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## **Climate change and firm performance**

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## Abstract

This thesis explores the impact of climate change on firm performance and examines the possible mechanism by which weather shocks influence sales outcomes. Leveraging a comprehensive dataset spanning Brazilian manufacturing firms between 2003 and 2009, coupled with high-resolution weather data, the study analyzes the impact of weather shocks. Employing the identification strategy of location-specific z-scores with the analytical framework advanced by Colmer (2021), the findings underscore the profound effect of weather shocks causing substantial declines in firm sales. Furthermore, the research investigates the distributional impacts of weather fluctuations. A closer examination reveals that the Northern regions of the country bear the brunt of these adversities, experiencing disproportionately greater sales losses compared to their Southern counterparts. In addition, the study delves into the transmission mechanisms of the weather-firm performance nexus. It finds that frequent power outages and inclines in energy costs as drivers of the declines in sales through productivity shocks.

**Keywords:** Climate change, Brasil, Sales, Microdata, Firms.

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## **Resumo**

Esta tese explora o impacto das mudanças climáticas no desempenho das empresas e examina o mecanismo possível pelo qual os choques climáticos influenciam os resultados de vendas. Utilizando um conjunto abrangente de dados que abrange empresas manufatureiras brasileiras entre 2003 e 2009, juntamente com dados meteorológicos de alta resolução, o estudo analisa o impacto dos choques climáticos. Empregando a estratégia de identificação de escores z específicos de localização com o quadro analítico avançado por Colmer (2021), os resultados destacam o efeito profundo dos choques climáticos causando quedas substanciais nas vendas das empresas. Além disso, a pesquisa investiga os impactos distribucionais das flutuações climáticas. Uma análise mais detalhada revela que as regiões Norte do país sofrem mais com essas adversidades, experimentando perdas de vendas desproporcionalmente maiores em comparação com suas contrapartes do Sul. Além disso, o estudo adentra nos mecanismos de transmissão da relação clima-desempenho da empresa. Ele descobre que as frequentes quedas de energia e os aumentos nos custos de energia são impulsionadores das quedas nas vendas por meio de choques de produtividade.

**Palavras-chave:** Mudanças climáticas, Brasil, Vendas, Microdados, Empresas.

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# 1 Introduction

Climate change represents one of the most pressing challenges of the 21st century, with profound implications for economies, societies, and ecosystems worldwide. The increase in global temperatures, shifts in precipitation patterns, and the rise in the frequency and severity of extreme weather events have already begun to impact various sectors, particularly agriculture, water resources, and public health. However, the repercussions of climate change extend far beyond these areas, increasingly affecting industrial and manufacturing sectors in diverse and complex ways.

Despite the extensive studies providing evidence of the negative effects of climate change on agricultural productivity (Reilly and Hohmann, 1993), the impact on manufacturing firms remains less well understood. Custodio et al. (2022) finds that a one-degree temperature change reduces firm sales by 2 percent. The findings from Huppertz (2023) indicate that weather shocks negatively affect firm sales, particularly exporters, leading to a reduction in expenditure on productive capabilities. However, the mechanism by which firms react to the shocks and the regional impacts remain largely unexplored topics. Quantifying these effects and the channels is essential for policy-making. The distributional impacts of weather shocks can exacerbate inequality, and evaluating these effects by region can inform more equitable resource allocation decisions in the future.

The thesis aims to fill a gap by investigating the effects of weather shocks on manufacturing firms in Brazil by using a combination of firm-level surveys, municipal data, and weather data. The analysis suggests that weather shocks have significant impacts on firms in Brazil, with adverse effects observed on sales performance. Furthermore, the analysis uncovers that sales in the Northern regions of the country exhibit more pronounced declines compared to their counterparts in the South.

I then present an estimate following Xiao et al. (2022) of possible mechanisms of transmission of weather shocks. I find that power outages can decrease sales by up to 8.3 percent and that each day of extreme heat further decreases sales by 0.2 percent.

The thesis proceeds as follows, Section 2 provides an in-depth literature review. Section 3 presents the data. Section 4 describes the empirical methodology. Sections 5 and 6 present the evidence of the effects of weather shocks and explore further robustness checks. Section 7 presents the conclusion.

## 2 Literature Review

The thesis builds on the wide literature on climate change. I contribute to three main strands.

