Assessing the Labor Market Impacts on Firms of an Industrial Rock Salt Mining Disaster: The Case of the City of Maceió, Brazil *

Carlos Rafael Ferreira Góes † Raul da Mota Silveira Neto ‡

Mary Arends-Kuenning § Geoffrey J. D. Hewings ¶

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Abstract

This paper investigates the labor market consequences of a major industrial disaster in Maceió, Brazil, caused by decades of rock salt extraction by a petrochemical company. Using rich administrative data and a difference-in-differences strategy, we estimate the effects of the disaster on firms in evacuation-designated areas. Our results reveal sharp and persistent employment losses among affected firms, with employment declining by nearly 21% within three years and business closure rates rising significantly—particularly in the service sector. These findings underscore the unequal burden of disaster shocks and the limited reach of existing safety nets. The study contributes to the literature on urban resilience and disaster economics by highlighting how slow-onset industrial crises can produce deep and uneven labor market disruptions, with important implications for social protection in urban settings.

Keywords: Disaster, Employment, Business Closure, Labor-income, Labor Market

JEL Codes: O18, R11

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†PhD Candidate at PIMES/UFPE - Federal University of Pernambuco, Av. Prof. Moraes Rego, 1235 - Cidade Universitária, Recife, Pernambuco 50670-901 Brazil

‡Professor at PIMES/UFPE - Federal University of Pernambuco, Av. Prof. Moraes Rego, 1235 - Cidade Universitária, Recife, Pernambuco 50670-901 Brazil, CNPq Research Productivity Fellow

§Associate Professor in the Department of Agricultural and Consumer Economics - University of Illinois at Urbana-Champaign, 408 Mumford Hall, MC-710 1301 W. Gregory Drive Urbana, IL 61801

¶Director Emeritus at University of Illinois Urbana-Champaign, IGPA 1007 W Nevada Urbana, IL 61801

1 Introduction

While the economic literature on disasters has primarily centered on natural events—such as floods, hurricanes, and droughts—far less is known about the impacts of industrial disasters, particularly those unfolding in densely populated urban areas (CRED, 2022). In contrast to natural shocks, which are largely driven by climatic or environmental forces, industrial disasters often stem from corporate malfeasance, regulatory oversight failures, or long-term structural degradation. These events may develop gradually, yet yield profound and irreversible consequences.

This paper leverages a major urban disaster in Maceió, in Brazil's Northeast, to examine the labor market impacts in areas affected by the failed rock salt extraction by a petrochemical company. In particular, we aim to provide a causal investigation into the labor market consequences of the disaster in Maceió City, focusing on firms in affected areas. Understanding these effects is critical, as urban disasters of this scale and origin pose significant risks to local economies, which are often overlooked in disaster response strategies. Given the increasing frequency of disasters due not just human intervention but also related to climate change, this analysis is particularly relevant for informing both policy and economic resilience planning.

This study draws on a comprehensive administrative dataset: the *Relação Anual de Informações Sociais* (RAIS), an annual employer–employee matched database containing detailed information on establishments and their workers. We use RAIS data covering all formal-sector firms operating in the municipality of Maceió from 2014 to 2022.

To the best of our knowledge, this study is the first to evaluate the labor market impacts of Brazil's largest industrial urban disaster using a causal inference approach. By analyzing this distinctive case, we contribute to the literature on urban vulnerability and the labor market effects of man-made disasters, emphasizing how slow-onset crises can undermine economic stability long before their physical manifestations become visible.

Our results reveal substantial and persistent economic consequences of the disaster for firms in the affected areas. We find that businesses located in evacuation zones experienced a sharp and prolonged decline in employment, with the number of employees falling by nearly 21% within three years of the shock. This employment contraction was accompanied by a significant rise in the probability of business closures, while wages and payroll remained largely

unchanged—suggesting that firms attempted to absorb the shock by reducing headcount before ultimately shutting down. These findings underscore the broad and uneven impact of the disaster, showing that firms faced significant economic setbacks, particularly in the services, manufacturing, and retail trade sectors.

This paper builds on a growing literature that examines the economic consequences of disasters—both natural and man-made. While several studies have assessed the labor market impacts of floods, earthquakes, and hurricanes in developed and developing countries, the evidence remains mixed and context-dependent. For instance, studies of major natural disasters such as Hurricane Katrina in the U.S. or the 1993 Midwest floods suggest limited or short-lived economic disruption, with rapid rebounds in employment and income levels (Xiao, 2011; Deryugina, Kawano, and Levitt, 2018). In contrast, evidence from Brazil points to more persistent effects. Lima and Barbosa (2019) and Alves, Andrade Lima, and Emanuel (2022) document meaningful declines in employment and output following floods and landslides, particularly in less diversified local economies. However, most of this literature focuses on rural or mid-sized municipalities, leaving a critical gap regarding disaster effects in major urban centers.

The remainder of the paper is organized as follows. In the section 2, I present the background of the disaster. In section 3, I describe the empirical strategies, and in section 4, I address the data and variables. Finally, in section 5, I exhibit the results, while in section 6, I present the robustness checks and heterogeneity analysis. Finally, in section 7, I display the concluding remarks.

2 Background: Characteristics of the Industrial Disaster in Maceió City

Between February and March 2018, the Civil Defense of Maceió was called to investigate a crack approximately 280 meters long in the Pinheiro neighborhood, along with other cracks in properties in the area that appeared after heavy rains and a seismic tremor with a magnitude of 2.4 on the Richter scale, as shown in Figure 1. After confirming the extent of the damage, officials collected evidence and consulted with geologists and geotechnical engineers to conduct a comprehensive assessment of the situation (Justiça CNJ, 2021).

