2001-2010 or the average excess dryness as regressors.

Second, when a spatial reallocation of factors occurs, those regions that are not directly a ected by dryness but destinations or origins of factors that move might also experience changes in their overall amount of labor. We refer to this mechanism as the *indirect e ect*. To capture this e ect for labor ows, we construct a measure of exposure of municipalities to droughts through migration links. For this, we assume that destinations that received a higher share of migrants (out of all migrants) from certain origins in the past (i.e. before the drought period) are more likely to receive migrants from these origins when droughts occur there than those destinations that had previously received a lower share of migrants from them. Thus, we employ the well-documented network channel, according to which migrants tend to choose destinations that were previously chosen by migrants [illegible] size of the migrant ow from *o* to *d* between 1995 and 2000, and $M_{d;2000}$ the total number of persons that migrated during this period to *d*.

e ects, which are highly correlated due to the spatial clustering of weather shocks, implying that dry areas are more likely to be connected through migration links to other dry areas. Thus, the estimate of the direct population e ect is biased upwards when considering local dryness only, if connected regions are more likely to receive migrants.

In order to quantitatively interpret the direct population e ects implied by these regressions at the decadal level, we compute the population e ect of going from the median to the 90th percentile implied by the coe cient in column (3) as $0.0391 \quad 0.7 = \quad 0.027$. Thus, a municipality at the 90th percentile of reported droughts loses 2.7 percent of its population over ten years relative to a municipality at the median of the distribution (meaning zero reported droughts). A move from the median to the 90th percentile of the SPEI (

that expand their employment when the indirect exposure to droughts via previous migration links increases. Hence, these findings strongly suggest that dry weather shocks lead to a reallocation of labor from affected to not directly affected (but connected) regions through migration of workers primarily in agriculture and non-tradable sectors. Further, in directly affected regions, some released workers are absorbed by an expansion of the manufacturing sector. Figure VI illustrates the results by sector shown in columns (2)-(5) of Panel B using bars that indicate the size of the effects computed with the above described quantification method. Moving from the 50th to the 90th percentile in excess dryness leads to a fall in agricultural employment by almost 11 percent and an increase in manufacturing employment by more than 8 percent. The indirect effect implies that agricultural employment expands by 0.85 percent, while manufacturing employment contracts by 0.53 percent.

Finally, to provide additional evidence on the extent to which internal migration is the driver of labor reallocation across regions, in Table VII we use the above described 2005-

I

Overall, an increase in excess dryness from the median to the 90th percentile implies a decline in the net migration rate of 1.78 percentage points. Thus, around one third of the population decline of 5.7 percent can be explained by the observed migration patterns.

III.D Migrant Selection and Labor Market Outcomes at Destination

III.D.1 Specification

In this section, we turn to the Census micro data in order to document differences in the selection and labor market outcomes of workers that have migrated from another region during the previous five years, depending on whether their origin was affected by dryness. Thus, our aim is to provide descriptive evidence on how outcomes of climate migrants differ from those of "voluntary" migrants and non-migrants in the destination. For this purpose, we use a sample of male workers aged 18 to 64 from the 2010 Census and run the following regression:

$$y_{iod;2010} = \alpha_d + \beta_1 Migrant_{iod} + \beta_2 Migrant_{iod} \times Dryness_{io;2001-2010} + \gamma Age_{iod} + u_{iod}; \tag{7}$$

where o and d are the municipalities of residence in 2005 and in 2010 of individual i, respectively, $Migrant_{iod}$ is a dummy indicating $o \neq d$ and $Dryness_{io;2001-2010}$ is the average number of reported droughts or excess dryness in municipality o between 2001 and 2010. Thus, the base individual in this regression is a non-migrant in municipality of residence d. The vector Age_{iod} includes both age and age squared. As outcomes we consider a dummy indicating whether an individual completed high school, a dummy for being employed and the log of total income.

With the inclusion of destination municipality fixed effects α_d, the interpretation of the coefficients of interest is as follows: β_1 indicates the difference in the outcome between a migrant from a region without droughts or a region with the long-term average SPEI and a worker (of the same age) in the destination municipality, while

III.D.2 Results

Table VIII presents the regression results. The rst three columns show the estimates with destination xed e ects, while the nal three columns show those with origin xed e ects. Note that since around 50 percent of municipalities report zero droughts, the coef- cient $_1$ in Panel A indicates the average relative outcome of migrants from municipalities in the \less dry" half of the distribution. On the other hand, when using the continuous SPEI in Panel B, $_1$ indicates the relative outcome of migrants from municipalities with average weather in terms of dryness.