The first strand, starting with Schelling (1992) related the impact of climate change on national income. Mendelsohn and Williams (2006), used climate projections to study the distributional effects of climate change, showing a relationship between lower levels of GDP and higher losses caused by climate change. Similarly Cevik and Jalles (2022) find that climate change does not significantly affect within-nation inequality for wealthier countries, instead, for poor ones, the effects are up to seven times more significant and a potential driver for disparity in the future. The studies, however, highlight the importance of future literature to focus on more in-depth country analysis, to better understand the localized effects of climate change. My research addresses a critical gap in the literature by examining the distributional impacts of climate change within a specific country, particularly its effects on manufacturing firms.

The second strand examines the effects of climate change on Brazil. Tebaldi and Beaudin (2016) relate the effects of climate change on GDP growth. The study revealed that weather shocks have varying effects on different regions of the country, with the Northern region suffering the highest losses. Ferreira Filho and Moraes (2015) found similar results focusing on the effects on agricultural firms. I expand the current literature on the country, by focusing on the impacts of climate change at the level of manufacturing firms, finding that weather shocks cause higher sales loss for the North and North East compared to other regions.

A third group of studies focuses on the firm-level effects of weather shocks. Custodio et al. (2022) analyzed for the United States the effect of temperature change on manufacturing firm's sales. The research finds that a one-Celsius degree change in temperature leads to a 2 percent decrease in sales, through a decrease in productivity. Huppertz (2023) examines the effects of weather shocks on sales, finding that weather shocks cause a decline in sales and that firms react to them by adjusting expenditures on productive capabilities. My thesis finds similar results for the effects of weather shocks on sales. I then follow Xiao et al. (2022), where they relate power outages to declines in productivity. I show that weather shocks cause strong and negative effects on the sales of firms driven by the increased amount of power outages and the incline in electricity costs.

In addition, the thesis contributes to the growing literature on spatial models. I used the empirical model proposed by Colmer (2021). The author studied the effects of climate change on prices and yields of crops in India. I find that, even when the model is applied to non-agricultural firms there is a strong presence of positive spatial correlation.

## 3 Data and Descriptive statistics

### 3.1 Data

In this Section, I offer an overview of the data employed in my research. My analysis focuses on non-agricultural Brazilian firms. I focus on Brazil for two reasons. First, the country exhibits significant disparities between regions. Second, its climate varies considerably across different areas. Understanding the magnitude of the effects of climate change on the different regions is especially important for policy-making decisions. The paper draws from four datasets:

1. *Enterprise Survey data* (ES): First, I utilized the Enterprise Survey, a firm-level survey gathered by the World Bank. I used the harmonized Brazil data for the survey between 2003 and 2009. The strength of the dataset is that it contains a wide range of characteristics of the firms. Moreover, the ES has very wide geographic coverage, which is useful for studying the overall implications of climate change.
2. *Open Street Map*: Secondly, Open Street Map was used to geocode the location of the firms in the dataset, to obtain accurate information on their latitude and longitude.<sup>1</sup>
3. *Open Meteo*: I utilized Open Meteo to acquire weather data for the firms in the dataset. By matching the firms' latitude and longitude to the nearest municipality, I was able to obtain daily weather data. I collected data for ten years before the survey, for the temperature and precipitation. Then following the method used by Huppertz (2023) I calculated:

$$\tilde{x}_{it} = \frac{x_{it} - \bar{x}_{it}}{\hat{\sigma}_{it}}$$

Where  $\bar{x}_{it}$  is the mean of the variable for location  $i$  for the last 10 years. This was done for both the mean and the variance to allow the index to capture more information. Then, the z-score was built by taking the means of the  $\tilde{x}$ .<sup>2</sup> The division by the standard deviation is to ensure the interpretability of the results, this does not affect the significance level, and translates one standard deviation movement in the index to a one standard deviation weather shock. Figure 1-2 show a histogram of the resulting indexes.

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<sup>1</sup>For additional data on Open Street Map, please see: <https://tinyurl.com/5xpve2px>

<sup>2</sup>For additional data on Open Meteo, please see: <https://open-meteo.com/en/docs>

4. *Instituto Brasileiro de Geografia e Estatística* (IBGE): From the IBGE I obtained the municipalities gross domestic product, the number of inhabitants and the shapefiles.

## **3.2 Descriptive statistics**

From the initial dataset, I ruled out observations that were missing key variables such as sales or the number of employees. Additionally, observations were dropped when the municipality name could not be geocoded. Finally, I reverse-geocoded the latitude and longitude to avoid the incorrect identification of the locations.

The resulting dataset contains full information about 2717 firms, from 2003 and 2009. The panel contains an identifier, allowing to track firms through time. However, I will treat the dataset as cross-sectional, as there are numerous gaps due to firms not being able to be tracked through time. Table 3 presents the density of firms by State. The firms are divided in size depending on the number of employees, with less than ten being small and more than a hundred being considered large.