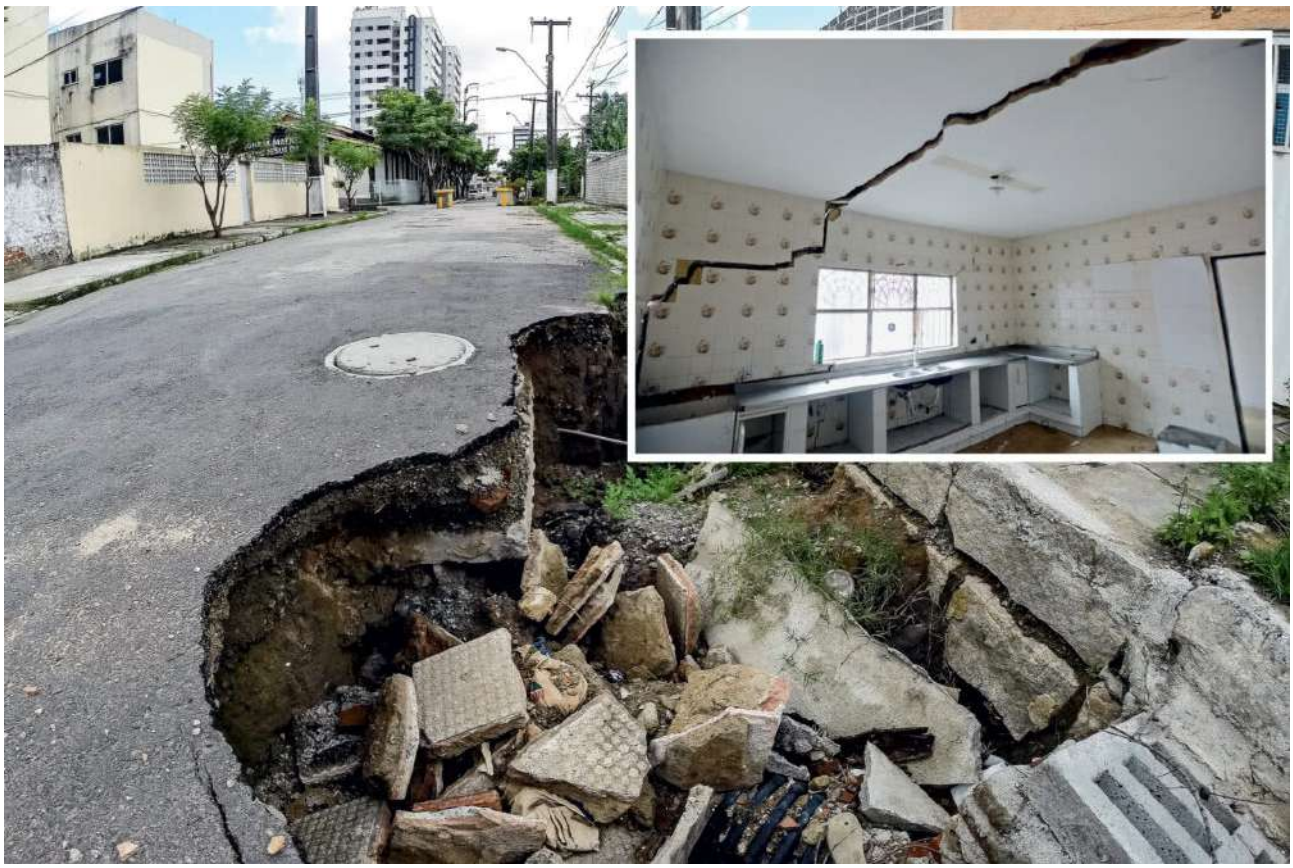


Figure 1: Damages on properties and streets
Source: Gazeweb.

In June 2018, as a precautionary measure, the Brazilian Geological Service (CPRM) advocated for the evacuation of the affected area and the establishment of a designated protected zone due to commenced an inquiry into the occurrence and ascertained a destabilization of formations stemming from rock salt, inducing the movement of subterranean salt, termed halo kinesis. This phenomenon precipitated land subsidence, fissures in the soil, and structural implications for buildings in the vicinity.

Subsequently, in December 2018, in light of the escalating severity of the cracks, the Municipality of Maceió formally declared a state of emergency in the Pinheiro neighborhood, a proclamation published in the Official Gazette of the Municipality. Following the Federal Government's recognition of this state of emergency, hundreds of families received social housing assistance, coupled with advisories to evacuate their residences.

In a collaborative effort, in April 2019, the Municipality of Maceió and the mining company Braskem executed a Work Plan outlining the initiatives the company would undertake in the affected region, implementing measures to mitigate the impact of precipitation on roads and properties affected by the structural instabilities. As the fractures in buildings and public

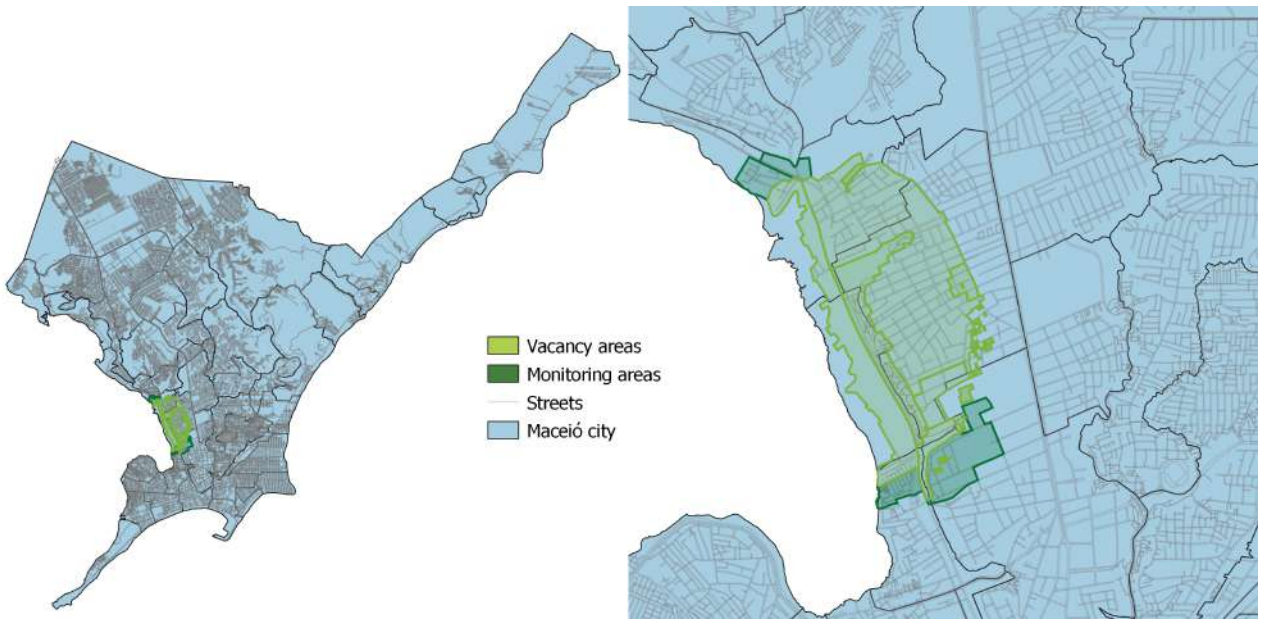


Figure 2: Vacancy and Monitoring Areas Affected by the Disaster
Notes: Elaboration by the Author. Database from Civil Defense of Maceió City.

thoroughfares intensified, in May 2019, the municipality of Maceió declared a state of public calamity encompassing areas in the Pinheiro, Mutange and Bebedouro and Bom Parto neighborhoods.