Looking at the rst column of Panel A, we nd that migrants from non-drought areas are positively selected in terms of education relative to the destination population. However, the more droughts there are reported in a migrant's origin, the lower is the predicted di erence in the probability of having completed high school. While a migrant from a non-drought origin on average has a 4.8 percentage points *higher* probability of being a high school graduate than a non-migrant at the destination, a migrant from a municipality at the 90th percentile of average droughts (0.7 droughts per year) is predicted to have a 7.8 percentage points *lower* probability (0:0483 0:181 0:7).

Also when using the SPEI in Panel B, we nd a signi cant lower probability of completing high school for migrants from dryer origins. To compare the e ects obtained in Panel B with those in Panel A in quantitative terms, we predict rst the average relative outcome of migrants from origins in the \less dry" half of the distribution. The average SPEI (1) in this half is -0.438 and thus the predicted average e ect for migrants from these origins is 0:00132 + (0:438 0:0943) = 0:043. Hence, the di erence in the probability of high school graduation for a migrant from an average \wet" origin is very similar to that found in Panel A. Similarly, we can calculate the di erence for a migrant who comes from a region at the 90th percentile of the SPEI distribution as 0:

xed e ects, we nd that coe cients switch signs in columns (4) and (6). This implies that despite doing worse than other migrants and non-migrants at the destination, those that come from dryer regions have a higher probability of having completed high school and tend to earn more than non-migrants at their *origin*. Especially the income e ect is sizable, with a migrant from a region with 0.7 droughts per year earning on average 48 percent more than a non-migrant that stayed in that region.

Thus, our main conclusion from this exercise is that despite having a higher probability of being employed, climate migrants are negatively selected in terms of education relative to other migrants and non-migrants in their destination region and accordingly earn lower incomes. However, migrants from dryer regions tend to have a higher education level and also fare much better in terms of income relative to those that remained in their origin municipality.

III.E Labor Reallocation at Firm-level

III.E.1 Speci cation

In section III.C

measures of municipality exposure described in section III.C. As a rst step, we construct weights capturing the degree of labor market integration between each municipality in Brazil and a given rm. To compute these weights, we use past migration ows as follows:

$$ {}_{oi(d);t} = L_{i(d);t\ ;o\ !\ d} $$

relationship, we can augment equation (9) with both origin and destination xed e ects.

Estimating equation (9) is computationally intensive as it requires to work with a

Figure VIII reports the results by sector. The first finding is that firms in agriculture tend to be more connected to climate change regions via their network of migrant workers. This finding is robust to using droughts (Panel a) or the excess dryness index (Panel b) to capture exposure to climate change. The magnitudes reported in Panel b indicate that region and a dummy capturing high exposure to climate change of that origin measured by the number of droughts. The point estimates of both β_1 and β_2 are positive and statistically significant. The estimated coefficient β_2 indicates that workers flows to destination firms are relatively larger from regions that experience a larger increase in droughts during the 2006-2010 period.

Even within a given destination municipality, firms more connected to climate change areas via past migrant flows might be more connected to those areas also via trade networks or financial links. If that is the case, then the coefficient β_2 cannot be interpreted as capturing the effect of climate change on firms via labor reallocation. Thus, in column (3), we estimate equation (10) including firm fixed effects. This specification absorbs any firm-level differences in exposure to climate change areas via other channels, such as trade or capital. We find that, when fully accounting for firm-level differences, the estimated coefficient β_2 remains positive and increases in magnitude, which indicates that other firm-level connections with climate change areas — such as trade linkages — tend to have a negative effect on firm growth.

In columns (4)-(6) we split our sample by sector. As shown, the differential increase in worker flows from areas more exposed to climate change is larger for firms in the agricultural sector than for those in the manufacturing and services sector. In addition, as to reporting bias in droughts. Overall, the results are similar, both qualitatively and that labor market frictions have declined in Brazil relative to the previous decade.

IV Concluding Remarks

We study the effects of climate change on labor and capital reallocation across regions, sectors and firms. In particular, we use a measure of unusual dryness in a location defined as its moisture deficit relative to its 100 year average, which is based on local precipitation and temperature data, the SPEI index. We show that this index is a strong predictor for extreme droughts that occurred in Brazil during the last two decades, as reported to the National System of Civil Protection in Brazil (SINPDEC).