Table 1 presents descriptive statistics of the firms. The majority of the firms in the datasets are small to medium-sized manufacturing firms. The average number of employees is 38 and the average sales are around 1.6 million reais. The average percentage of sales from the domestic market is 94, with only a few firms being full exporters. Only 18.7 percent of the firms obtained a quality certification, and among those 50 percent of them are large firms. Almost 45 percent of the firms experience power outages, with an average of 1.2 power outages a month, estimating a loss of 3 percent of sales. Only 14 percent of the firms own a generator, either independent or shared. Lastly, on average firms experience 30 days of extreme heat per year, where extreme heat is defined as temperatures over 32 Celsius degrees.

Table 1: Summary statistics

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
ln Sales	2,717	14.326	2.293	6.908	12.940	15.825	22.134
ln Sales per employee	2,717	10.728	1.784	4.416	9.828	11.718	19.782
Firm size	2,717	2.063	0.607	1	2	2	3
Size of municipality	2,716	2.525	1.410	1	1	4	5
Sector Manufacturing	2,717	0.915	0.279	0	1	1	1
Quality Certification	2,717	0.187	0.390	0	0	0	1
Domestic Sales as percentage of total	2,717	94.030	17.886	0.000	99.000	100.000	100.000
ln Labor cost	2,717	12.590	2.166	5.298	11.489	13.866	20.030
ln Employees	2,717	3.646	1.340	0.000	2.708	4.419	8.896
Manager experience	2,715	14.463	13.008	0.000	1.000	23.000	60.000
ln GDPPC municipalities	2,717	9.651	0.637	7.324	9.275	10.110	11.955
ln Cost of electricity	2,451	9.846	2.275	0.000	8.542	11.184	20.212
ln Investments in new machines	1,767	11.019	2.550	0.000	9.641	12.459	19.120
Power outage	2,717	0.452	0.498	0	0	1	1
Number of power outages	2,717	1.245	4.386	0.000	0.000	1.000	100.000
Percentage of sales loss to power outage	1,133	3.100	8.193	0.000	0.006	3.000	100.000
Generator	2,352	0.143	0.350	0	0	0	1
Extreme days	2,717	30.479	44.780	0	1	33	281
Z Score Temperature	2,717	0.000	1.000	-2.339	-0.531	0.482	7.908
Z Score Precipitation	2,717	0.000	1.000	-2.722	-0.531	0.636	2.446

## 4 Empirical approach

The main aim of the thesis is to estimate the effects of climate change on sales of firms in Brazil. The identification strategy follows the method proposed by Huppertz (2023). In his research, location Z-scores were calculated by using the mean and variance of the temperature during the previous years. The main advantage, compared to using the difference between temperature over the years is that it is easy to comprehend and is able to catch more information about the real change in temperature per location.

I then estimate the regression of the form:

$$Y_{ijt} = \beta_1 X_{ijt} + \beta_2 Z_{ijt} + \delta_j + \epsilon_{ijt} \quad (1)$$

Where  $Y$  is the logarithm of sales for firm  $i$  at location  $j$  at time  $t$ ,  $X$  is a set of firm characteristics including the GDP per capita of the municipality in which the firm is located,  $Z$  is a vector containing the Z scores of the weather variables I collected and  $\delta$  is a vector containing fixed effects.

Estimating these models poses two primary difficulties. The first, concerns the challenge of isolating the effects of weather shocks, as firms with varying levels of productivity might be situated in regions with either warmer or colder climates (Burke and Emerick, 2016). The second challenge, as pointed out by Kelly (2020) is that the error term tends to be correlated across space, leading to inefficient estimates and biased standard errors. To overcome these issues, I combine State fixed effects with the spatial model proposed by Colmer (2021). I assume that errors are correlated across firms located close to each other and that these firms are exposed to similar weather shocks, with a distance of 150 kilometres. This allows for spillovers between proximate firms, ensuring that firms close to each other can influence one another, while firms that are further apart remain segregated and do not affect each other's outcomes. This methodology is equivalent to the GMM model described by Conley (1999). The model thus becomes:

$$Y_{ijt} = W^* Y_{ijt} + \beta_1 X_{ijt} + \beta_2 Z_{ijt} + \delta_j + \epsilon_{ijt} \quad (2)$$

Where the  $W$  matrix is the spatial weighting matrix applied to the dependent variable. The approach chosen to create the spatial weighting matrix is the inverse distance method. The

inverse distance method computes the function  $w_{ij} = f(d_{ij}, \theta)$  with  $f$  as the functional form and  $\theta$  as the vector of parameters. The values in the matrix for observation  $i$  and  $j$  are then:  $d_{ij}^{-1}$ , computed for all the observations within the distance cutoff of 150 kilometres.