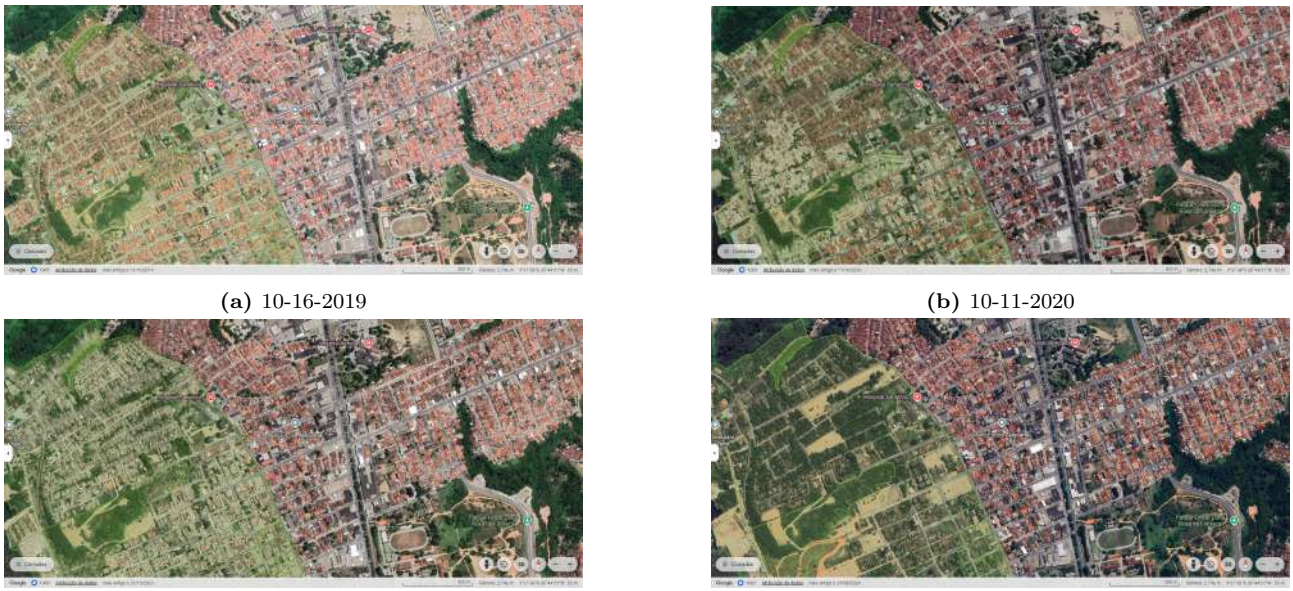
Then, the evacuation was staggered implemented by Civil Defense of the city assessed and determined new vacancy areas (Braskem, 2021). In December 2019, the official process of evacuations started, accompanied by the establishment of the Financial Compensation and Relocation Support Program (*Programa de Compensação Financeira e Apoio – PCF*). The program was designed to proactively relocate residents and expedite the compensation process. It successfully met its objectives and, as of the conclusion of 2022, has achieved a relocation rate exceeding 98% for families residing in areas deemed at risk (Braskem, 2022).

The Figure 2 displays the geographical layout of Maceió City, outlining the areas impacted by the disaster as demarcated by the Civil Defense. The light green area represents the vacancy areas while the dark green areas represents the monitoring areas. By the way, the properties in the vacancy areas were determined in Braskem's Financial Compensation and Relocation Support Program (PCF) by the Federal Court while in the monitoring areas the inclusion in the PCF is optional. However, if individuals do not decide to migrate they must access to a Material Damage Repair Program, caused by the devaluation of the properties (MPF, 2023).

The neighborhoods of Bebedouro, Pinheiro, Bom Parto, Mutange, and a portion of Farol have been designated as high-risk areas, subject to vacancy and monitoring protocols. Addition-

ally, among the five census tracts with the highest average number of residents per household, three are within the designated risk zone. In total, the area designated as vacant spans approximately 6.5 km^2, constituting 5.6% of Maceió's total urban area according to the 2010 Census. The mandatory relocation affected an estimated 53,000 individuals, amounting to 5.5% of the city's total population (Censo, 2010).

Figure 3 shows satellite images from Google Earth of a portion of the displaced area in Pinheiro, the most affected neighborhood, over time. Image (a) shows the area prior to the displacement plan. One year later, in October 2020, the visual effects of the evacuation measures on property damage are evident. The progression of abandonment is further observed in images (c) and (d). While damage has increased over time, it appears primarily contained within the evacuation boundaries, although surrounding areas have also been impacted by the disaster.



(a) 10-16-2019

(b) 10-11-2020

(c) 10-25-2021

(d) 09-03-2024

Figure 3: Effects of the Evacuation on Properties

Source: Google Earth

3 Empirical Strategy

We employ a two-way fixed effects (TWFE) framework to estimate the causal impact of the disaster on firm-level labor market outcomes. In this approach, unit and time fixed effects accounts for both unit-specific (but time-invariant) and time-specific (but unit-invariant)

unobserved confounders (Imai and Kim, 2021). The firm-level analysis examines changes in employment, wages, payroll, and firm survival, providing a comprehensive view of business resilience in the aftermath of the disaster.

Our specification does not face issues related to staggered treatment timing, as treatment effects are not expected to vary over time. We assume a one-time disaster shock, given that the evacuation process, although unfolding over several months, occurred within the same year. As a result, there is no time-varying treatment effect heterogeneity that would compromise the validity of the TWFE estimator (De Chaisemartin and d'Haultfoeuille, 2020; Goodman-Bacon, 2021).

We estimate dynamic treatment effects using an event-study specification within a two-way fixed effects (TWFE) framework. This allows us to trace the impact of displacement caused by the disaster over time:

$$log(y)_{it} = \mu_i + \lambda_t + \sum_{k=-L}^{-2} \tau^k Disaster_{it}^k + \sum_{k=1}^{K} \tau^k Disaster_{it}^k + \epsilon_{it} \tag{1}$$

where $\log(y)it$ denotes the labor market outcome for firm i in year t; $Disasterit^k$ is an indicator equal to 1 if unit i is k periods away from the disaster (negative k indicates leads, positive k indicates lags), and 0 otherwise; μ_i captures unit fixed effects; λ_t captures year fixed effects; and ϵ_{it} is the error term. The coefficients of interest, τ^k, capture the average effect of being k periods from the onset of the disaster. For $k < 0$, these are referred to as "pre-trend" coefficients and serve as placebo tests for the parallel trends assumption. A lack of significant effects prior to treatment strengthens the credibility of the causal interpretation (Butts and Gardner, 2021).

While the event-study framework outlined above enables us to estimate dynamic treatment effects over time, the implementation of this strategy faces important limitations, particularly in the firm-level analysis. One key constraint is the lack of granular information on potential confounders such as firms' financial health or credit access. More critically, the identification strategy could be compromised if the location choices of firms—especially those near the time of the disaster—were themselves influenced by the anticipated risk of the disaster.