We document two main results. In the short run, local economies insure themselves against negative weather shocks via financial integration with other regions. However, in the long run, affected regions experience capital outflows, driven by a reduction in loans, consistent with a permanent decrease in investment opportunities. Second, we find that abnormal dryness affects the structure of both the local economy and the economy of areas connected via migrant networks. Directly affected areas experience a sharp reduction in population and employment, concentrated in agriculture and services. While local manufacturing absorbs part of the displaced workers, these regions experience large out-migration. Regions receiving climate migrants expand employment in agriculture and services, but not in manufacturing. Using social security data, we provide evidence that labor market frictions direct migrants to firms connected to migrants' social networks, which are mostly disconnected from manufacturing firms at destination. This force generates deindustrialization and increases the weight of small firms in the firm size distribution in destination regions.

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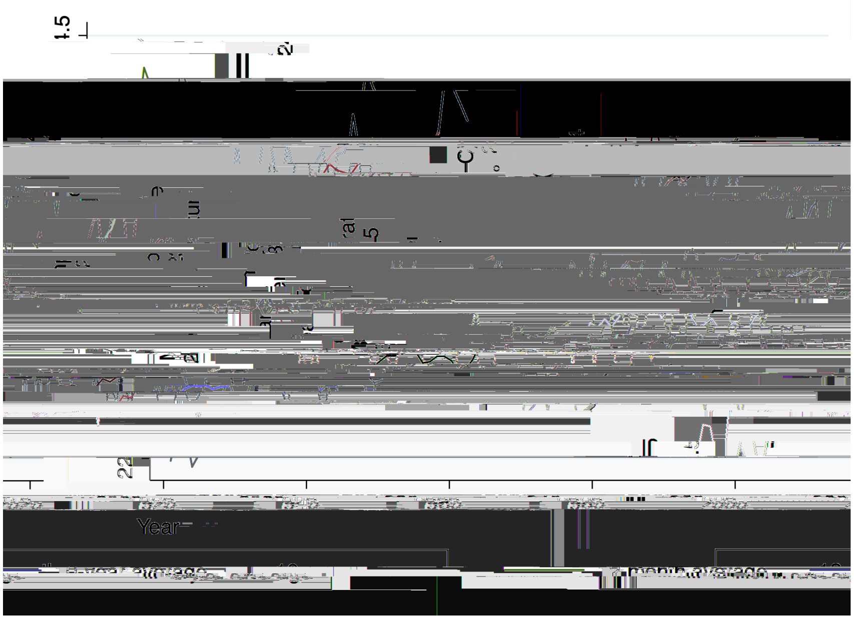
Figures