To explore different sources of spatial correlation, I also propose the the spatial error model, which has similar properties to the model described beforehand, but assumes that only the errors are affected. The form of the equation is the following:

$$Y_{ijt} = \beta_1 X_{ijt} + \beta_2 Z_{ijt} + \delta_j + W^* \epsilon_{ijt} \quad (3)$$

The objective of equations 1 to 3 is to estimate the effect of weather shocks on sales. The second part of the thesis will try to unveil the mechanism of transmission of shocks to firms, investigating whether they can be considered supply or demand shocks.

In Pankratz et al. (2023) decreases in operating income are caused by increase in costs, "possibly of the costs of electricity due to cooling". I run the following random effect regression to look at the possible causes, using the variables in my dataset:

$$Y_{ijt} = \beta_1 X_{ijt} + \beta_2 Z_{ijt} + \gamma_{ijt} + \epsilon_{ijt} \quad (4)$$

For equation 4, I use two separate outcome variable, the logarithm of energy costs incurred by the firm and whether the firm experienced frequent power outages during the year. On the other hand of the equation the vector  $X$  contains a series of dummies as controls, while  $Z$  is the vector for the weather variables. Among the weather variables other than the  $Z$  score I also consider the number of days with high temperatures, as an alternative weather variable Peillex et al. (2021). Lastly, I estimate, following Xiao et al. (2022) the effect of power outages on firm sales:

$$Y_{ijt} = \beta_1 X_{ijt} + \beta_2 Z_{ijt} + \gamma_{ijt} + \epsilon_{ijt} \quad (5)$$

Where  $Y$  is the logarithm of the sales of the firm,  $X$  is a vector with characteristics of the quality of the firm,  $Z$  is a vector with the key variables and  $\gamma$  is a series of dummy including the state, sector and year.

## 5 Results

### 5.1 Effect of Weather Shocks on the Sales of Firms

In this Section, I present the results of weather shocks on Brazilian firms' sales.

Table 2 shows the outcome of the four different models discussed in the methodology. One standard deviation shock in temperature causes a decrease of 9.3 percent in firm's sales, with the result remaining consistent throughout the models. On the other hand, precipitation shocks cause tiny declines in firms' sales, decreasing sales by only 0.2 percent, with significant results only for the OLS and the spatial error model.

Table 2: Effect of weather variables on Sales.

	(OLS)	(SAR)	(SAR HAC)	(SEM)
	ln Sales	ln Sales	ln Sales	ln Sales
ln GDPPC	0.284 (0.483)	0.284 (0.520)	0.284 (0.520)	0.410 (0.481)
ln GDPPC previous year	-0.163 (0.484)	-0.163 (0.528)	-0.163 (0.528)	-0.288 (0.484)
Z temperature	-0.093** (0.044)	-0.093* (0.050)	-0.093* (0.050)	-0.093* (0.052)
Z precipitation	-0.002* (0.001)	-0.002 (0.002)	-0.002 (0.002)	-0.002* (0.001)
Quality Certification	0.720*** (0.090)	0.720*** (0.090)	0.720*** (0.090)	0.732*** (0.096)
ln Employees	1.008*** (0.025)	1.008*** (0.031)	1.008*** (0.031)	1.009*** (0.030)
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes
Firm Size FE	Yes	Yes	Yes	Yes
<i>N</i>	2677	2677	2677	2677

*p*-values in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

One disadvantage of spatial models is the higher likelihood of the presence of heteroscedastic errors leading to inconsistent results. I computed the modified White's test (White, 1980) in Table 12, where I rejected the null hypothesis of homoskedasticity. Although, after plotting the residuals to the fitted values in Figure 4 it is likely that there is only a presence of mild heteroskedasticity. This explains the small differences in Table 2 between the model with and without robust standard errors. To avoid inconsistent results, I estimated the following regressions using the heteroskedastic and auto-correlation consistent errors in Conley (1999).

Based on the country-level results, I decided to examine the effects at the regional level. This approach provides a larger sample compared to state-level differences and highlights the significant gap between the Northern and Southern regions of the country.

The results in Table 4 have been computed by including the same controls as in Table 2 using the SAR with robust standard errors. Shocks in temperature cause higher loss of sales in the North and North-East Region compared to the South and the Center. Precipitation shocks, on the other hand, show little effect on the different regions, apart from the Central region, heavily affected by these shocks reducing sales by up to 33 percent.