To mitigate these concerns, we impose a sample restriction that enhances the plausibility of the identifying assumptions. Specifically, we exclude firms that first appear in the data shortly before the disaster. There are two main motivations for this exclusion. First, younger

firms are more likely to exit the market due to business volatility unrelated to the disaster. Including such firms could introduce noise and bias our estimates by conflating disaster effects with high baseline exit risks. Second, and more importantly, firms established shortly before the disaster may have located themselves in treated or untreated regions based on expectations or early signals of the forthcoming disaster. In such cases, firm location would be endogenous to the treatment, undermining the causal interpretation of our estimates.

To address these issues, we restrict the sample to firms that were already operating in 2014, the initial year of our panel. This ensures that all firms in both treated and control regions had been established for at least five years prior to the disaster, which occurred in 2019. By focusing on this subset of well-established firms, we reduce the likelihood that firm entry or location decisions were driven by anticipatory behavior or selection into treatment status. This restriction reinforces the interpretation of the disaster as an exogenous shock to the firms in our sample and improves the internal validity of our design.

By applying these sample restrictions and conducting a series of robustness checks, we enhance the credibility of our empirical strategy and bolster the causal interpretation of the estimated effects on firm-level labor market outcomes in the aftermath of the disaster.

4 Data and Variables

This paper draws a rich administrative dataset. The source is the *Relação Anual de Informações Sociais* (RAIS), an annual employer-employee matched dataset which provides detailed information on establishments and their employees, including number of active employees, dates of firms closure and opening, type of activity, firm size, sector, sub-sector, ZIP code, legal nature, address, firm ID, and if firms attend worker food program information, wages, payroll, and tax advantages. Our sample spans the years 2014 to 2022 and includes all formal sector firms operating in the municipality of Maceió.

To define treatment status, we spatially merge both datasets with georeferenced shapefiles obtained from the Civil Defense of Maceió, which outline the official boundaries of the vacancy areas and adjacent monitoring zones affected by the disaster. Treated units are defined as firms located within the vacancy areas at the time the local government declared a state of public calamity. Control units, in contrast, consist of firms situated at least 3 kilometers away from

these designated risk zones, ensuring they remained unaffected by the disaster's direct impacts. This spatial identification strategy enhances the precision of our exposure classification and allows for a credible comparison between treated and untreated units over time.

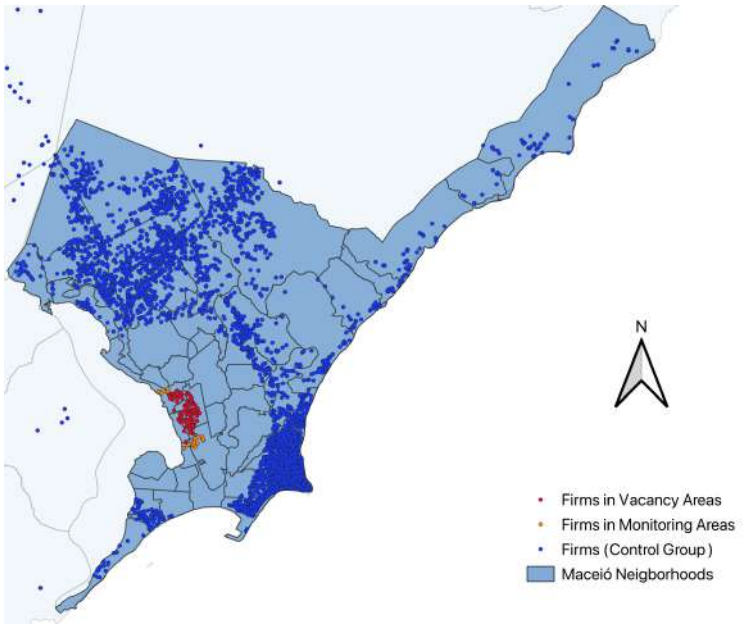


Figure 4: Firms Localization and Definition of the Treated and Control
Elaboration by the Author. Database from RAIS and Database from Civil Defense of Maceió City.

Figure 4 provides a visual representation of the spatial distribution of treated and control units used in our analysis. It depicts the geographic location of firms: red dots represent firms situated within the officially designated evacuation zones and thus classified as treated; orange dots correspond to firms located in the adjacent monitoring zones (used for a robustness exercise); and blue dots indicate firms in the control group, located at least 3 kilometers away from the boundaries of the evacuation areas.

The choice of a 3-kilometer threshold aims to ensure a clean separation between treated and control units by minimizing potential spillover effects. Firms and households located within the same neighborhood—or even in adjacent neighborhoods—may share access to similar infrastructure, public services, and transportation networks, and thus may still be indirectly exposed to the consequences of the disaster. By excluding such areas from the control group, we enhance the credibility of our identification strategy. To assess the robustness of this spatial buffer, we conduct sensitivity analyses using alternative distance thresholds, confirming that our results are not driven by this specific choice. Nonetheless, the 3-kilometer cutoff provides a conservative and substantively meaningful boundary to reduce the likelihood of contamination between treated and control areas.

Table 1: Summary Statistics by Treatment Group

Variable	Unaffected	Affected
Firm Characteristics		
Employment	11.89	12.55
Establishment Size	2.18	1.82
Operating Years	23.80	19.75
Average Wage	0.15	0.14
Share in Manufacturing	0.07	0.04
Share in Services	0.93	0.95
Share in Retail Trade	0.33	0.34
Total Firms	63,873	1,206

Table 1 presents summary statistics for firm characteristics, disaggregated by treatment status. This descriptive analysis provides a general overview of the sample and helps contextualize the magnitudes of the variables under study. Overall, the comparison reveals no substantial differences between treated and untreated units. Firm characteristics such as employment size, operating years, and closure rates are remarkably similar across groups. While exact balance is not required for identification in a difference-in-differences framework, which relies instead on the parallel trends assumption, the close resemblance in baseline characteristics supports the comparability of the treatment and control groups.

5 Results - Estimated Impacts on Firms

We begin our analysis by examining the estimated effects of the disaster on firms located in areas designated for evacuation. We estimate the effects for several labor market outcomes. Table 2 presents the estimated effects by year of displacement of the estimation of Equation1 for the following outcomes: log of the number of employees, business closure dummy, log of the average wage, and log of the payroll. For each dependent variable, we provide specifications that consider firm fixed effect, time fixed effects, and neighborhood-specific trends. In doing so, we control for individual and time-invariant non-observables, and the neighborhood specific trends is useful to capture non-observables at the neighborhood level that vary linearly over time and can affect firms outcomes.