Figure I: Average temperature in Brazil since 1920

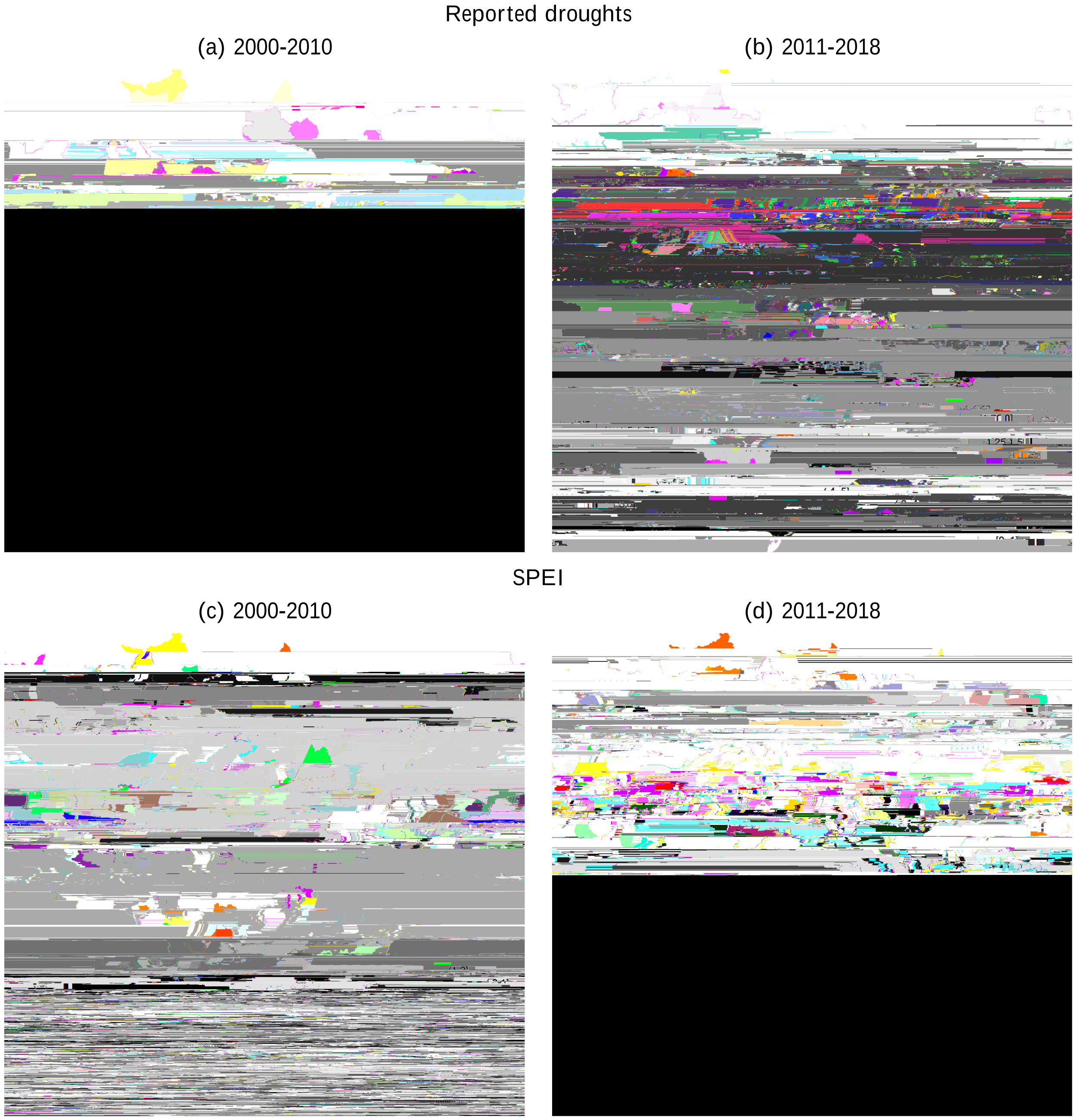


Source: Climatic Research Unit, University of East Anglia, available at `https://lr1.uea.ac.uk/cru/data`.

Figure II: Reported Natural Disasters By Year: 2000-2018

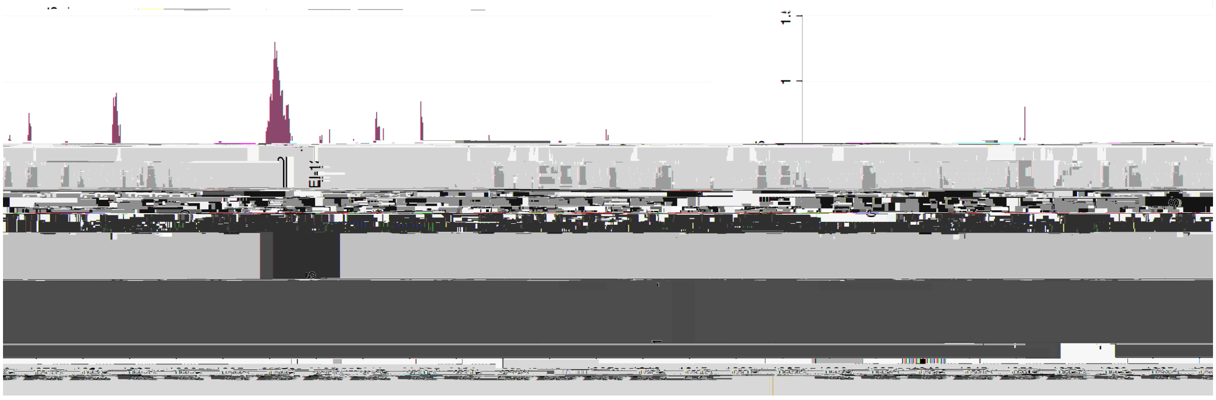
Source: Sistema Nacional de Protecao e Defesa Civil - SINPDEC

Figure III: Geographical distribution of reported droughts and SPEI



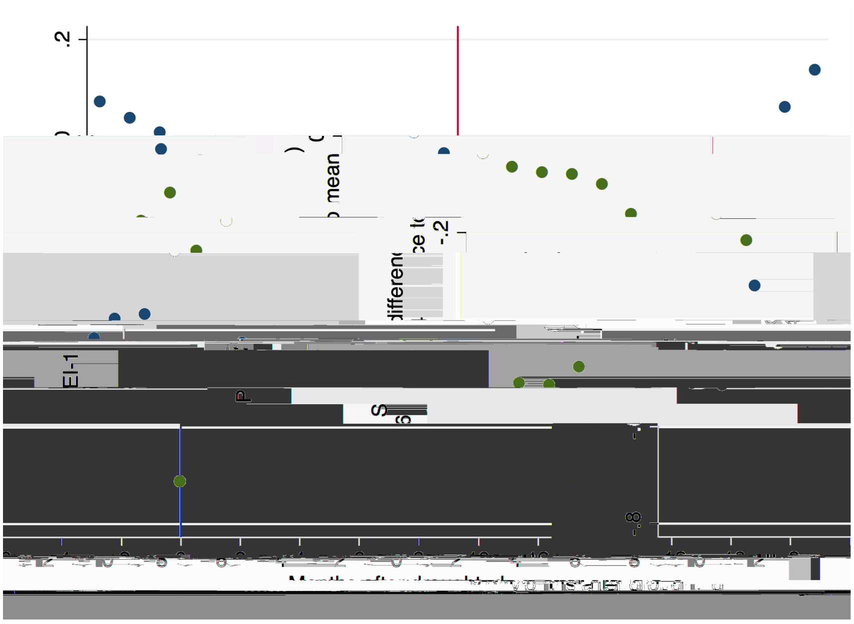
Notes: The upper two maps show the average number of reported droughts per year during the indicated time period. The lower two maps show the average SPEI multiplied by -1 during the indicated time period.