Furthermore, I look at the effects of the shocks by industry. I exclude firms which are part of the service sector and group manufacturing businesses by macro sectors to obtain a wider sample. The results show that only the food and mechanic and automotive industries are significant, with a decrement in sales by 23.4 and 10.4 percent, respectively.

## **5.2 Transmission Mechanism of Weather Shocks**

In this section, I provide a possible explanation of how weather shocks can decrease firm sales. There are two main mechanisms by which weather shocks can decrease firm sales, through reducing demand or by increasing costs and effectively reducing production. I explore the supply shock mechanism by looking at power outages and the electricity cost. Table 7 panel A the outcome of a probit with random effects is presented, with the power outage being the dependent variable. The results show that only precipitation is a significant factor, with a one standard deviation shock increasing the probability of experiencing power outages by 7.5 percent. In panel B, an OLS with random effect is presented, showing that a one standard deviation shock in precipitation increases electricity costs by 3.9 percent, while each day in which the temperature is higher than 32 degrees, increases the cost of electricity by 0.3 percent.

Table 7 present the result of the spatial regression that follows the specification described by Xiao et al. Unfortunately, the cost of electricity cannot be used as an independent variable because price differences between firms make isolating climate change effects challenging. Instead, I include the number of days with extreme weather in the regression. While this does not provide a strict causal effect, it still yields meaningful results. Regressions from 1 to 7

contain additionally the size of the firms, the total value of assets used for production, quality certification and skilled labour. Regression 1 shows that experiencing power outages reduces sales by 8.3 percent. Although, when looking at regressions 2 and 4, the number of power outages per month is a more important metric to explain sale loss, with a decline of sales by 1.6 percent for each power outage. Interestingly, in regressions 3-4 and 7, it is possible to see that owning a generator increases sales, this could be because, in case of a power outage, companies can still have electricity for production. Lastly, similarly to the result shown in table 7, each day with extreme temperature reduces sales by 0.2 percent.

Table 9 presents the impact of power outages across various sectors. Power outages significantly affect the chemical and mechanical and automotive sectors, resulting in sales decreases of 49.3 and 26.7 percent, respectively. On the other hand, the number of days with extreme temperatures mostly affects the textile and food industries. These results can be explained by the fact that more labor-intensive firms, experience increases in the costs of cooling, necessary for the employees to keep on production, while power outages do not pose an obstacle to production, as these firms rely less on machinery. Lastly, Table 8 computes the same regression shown in Table 7 regression 7, by computing the results by region. The results, while in line with the ones shown in table 7, are not significant, except for the South East region, with a similar decline in sales caused by power outages as in Table 7.

## 6 Robustness Checks and Threats to Identification

In this Section, I provide additional robustness checks for the models previously estimated and support their results. First I explore reverse causality in Table 2, between gross domestic product and sales. It could be argued that firms with more sales are located in richer areas, but the opposite can also be true. To test this, I run a regression of the GDP on Sales in Table 11. The results show that there is no positive impact of sales on GDP, it is also possible to see that weather shocks tend to have small impacts, meaning that richer municipalities are either situated in localities less affected by these shocks or that they can mitigate better the damages caused by the events.

After that, I provide a different measure for the effect of weather shocks on firms. Following the robustness checks in Huppertz (2023), I use the sales per employee and the total value of assets employed for production by the firm. The estimates in Table 13 show that even when the dependent variable changes, the effects of climate shocks remain consistent with what is shown in Table 2.

Lastly, I test a different set of weather variables to estimate the effect of climate change on firms' sales. Following Custodio et al. (2022), I compute the change in percentage of temperature and precipitation between years by location:

$$\Delta Temp = \frac{Temp_{jt} - Temp_{jt-1}}{Temp_{jt-1}} \quad (6)$$

$$\Delta Prec = \frac{Prec_{jt} - Prec_{jt-1}}{Prec_{jt-1}} \quad (7)$$

I then regress my variables following the specification in Equation 2. Table 14 presents the results. A one percentage point increase in average temperature decreases sales by 8.4 percent, while a one percentage point increase in average precipitation decreases sales by approximately 0.2 percent. These results are in line with the estimates from Table 2, suggesting that the estimates from the initial findings are reliable and are not influenced by the use of the temperature index.