We begin by estimating the effects of the disaster on firms located in areas designated for evacuation, focusing on labor market outcomes. Table 2 reports the results from Equation 1

for the following dependent variables: log of the number of employees, business closure dummy, log of average wage, and log of payroll. All specifications include firm fixed effects, year fixed effects, and neighborhood-specific linear trends. This approach controls for time-invariant firm characteristics and common temporal shocks, while capturing neighborhood-level unobserved factors that vary linearly over time and potentially affect firm outcomes.

We find that firms located in areas designated for evacuation in Maceió experienced a persistent and significant reduction in employment following the disaster (column (1)). In the first year of displacement (2019), treated firms registered a 12.8% decline in their number of employees. This negative effect grows over time, reaching a reduction of 20.9% by the third year, with some recovery in the fourth year, though employment remains significantly below the pre-disaster level. In contrast, we observe no evidence of significant wage reductions (column (3)) or payroll changes (column (4)) in the years immediately following the shock, suggesting that employment losses were not driven by wage adjustments. Instead, we observe a 10% of increase in the probability of business closure in the second year after the disaster (2020), which rises to over 12% by the third year (2021), as shown in column (2). These results suggest that firms initially responded to the disaster by adjusting employment levels, attempting to remain operational despite the shock. However, by the second year, this strategy appears to have been insufficient, as evidenced by the subsequent increase in business closures. This pattern is consistent with the nature of the disaster, which did not represent a typical demand-side shock. Rather than experiencing a decline in demand, firms faced a structural disruption that eventually led some to shut down operations altogether.

In terms of magnitude, when compared to studies evaluating the labor market effects of disasters in developed countries, the results from Maceió's Disaster reveal significantly larger and more persistent impacts. In our most comprehensive specification, the number of employees in affected firms dropped by approximately 12.8% in the first year after displacement, reaching a peak decline of 20.9% in the third year. These effects are considerably stronger than those reported by Meltzer et al. (2020) and Okubo and Strobl (2021), who find limited or statistically weak employment effects following Hurricane Sandy in the U.S. and the Ise Bay Typhoon in Japan, respectively. Similarly, Tanaka (2015), studying the 1995 Kobe earthquake, documents a more modest reduction in employment, with a 2.8% drop in the year of the event and 3.8%

Table 2: Estimated Effects of Maceió's Disaster on Firms.

	Employees	Closure	Wage	Payroll
	(1)	(2)	(3)	(4)
1st year Displacement	-0.1282***	0.0161	0.0160	-0.0404
	(0.0312)	(0.0190)	(0.0205)	(0.0579)
2nd year Displacement	-0.1431***	0.0998***	0.0593	-0.0728
	(0.0389)	(0.0285)	(0.0365)	(0.1046)
3rd year Displacement	-0.2091***	0.1226***	0.0467	-0.1926*
	(0.0467)	(0.0314)	(0.0394)	(0.1014)
4th year Displacement	-0.1781***	0.1134***	-0.0398	-0.1185
	(0.0401)	(0.0289)	(0.0423)	(0.1755)
Establishment FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Neighborhood Trend	Yes	Yes	Yes	Yes
Observations	65,079	65,079	37,785	37,785
No. of Firms	13,936	13,936	8,891	8,891
Adjusted R^2	0.841	0.462	0.874	0.915

Notes: This table presents the estimates of equation (1) using the following outcomes: log (employment level + 1), dummy for business closure, log(average wage), and log(payroll). We report the two-way clustered standard errors (at the neighborhood and year level) in parenthesis. *** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.1$.

after four years. Indaco et al. (2020) report a 3% decline in employment for businesses affected by Hurricane Sandy, while Leiter et al. (2009) even observe a positive employment effect for firms hit by floods in Europe.

In Brazil, the negative employment effects we document are also substantially larger than those found in previous studies assessing the labor market impacts of disasters. For instance, Lima and Barbosa (2019) examines the 2011 landslides in Rio de Janeiro, Brazil and they found a relatively modest and gradual decline in employment, whereas our results show a reduction nearly seven times greater in the first year alone. This sharp contrast underscores the severity of the disaster in Maceió and its substantial disruption to local economic activity. Moreover, while the Rio de Janeiro event did not significantly affect business closures, our findings reveal a notable increase in the likelihood of firms shutting down, further highlighting the broader and more damaging consequences of this displacement shock in a developing country context. Taken together, these comparisons underscore the disproportionate vulnerability of firms in developing country contexts, where institutional support and economic resilience tend to be weaker.

To assess the plausibility of the parallel trends assumption and investigate potential anticipatory effects, we estimate an event-study specification as outlined in 1. Figure 5 presents the dynamic effects of displacement on firm-level outcomes. Importantly, the coefficients associated with the pre-disaster periods (i.e., for years prior to 2019) are statistically indistinguishable from zero across all outcomes. This pattern indicates that, before the onset of the shock, firms located in evacuation-designated areas exhibited no differential trends compared to firms in the control group. The absence of pre-trends alleviates concerns that the effects presented in Table 2 are driven by pre-existing differences or selection into treatment.