Figure IV: Average monthly SPEI for Brazil since 1902



Source: Vicente-Serrano et al. (2010), available at `https://spei.csic.es/database.html`

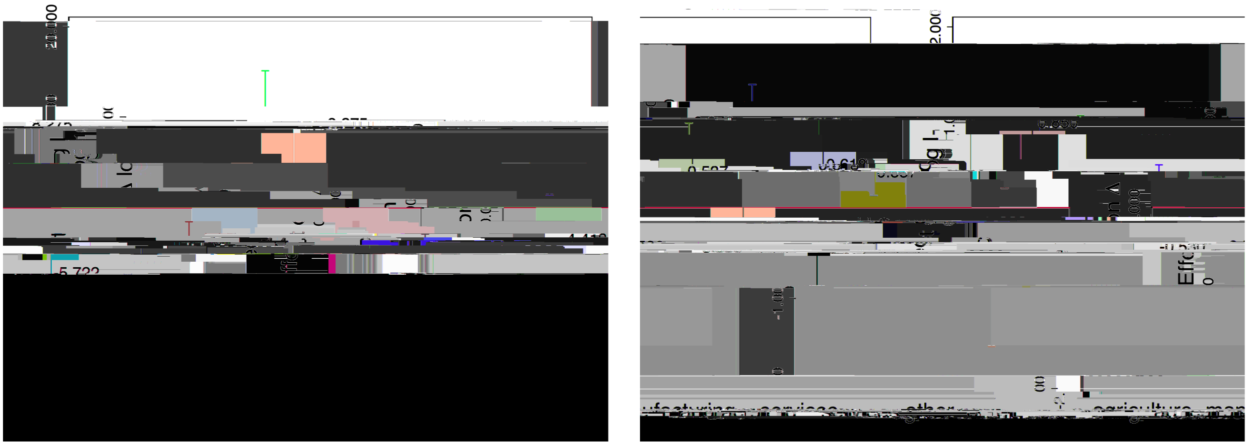
Figure V: SPEI around drought events



Notes: The gures shows the coe cients of a regression of the SPEI on a constant and 12 leads and 12 lags of a dummy indicating a reported drought, using monthly data at the municipality level from 2000 to 2018.