## 7 Conclusion

In this thesis, I showed the negative effect of weather shocks on sales. Shocks in temperature cause sales loss of 9.3 percent, while precipitation shocks cause lower losses of 0.2 percent. This is in line with Custodio et al. (2022), with evidence that smaller manufacturing firms are more affected by the shocks compared to their larger counterparts. My estimates point out that firms in the Northern part of the country are more affected by temperature shocks compared to Southern regions, with losses of 12.2 and 7.7 percent respectively. On the other hand, precipitation shocks cause high losses in the Centre region, with declines in sales of up to 33 percent.

In my thesis, I also studied the possible transmission mechanism of weather shocks. Power outages and increments in the cost of energy are one of the dimensions I explored. I find that experiencing power outages can cause a decline in sales by approximately 12 percent and that each day of extreme heat can additionally decrease sales by 0.2 percent. Interestingly, firms that own a generator experience a sales increase that can negate the effects of power outages. In addition, results by sector suggest that firms that work in an industry that is relatively more capital-intensive are subject to higher losses caused by power outages.

Although this research provides important insights, it is important to note that the analysis only focused on the firm-side effects. Further research could also analyse whether weather shocks cause a decline in labour productivity, by using a dataset that matches employers to employees. In addition, the thesis provides limited guidance on how weather shocks influence firms. Additional research would examine how the shocks affect firms and how they react over time to them. This will be essential in the future to assess the most effective policy action against climate change.

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## Tables

Table 3: Size of firms by regions

Region	Small	Medium	Large	Total
SP	69	390	142	601
RJ	43	156	34	233
MG	57	206	81	344
SC	55	169	71	295
RS	44	180	77	301
PR	27	157	72	256
DF	4	5	0	9
MT	10	45	12	67
CE	27	97	39	163
PE	13	21	3	37
MA	0	16	6	22
BA	27	104	12	143
AM	15	36	14	65
GO	28	86	22	136
PB	1	37	7	45
Total	420	1,705	592	2,717

Table 4: Effect on Sales by Region

	(ln Sales)
<b>Panel A: Central Region</b>	
Z Temperature	0.048 (0.169)
Z Precipitation	-0.330** (0.139)
N. of observations	212
<b>Panel B: North and North-East Region</b>	
Z Temperature	-0.122*** (0.047)
Z Precipitation	-0.019 (0.040)
N. of observations	465
<b>Panel C: South-East Region</b>	
Z Temperature	-0.077** (0.044)
Z Precipitation	-0.011 (0.047)
N. of observations	1158
<b>Panel D: South Region</b>	
Z Temperature	-0.004 (0.036)
Z Precipitation	-0.014 (0.034)
N. of observations	846

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Note that this includes also the regressors from Table 2.

Table 5: Effect on Sales by Industry

	(1) ln Sales
<b>Panel A: Textiles</b>	
Z Temperature	-0.126 (0.078)
Z Precipitation	-0.056 (0.079)
N. of observations	959
<b>Panel B: Food</b>	
Z Temperature	-0.234* (0.127)
Z Precipitation	0.049 (0.121)
N. of observations	211
<b>Panel B: Chemical</b>	
Z Temperature	-0.155 (0.226)
Z Precipitation	-0.078 (0.277)
N. of observations	169
<b>Panel D: Mechanic and Automotive</b>	
Z Temperature	-0.104* (0.065)
Z Precipitation	-0.0374 (.070)
<i>N</i>	935

Standard Errors in Parenthesis

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 6: RE Regression of Power outage and Energy cost on weather variables

	(1)	(2)	(3)
<b>Panel A: Power Outages</b>			
Z Precipitation	0.075** (0.035)		
Extreme Heat (days)		-0.001 (0.001)	
Z Temperature			-0.081 (0.062)
N. of observations	2716	2716	2716
<b>Panel B: Electricity Cost</b>			
Z Precipitation	0.039** (0.016)		
Extreme Heat (days)		0.003*** (0.001)	
Z Temperature			0.035 (0.046)
R-squared	0.308	0.309	0.306
N. of observations	2450	2450	2450
F-statistic	332.076	333.370	328.730

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Note: Both regression include control dummies.