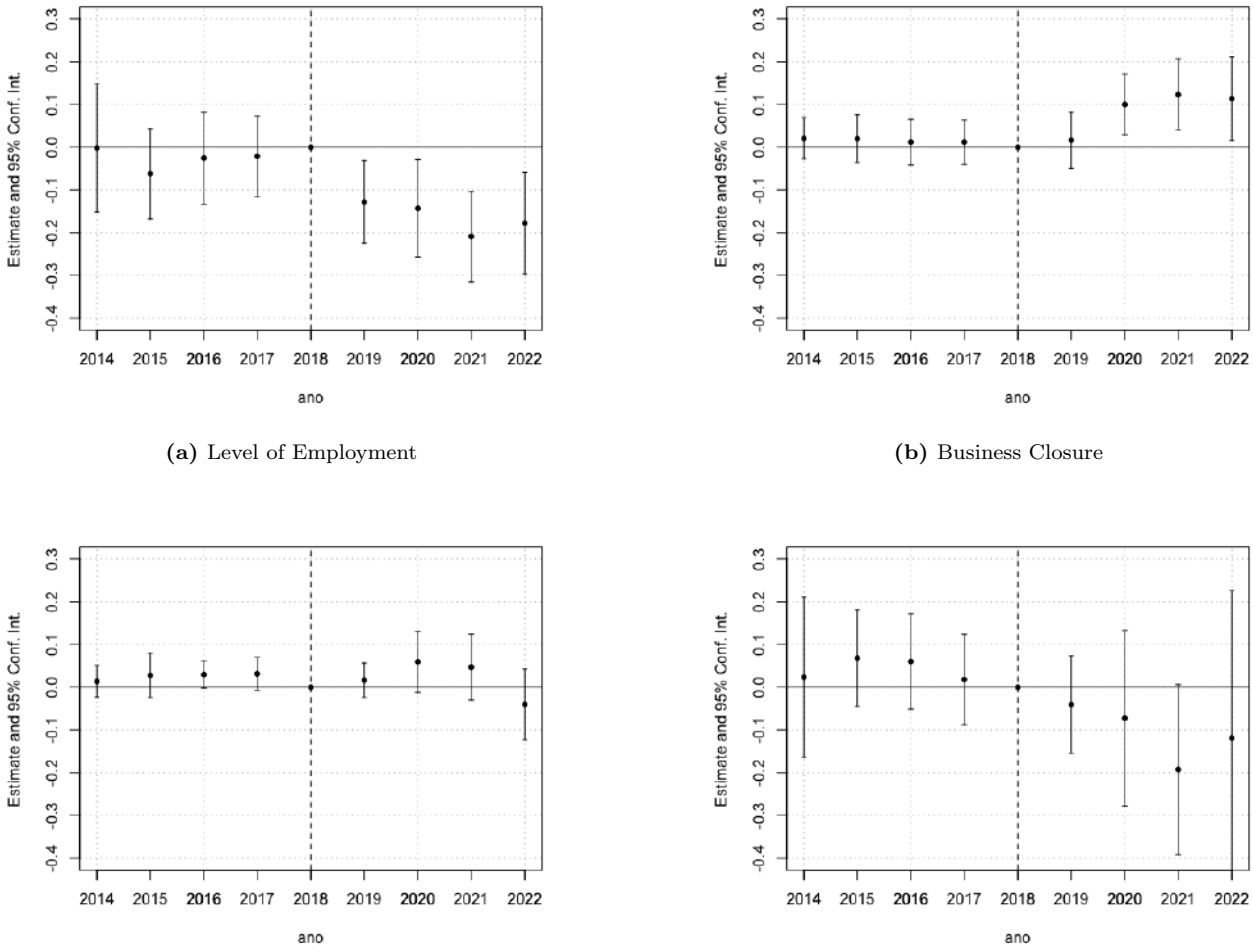
Instead, we observe clear and statistically significant effects beginning in the year of the displacement (2019) and persisting thereafter, particularly for employment and business closure. These dynamic results reinforce the interpretation that the labor market impacts are causally attributable to the disaster.

The validity of our results is supported not only by the fulfillment of the parallel trends assumption, but also by the construction of our sample, which includes only firms that were already operating in 2014. While we do not observe firms' financial constraints directly, this restriction ensures that we are not capturing the behavior of new entrants (who are typically more vulnerable to adverse shocks such as disasters). More importantly, this design choice helps rule out endogenous sorting, as all firms in the sample had established their location prior to the disaster and thus could not have chosen their location in response to the risk of displacement.

6 Robustness Checks and Heterogeneity Analysis

6.1 Falsification Test Using Near-Border Firms as Treated

As a robustness check, we conduct a falsification test by re-estimating our event-study specification, this time treating as "affected" those firms located just outside the official vacancy areas—specifically, within 200 meters of the boundary. The goal of this exercise is to verify whether firms close to, but not within, the evacuated zones exhibit labor market dynamics similar to the treated group. If they do not, this would strengthen the case that the observed effects are indeed driven by the displacement itself, rather than by broader spatial trends or



(a) Level of Employment

(b) Business Closure

(c) Average Wage

(d) Payroll

Figure 5: Event Study - Estimated Effect of Maceió's Disaster on Firms.

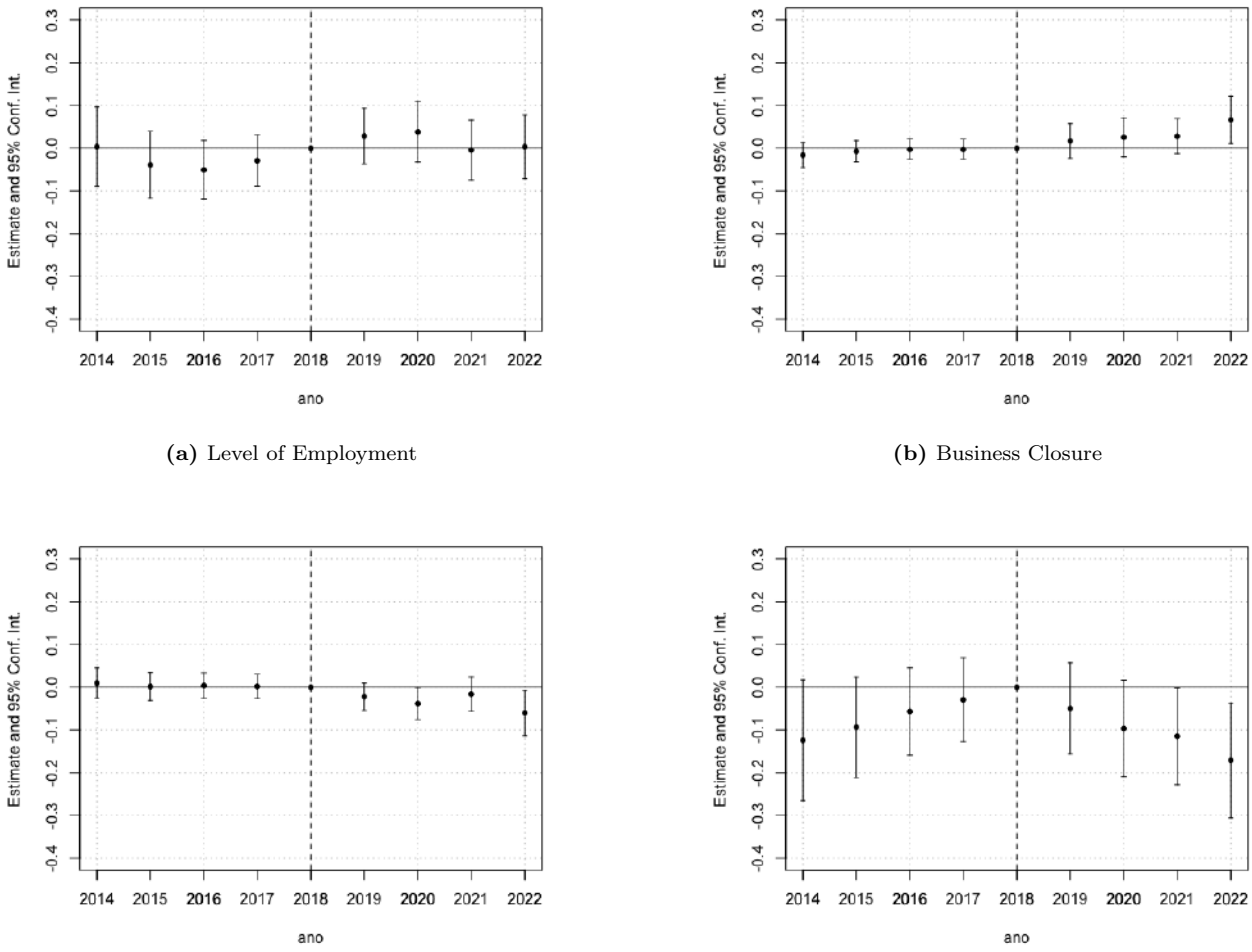
Notes: These event-study plots display the estimated effects relative to the baseline year of 2018, which serves as the reference period. The first year of the shock is 2019. The estimates are derived from a two-way fixed effects model that controls for firm fixed effects and year fixed effects. All figures show 95 percent confidence intervals. We report the two-way clustered standard errors (at the neighborhood and year level).

other unobserved factors.