Figure VI: Effects of SPEI on Change in Employment

(a) Direct e ect | (b) Indirect e ect

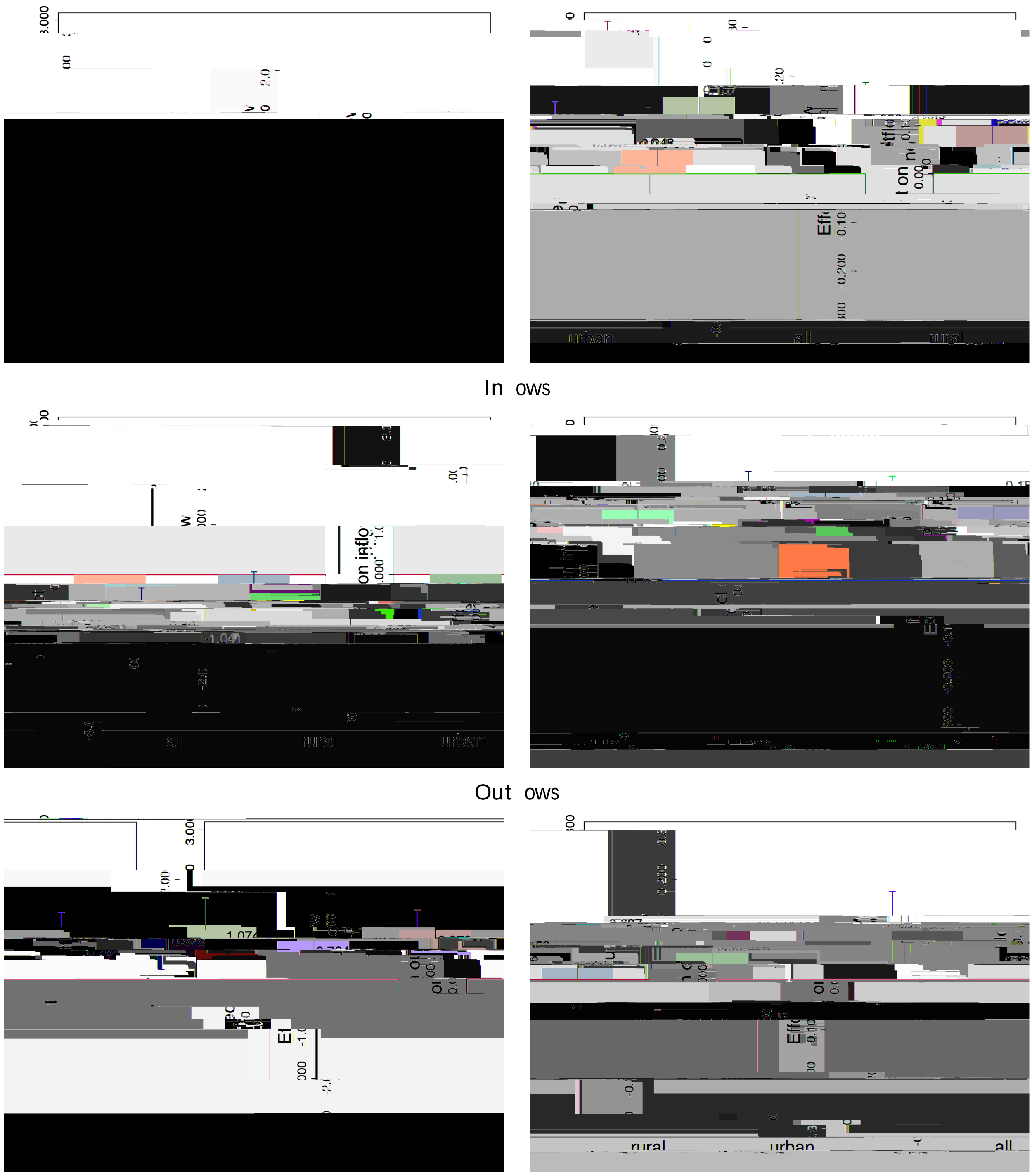


Notes: The plot on the left shows the percentage change in employment predicted in a municipality moving from the median to the 90th percentile of the distribution of the average SPEI (1) during 2001-2010, which implies an increase by 0.44. The plot on the right shows the e ect when 10% of the origins of migrants received during 1995-2000 move from the median to the 90th percentile of the distribution of the average SPEI (1). The predictions are based on the estimates in Panel B of Table VI.

Figure VII: Effects of SPEI on Migration Flows

(a) Direct e ect (b) Indirect e ect

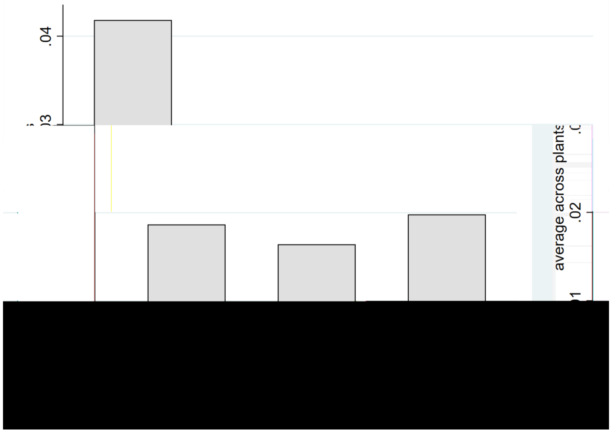
Net ows



Notes: The plots on the left show the percentage point change in the 2005-2010 net-, in- or out-migration rate of a municipality moving from the median to the 90th percentile of the distribution of the average SPEI (1) during 2001-2010, which implies an increase by 0.44. The plots on the right show the e ects when 10% of the origins of migrants received during 1995-2000 move from the median to the 90th percentile of the distribution of the average SPEI (1). The