Table 7: Effect of Power outages and days of extreme heat on Sales

Dep.var: ln Sales	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Production Assets	0.156*** (0.017)	0.155*** (0.017)	0.150*** (0.017)	0.150*** (0.017)	0.156*** (0.020)	0.156*** (0.019)	0.150*** (0.019)
Quality Certification	0.748*** (0.093)	0.747*** (0.093)	0.707*** (0.092)	0.706*** (0.093)	0.805*** (0.099)	0.800*** (0.099)	0.755*** (0.097)
Skilled labor	0.274*** (0.043)	0.272*** (0.043)	0.247*** (0.043)	0.246*** (0.043)	0.281*** (0.044)	0.282*** (0.044)	0.254*** (0.044)
Size location	0.043 (0.034)	0.041 (0.034)	0.036 (0.034)	0.034 (0.034)	0.041 (0.036)	0.041 (0.035)	0.035 (0.035)
Firm Size	1.254*** (0.099)	1.260*** (0.098)	1.191*** (0.097)	1.197*** (0.096)	1.267*** (0.097)	1.265*** (0.097)	1.204*** (0.094)
Power Outage	-0.083* (0.062)	-0.048 (0.066)	-0.098* (0.049)	-0.054 (0.064)		-0.106 (0.071)	-0.119* (0.070)
Extreme heat (Days)					-0.002* (0.001)	-0.002* (0.001)	-0.002** (0.001)
Number of outages monthly		-0.016** (0.008)		-0.016** (0.007)			
Shared Generator			0.623*** (0.112)	0.622*** (0.112)			0.635*** (0.115)
State Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.989	0.989	0.990	0.990	0.989	0.989	0.989
N. of observations	2190	2190	2190	2190	2190	2190	2190

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 8: Regression Results Power Outages and Extreme Weather by Region

	(1)	(2)	(3)	(4)
	North & North East	Center	South	South East
Production Assets	0.232*** (0.030)	0.124* (0.069)	0.119*** (0.025)	0.184*** (0.031)
Quality Certification	0.848*** (0.196)	0.665 (0.499)	0.923*** (0.155)	0.672*** (0.153)
Skilled Labor	0.272*** (0.075)	0.344*** (0.115)	0.306*** (0.062)	0.232*** (0.051)
Extreme Heat (days)	-0.002 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.004 (0.003)
Power Outage	-0.087 (0.159)	-0.105 (0.251)	-0.189 (0.124)	-0.037 (0.104)
Number of outages monthly	-0.030 (0.024)	-0.016 (0.019)	-0.022** (0.010)	-0.003 (0.035)
Firm Size	1.124*** (0.238)	0.877*** (0.218)	1.491*** (0.182)	1.093*** (0.114)
Year Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.991	0.986	0.986	0.993
N. of observations	341	170	967	713

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 9: Effect of Power Outages by Sector

	(1) ln Sales
<b>Panel A: Textile</b>	
Extreme Heat (days)	-0.002* (0.001)
Power Outage	-0.019 (0.116)
Shared Generator	1.083*** (0.168)
N. of observations	885
<b>Panel B: Food</b>	
Extreme Heat (days)	-0.003* (0.002)
Power Outage	-0.009 (0.237)
Shared Generator	0.380 (0.262)
N. of observations	189
<b>Panel C: Chemical</b>	
Extreme Heat (days)	-0.004 (0.003)
Power Outage	-0.496* (0.305)
Shared Generator	0.354 (0.524)
N. of observations	155
<b>Panel D: Mechanical and Automotive</b>	
Extreme Heat (days)	-0.004*** (0.001)
Power Outage	-0.267** (0.109)
Shared Generator	0.446** (0.182)
<i>N</i>	871

Standard errors in parentheses

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Table 10: Moran Test for spatial autocorrelation.

	(1)
	Moran test
Chisq	10.40
Prob>Chisq	0.0014***

Under the H0: Error terms are i.i.d.

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 11: Reverse Causality regression

	(1)
	ln GDPPC
Ln GDPPC lag	0.991*** (0.003)
Ln Sales	0.000 (0.001)
Z Temperature	-0.004** (0.002)
Z Precipitation	-0.005*** (0.002)
Quality Certification	0.002 (0.004)
Ln Employees	-0.002 (0.001)
R-squared	0.990
N. of observations	2676
F	7385.375

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 12: Auxiliary Regression of Modified White test

	(1) Predicted Errors
Fitted Values ln Sales	-0.822*** (0.210)
Fitted Values ln Sales <sup>2</sup>	0.028*** (0.007)
Constant	5.977*** (1.543)
R-squared	0.0057
N. of observations	2675

Standard errors in parentheses

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Table 13: Robustness Check

	(1) ln Sales per Employee	(2) ln Production Assets
Z Score Temperature	-0.091* (0.048)	-0.157* (0.093)
Z Score Precipitation	-0.007* (0.004)	-0.004* (0.002)
State Fixed effects	Yes	Yes
Year Fixed effects	Yes	Yes
Sector Fixed Effects	Yes	Yes
R-squared	0.980	0.922
N. of observations	2675	2267

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Please Note that the dependent variables in Table 2 are included

Table 14: Robustness Check with different measures of climate change

	(1)
	ln Sales
Average temperature change	-0.0840* (-1.73)
Average precipitations change	-0.00141 (-0.52)
State Fixed effects	Yes
Year Fixed effects	Yes
Sector Fixed Effects	Yes
<i>N</i>	2642

*t* statistics in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

# Figures

Figure 1: Temperature Index.