Figure 6 presents the dynamic effects of this alternative specification across four outcomes: level of employment, business closure, average wage, and payroll. Crucially, the results indicate that the two outcomes which previously exhibited strong effects—employment levels and firm closures—now show no statistically significant impacts when we treat near-border firms as affected. This suggests that firms located immediately outside the vacancy areas did not experience the same disruptions as those within, reinforcing the validity of our original treatment assignment.

The absence of meaningful effects in this placebo group provides further evidence that

the labor market impacts documented earlier are not driven by general economic conditions in the broader vicinity, but rather by the direct consequences of displacement. This robustness test thus supports the causal interpretation of our baseline findings.



(a) Level of Employment

(b) Business Closure

(c) Average Wage

(d) Payroll

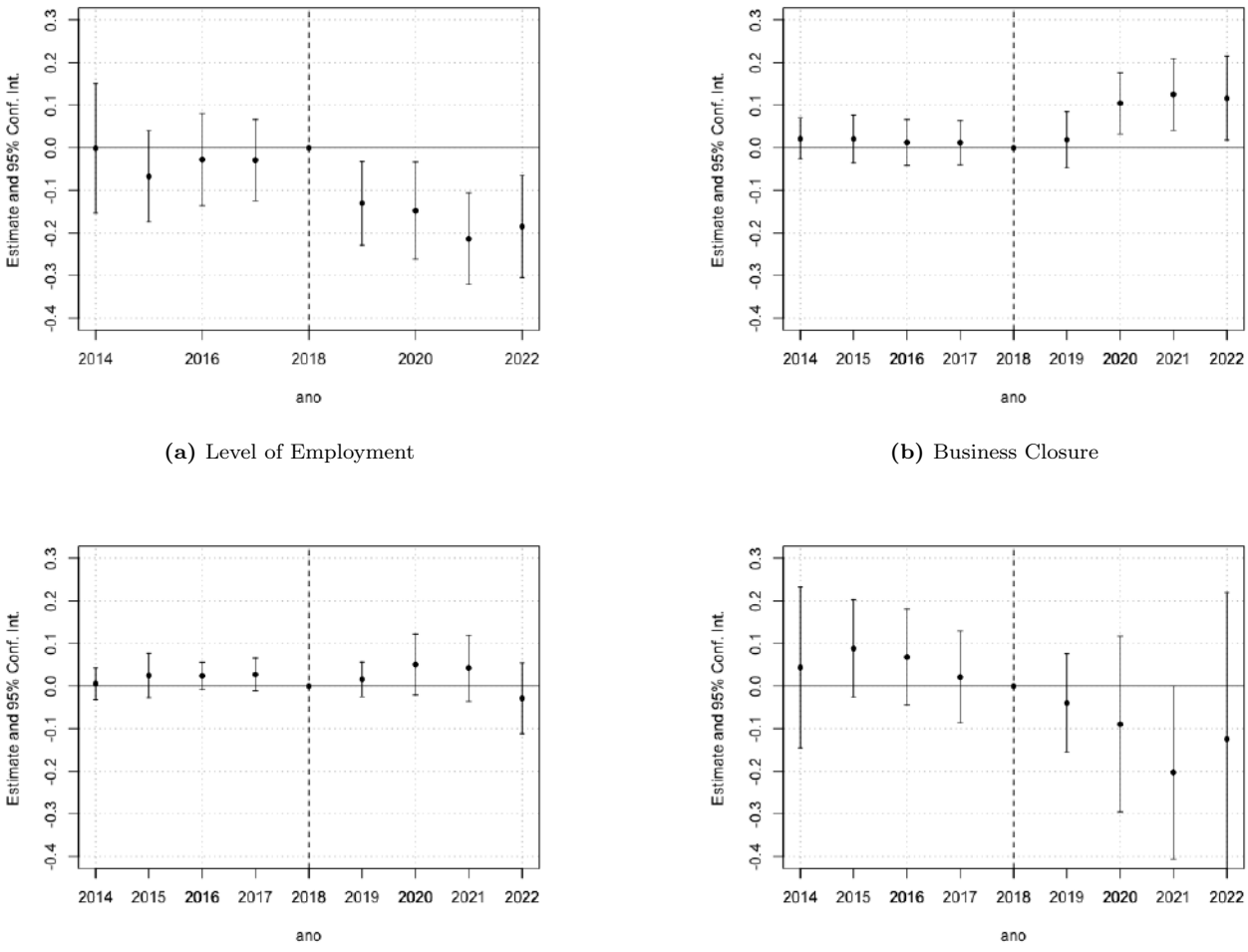
Figure 6: Robustness Check - Estimated Effect of Maceió's Disaster on Near-Border Firms.

Notes: These event-study plots display the estimated effects relative to the baseline year of 2018, which serves as the reference period. The first year of the shock is 2019. The estimates are derived from a two-way fixed effects model that controls for firm fixed effects and year fixed effects. All figures show 95 percent confidence intervals. We report the two-way clustered standard errors (at the neighborhood and year level).

6.2 Sensitivity Analysis

To assess the robustness of our findings to alternative control group definitions, we conduct a sensitivity analysis using a different distance threshold to define the control group. Specifically, in this specification, control firms are located 4 kilometers beyond the boundary

of the vacancy areas, rather than the baseline 3-kilometer threshold.



(a) Level of Employment

(b) Business Closure

(c) Average Wage

(d) Payroll

Figure 7: Robustness Check: Varying Distance Thresholds for Control Group

Notes: These event-study plots display the estimated effects relative to the baseline year of 2018, which serves as the reference period. The first year of the shock is 2019. The estimates are derived from a two-way fixed effects model that controls for firm fixed effects and year fixed effects. All figures show 95 percent confidence intervals. We report the two-way clustered standard errors (at the neighborhood and year level). Firms in the control group are located 4 km beyond the boundary of the vacancy areas.