Figure VIII: Firm Exposure to Climate Shocks via Past Workers' Flows - by Sector

(a) Initial connections to drought areas



(b) Initial connections to dry areas

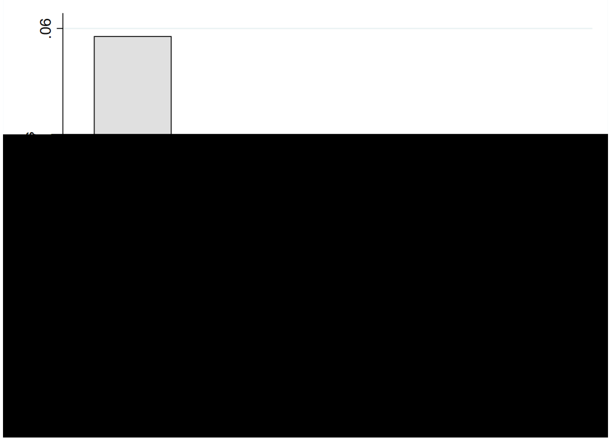
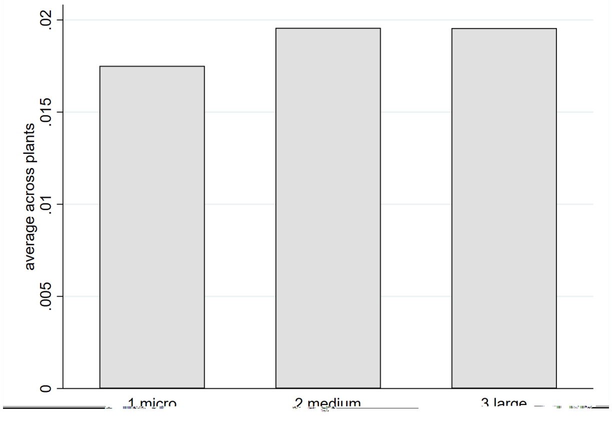


Figure IX: Firm Exposure to Climate Shocks via Past Workers' Flows - by Size

(a) Initial connections to drought areas



(b) Initial connections to dry areas

Tables

Table I: Number of reported droughts and excess dryness index (SPEI-12), 2000-2010

VARIABLES	(1) # droughts	(2) 1(drought > 0)	(3) # droughts	(4) # droughts	(5) # droughts
SPEI-12	-0.0703*** (0.00311)	-0.0601*** (0.00251)			
# months with SPEI-12<=-1			0.0126*** (0.000844)		
# months with SPEI-12<=-1.5				0.0137*** (0.00123)	
# months with SPEI-12<=-2					0.0233*** (0.00209)
Observations	46,794	46,794	46,794	46,794	46,794
R-squared	0.495	0.529	0.492	0.490	0.490
Year and AMC FE	y	y	y	y	y
RuralShare1991 x year FE	y	y	y	y	y
Dist Coast x year FE	y	y	y	y	y
Macro-region x year FE	y	y	y	y	y
First Stage F-stat	513	578	224	124	124

Notes: First stage F-stat is the Kleibergen-Paap rk Wald F statistic. Standard errors are clustered at the AMC level. A control for the number of reported oods is included in all columns.

Table II: Effects of droughts on agricultural outcomes

Panel A: Reported droughts

	(1)	(2)	(3)	(4)	(5)	(6)

Table IV: Capital outcomes, decadal changes 2000-2010

Panel A: Reported droughts

	(1)	(2)	(3)
	log deposits	log loans	K out ows
VARIABLES			
# Droughts	-0.0441	0.0165	-0.0817**
	(0.0403)	(0.0681)	(0.0367)
Indirect exposure to droughts via bank networks			0.114
			(0.0736)
Observations	2,799	2,799	2,795
R-squared	0.168	0.146	0.060
Macro FE	y	y	y
Controls	y	y	y

Panel B: Excess dryness index

	(1)	(2)	(3)
	log deposits	log loans	K out ows
VARIABLES			
SPEI-12 (1)	-0.0534	-0.295***	0.0530*
	(0.0360)	(0.0580)	(0.0314)
Indirect exposure to SPEI-12 (1) via bank networks			2.228***
			(0.347)
Observations	2,799	2,799	2,795
R-squared	0.168	0.155	0.081
Macro FE	y	y	y
Controls	y	y	y

Notes: Robust standard errors are reported in parenthesis. The set of additional controls at the municipality level includes the share of population living in rural areas, log income per capita, literacy rate, population density and changes in soy and maize potential yields.