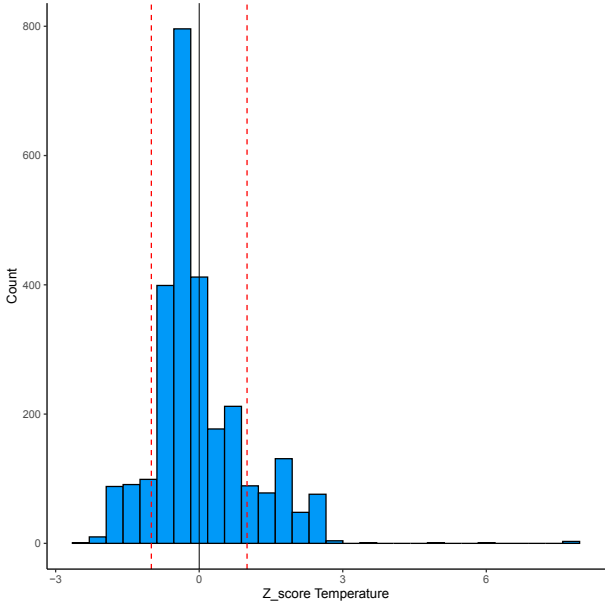


Figure 2: Precipitation Index.

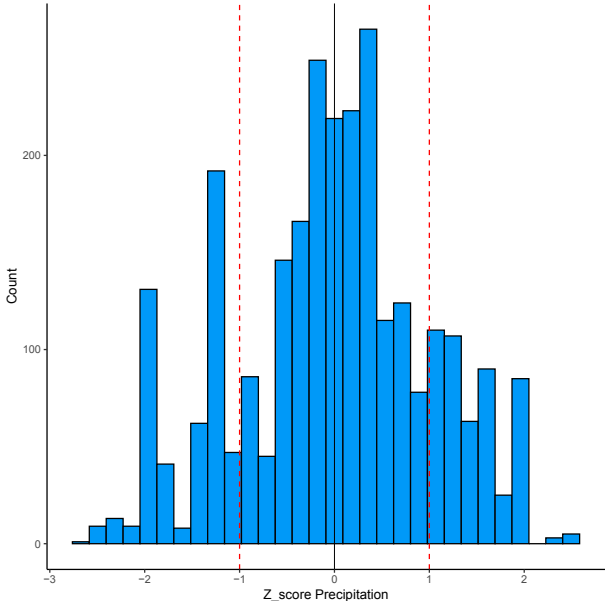
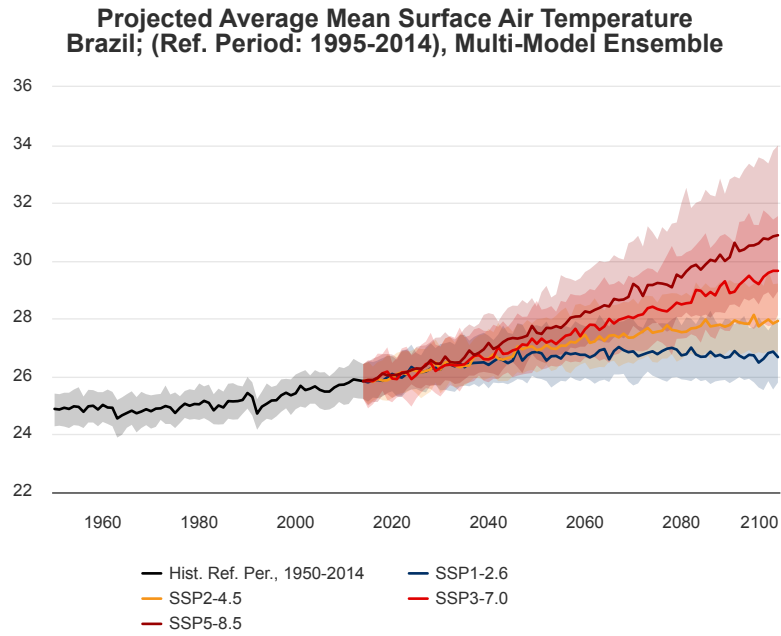


Figure 3: Average mean temperature projections in Brasil up to 2100.



Source: World Bank climate change knowledge portal.

Figure 4: Scatterplot of Fitted values to estimated residuals.