Figure 7 presents the dynamic effects of the disaster on employment, business closure, average wage, and payroll using this alternative control group. The results remain consistent with our baseline estimates, both in direction and statistical significance. Notably, the negative effects on employment and the increased probability of business closure persist, while no significant changes are observed for average wages or payroll.

These findings suggest that the estimated effects are not sensitive to the specific definition of the control group, reinforcing the credibility of our identification strategy. Additional robustness checks using various control group distances and sample restrictions are provided,

all of which confirm the main results and further strengthen our conclusions.

6.3 Heterogeneity Analysis

Table 3 reports the estimated effects of the disaster on labor market outcomes across distinct economic sectors. The results highlight notable sectoral differences in the intensity and persistence of the shock. Overall, the manufacturing sector appears to be among the most affected, with large, statistically significant declines across employment, wages, and total labor payments. Notably, the negative impact on formal employment is the most pronounced among the sectors, with significant declines beginning in 2020, the year in which the evacuation mandate was widespread implemented. These findings suggest that the disaster disproportionately disrupted manufacturing firms, likely due to their greater reliance on physical infrastructure and the displacement costs. As such, the results show the heightened vulnerability of capital-intensive and space-dependent industries to large-scale urban dislocations.

Likewise, the manufacturing sector exhibits a lagged response in business closures. Although early post-disaster years show limited statistical significance, the probability of closure increases markedly, by 44%, in 2022. The combination of rising closure rates and persistent reductions in employment levels lead to a substantial decline in overall payroll among manufacturing firms. Finally, average wages also display delayed adverse effects, decreasing by approximately 29% in 2021 and 21% in 2022, reinforcing the conclusion that the sector faced persistent economic strain in the aftermath of the disaster.

For the services sector, the negative effects on employment levels are more immediate and consistently statistically significant over time. This pattern is consistent with the expectation that the services sector is particularly sensitive to localized shocks, as it is closely tied to local demand. Similarly, the probability of business closure rises significantly beginning in 2020, with an estimated increase of approximately 10%. By contrast, we do not observe consistent or statistically significant effects on average wages or payroll in this sector.

Finally, in the retail trade sector, employment losses appear with a delay, reaching approximately 30% and becoming statistically significant only in 2021 and 2022. The effects on business closures are comparatively weaker and generally not statistically significant, a pattern that also holds for payroll outcomes. On the other, no significant effects are observed on average

Table 3: Estimated Effects on Labor Outcomes by Sector

Sector	Year	Employees	Closure	Wage	Payroll
Manufacturing	2019	-0.4579	0.0649	0.0171	-0.0904
		(0.3684)	(0.1878)	(0.0816)	(0.1682)
	2020	-0.7143**	0.2285	-0.2163*	-0.4735
		(0.3035)	(0.1917)	(0.1249)	(0.3047)
	2021	-0.7217**	0.1455	-0.2909***	-1.480***
		(0.3025)	(0.1916)	(0.0633)	(0.1576)
	2022	-0.6659**	0.4414**	-0.2092***	-0.7054***
		(0.3236)	(0.1980)	(0.0643)	(0.1604)
Services	2019	-0.1266**	0.0175	0.0188	-0.0315
		(0.0515)	(0.0317)	(0.0217)	(0.0617)
	2020	-0.1317**	0.1002***	0.0748*	-0.0423
		(0.0634)	(0.0345)	(0.0399)	(0.1102)
	2021	-0.2003***	0.1287***	0.0655	-0.1427
		(0.0591)	(0.0435)	(0.0430)	(0.1063)
	2022	-0.1684***	0.1089**	-0.0232	-0.0660
		(0.0626)	(0.0495)	(0.0449)	(0.1970)
Retail Trade	2019	-0.1318	-0.0092	0.0111	-0.0546
		(0.0998)	(0.0493)	(0.0259)	(0.0928)
	2020	-0.1714	0.0695	0.0593	-0.2687
		(0.1094)	(0.0539)	(0.0594)	(0.1719)
	2021	-0.2973**	0.1307*	-0.0156	-0.3750*
		(0.1313)	(0.0726)	(0.0466)	(0.2194)
	2022	-0.2759**	0.0708	-0.1542	-0.0814
		(0.1217)	(0.0754)	(0.0974)	(0.2021)

Notes: This table reports the estimated effects from Equation (1) for three sectors: manufacturing, services, and retail trade. The dependent variables include: log(employment level + 1), a dummy for business closure, log(average wage), and log(payroll). Each cell shows the estimated coefficient, with two-way clustered standard errors (at the neighborhood and year level) in parentheses directly below. All regressions include firm and year fixed effects. Significance levels are denoted as follows: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

wages.

Importantly, these results highlight that the economic impact of the disaster was not evenly distributed across sectors. Manufacturing firms appear to be particularly vulnerable, likely due to higher fixed costs and limited flexibility in relocating or adjusting operations.

Due to data limitations, we are unable to estimate the effects on the agricultural sector, as the disaster primarily affected urban areas, where agricultural activities are scarce or absent.

7 Concluding remarks

This paper provides a comprehensive analysis of the labor market consequences of a major industrial disaster in Maceió, Brazil, triggered by decades of rock salt extraction by the petrochemical company Braskem. Leveraging rich administrative data and causal inference

methods—including two-way fixed effects models and event-study designs—we examine how this slow-onset urban disaster affected formal firms in evacuation-designated areas.

Our findings reveal severe and persistent economic disruptions. On the firm side, businesses located in affected zones experienced a sharp contraction in employment—declining by 12.8% in the first year and reaching a 20.9% reduction by the third year after displacement. These employment losses were not accompanied by wage reductions but were followed by a marked rise in business closures, indicating structural strain rather than adjustments through labor costs.

In comparison to previous studies on disaster impacts—both in Brazil and internationally—the labor market effects documented here are significantly larger and more persistent, reflecting the scale and urban context of the disaster. Unlike sudden-onset natural disasters, the slow-moving nature of this industrial crisis disrupted economic life well before visible collapse, compounding the challenge of policy response and mitigation.

These findings carry important implications for resilience planning and social protection in urban areas of developing countries. First, disaster preparedness should include targeted support for firms that are more vulnerable to long-term structural shocks. Second, safety net systems must be designed to account for worker heterogeneity, particularly among employees in the service, manufacturing, and retail sectors. Finally, stronger regulatory oversight and corporate accountability are essential to preventing the gradual buildup of risk that can lead to crises of this magnitude.

In conclusion, this study contributes new evidence on the economic toll of industrial disasters in densely populated urban areas. By documenting the firm-level effects of the Maceió disaster, we highlight the critical need for proactive policy measures that enhance urban resilience and protect employers and employees from the prolonged economic fallout of environmental degradation driven by corporate activity.

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