Table V: Change in Population: 2000-2010

Panel A: Reported droughts

VARIABLES	(1) log Pop all	(2) all	(3) all	(4) rural	(5) urban
# Droughts	-0.0401***	-0.0135*	-0.0391***	-0.0171	-0.0688***
	(0.00629)	(0.00698)	(0.0110)	(0.0140)	(0.0176)
Indirect exposure to droughts					

Table VI: Change in Employment: 2000-2010

Panel A: Reported droughts

VARIABLES	(1) log L all	(2) agriculture	(3) manufacturing	(4) services	(5) other
# Droughts	-0.0414**	-0.0664**	0.0286	-0.0420*	-0.0569**
	(0.0164)	(0.0273)	(0.0533)	(0.0226)	(0.0230)
Indirect exposure to droughts	0.100***	0.188***	-0.0466	0.190***	0.0649
	(0.0294)	(0.0500)	(0.0985)	(0.0405)	(0.0424)
Observations	4,248	4,248	4,241	4,248	4,248
R-squared	0.128	0.058	0.080	0.082	0.043
mean Y	.185	.003	.247	.293	.302
Macro-region FE	y	y	y	y	y
Controls	y	y	y	y	y

Panel B: Excess dryness index

VARIABLES	(1) log L all	(2) agriculture	(3) manufacturing	(4) services	(5) other
SPEI-12 (1)	-0.0885***	-0.247***	0.188**	-0.130***	-0.100***
	(0.0236)	(0.0427)	(0.0794)	(0.0328)	(0.0334)
Indirect exposure to SPEI-12 (1)	0.0894***	0.193***	-0.120	0.122***	0.140***
	(0.0334)	(0.0594)	(0.116)	(0.0466)	(0.0466)
Observations	4,248	4,248	4,241	4,248	4,248

Table VII: Migration Flows between 2005-2010

Panel A: Reported droughts

VARIABLES	(1) Net all	(2) In all	(3) Out all	(4) Net rural	(5) Net urban
# Droughts	-0.0253***	-0.0226***	0.00274	-0.0123**	-0.0406***
	(0.00420)	(0.00288)	(0.00307)	(0.00502)	(0.00747)
Indirect exposure to droughts	0.0186**	0.0125**	-0.00612	0.0210**	0.0284**
	(0.00792)	(0.00571)	(0.00582)	(0.00976)	(0.0139)
Observations	4,248	4,248	4,248	2,128	2,120
R-squared	0.212	0.290	0.166	0.210	0.148
Macro-region FE	y	y	y	y	y
Controls	y	y	y	y	y

Panel B: Excess dryness index

VARIABLES	(1) Net all	(2) In all	(3) Out all	(4) Net rural	(5) Net urban
SPEI-12					

Table IX: Workers' Flows to Firms Exposed to Climate Change, 2006-2010

Panel A: Reported droughts

VARIABLES	(1) $\frac{L_{oi(d)2006\ 2010}}{Lavg_i}$ all	(2) all	(3) all	(4) agri	(5) manuf	(6) services	(7) micro	(8) medium	(9) large
rm connection to origin 1(#droughts> p75)		0.257***	0.388***	0.638***	0.466***	0.226***	0.714***	0.463***	0.315***
		(0.0395)	(0.0527)	(0.0763)	(0.0781)	(0.0686)	(0.0297)	(0.0307)	(0.0646)
rm connection to origin	0.642***	0.397***	0.462***	0.476***	0.406***	0.446***	0.319***	0.418***	0.492***
	(0.0149)	(0.0154)	(0.0144)	(0.0449)	(0.0210)	(0.0171)	(0.00981)	(0.0101)	(0.0177)
Observations	1,415,758	1,415,758	1,415,758	67,756	248,742	983,990	477,882	711,412	223,762
R-squared	0.267	0.393	0.683	0.649	0.673	0.708	0.627	0.647	0.696
mean Y	.13	.13	.13	.13	.13	.13	.13	.13	.13
destination AMC FE	y	y	y	y	y	y	y	y	y
origin FE	y	y	y	y	y	y	y	y	y
rm FE	n	n	y	y	y	y	y	y	y

Panel B: Excess dryness index

VARIABLES	(1) $\frac{L_{oi(d)2006\ 2010}}{Lavg_i}$ all	(2) all	(3) all	(4) agri	(5) manuf	(6) services	(7) micro	(8) medium	(9) large

.13 .13 .13 .13 .13 .13 .13 .13 .13
(n)-4932(n)-4482(y)-4182(y)-43185y y y

Table X: Workers' Flows to Firms Exposed to Climate Change, 2011-2017

Panel A: Reported droughts

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

VARIABJ4888eJ/F32 54 74 001 8422463Td 6.93d [(V)1LJ/F32 503.4 076 54.9.7570.1.738 [(V)1oiJ/F32 523.4 076 54.6.325Td [(Rep09)1J/F32 503.4 076 54.2.878Td [(RepdJ/F32 523