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NATURAL DISASTERS AND FINANCIAL TECHNOLOGY ADOPTION

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Keywords: Disasters, Technology adoption, Electronic payments, Financial flows.

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Natural Disasters and Financial Technology Adoption*

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1 Introduction

Financial technology has transformed the landscape of financial services, enabling faster and more efficient transactions, greater credit accessibility, and lower transaction costs for individuals.[1] However, technology adoption is a complex decision-making process that can be influenced by various factors, such as network effects, trust and security, and demographic characteristics, among others (Foster and Rosenzweig, 2010; Bachas et al., 2018; Higgins, 2019; Alvarez et al., 2022). Therefore, it is crucial to investigate technology adoption's determinants to understand the drivers and barriers that shape technology uptake. In this paper, we contribute to this literature by examining the impact of a negative economic shock on adopting new payment technology in a developing economy.

We focus on the adoption of the PIX payment system introduced by the Brazilian Central Bank, using data from the Brazilian economy. Leveraging the occurrence of natural disasters in Brazilian municipalities as an exogenous shock, we explore how exposure to the shock affects the adoption of the PIX payment system. Our analysis sheds light on the factors driving technology adoption, emphasizing that external shocks influence the speed of adopting new payment technology and the underlying mechanisms involved.

In November 2019, the Central Bank of Brazil (BCB) launched PIX, an instant payment system that revolutionized financial transactions. PIX was introduced to promote financial inclusion and enhance the speed of payment transactions. Unlike the previous payment alternatives, the system is designed to power inter-bank transfers instantaneously and at no cost without the need for any intermediaries. To use PIX, individuals only need access to a bank or payment institution account and register a key, which may be a social security number, phone number, email, or a random alphanumeric code. Duarte et al. (2022a) document how this new payment technology rapidly replaces traditional payment methods.[2]

Our analysis combines data from multiple sources. The data on natural disasters is

[1]For example, see Jack and Suri (2011), Jack et al. (2010), and Jack and Suri (2014) for the Kenyan experience with M-PESA.

[2]Fintech's exponential growth has made PIX significantly cheaper and more accessible to a larger population, further promoting financial inclusion in Brazil (Ferrarine, 2021).

obtained from the Ministry of Integration and Regional Development of Brazil through the Integrated Information System on Disasters. Regarding PIX information, we obtained data on payments sent and received from the Central Bank of Brazil through the Lei de Acesso à Informação (a FOIA-like law). We also utilized the Monthly Banking Statistics by Municipality database from the Central Bank of Brazil to analyze credit dynamics, using specific accounts of credit operations, loans, and saving deposits. We connect all this data and employ the Differences-in-Differences (DID) method of Callaway and Sant'Anna (2021) to measure the effect of disasters on PIX adoption. The panel covers the Brazilian municipalities using a monthly dataset from July 2021 to April 2022, during which we observed 16,460 natural disasters.

Our results show that the cumulative impact of a natural disaster on the increase in the quantity of PIX used is positive and significant for households and firms. We find an increase with estimates ranging from 6.4% to 8.9% for firms and 7.8% to 8.3% for households. Moreover, our estimations using the multiple periods DID method provide a more accurate estimate of the causal effect of natural disasters. The results show that the impact of a natural disaster on the adoption of PIX is positive and generally increases over time for both companies and individuals. However, there is a heterogeneity of this effect on firms. We find that certain sectors, such as human health and social services, commerce, and information technology, are more susceptible to the adoption of PIX after a disaster.

Next, we examine the role played by other potential factors that could be attributed to adopting this new financial technology. First, we look at the volume of credit circulating in each municipality because increasing the availability of money could boost the transactions between individuals and/or firms. However, we find a contraction in credit operations after a natural disaster. Therefore, one cannot conclude that adopting new technologies like PIX is associated with expanding credit availability. We also find a cumulative drop in savings deposits, which suggests that individuals have drawn on their savings and avoided taking out new loans after the disaster.

In addition, we document a spillover effect stemming from the adoption of PIX in disaster-affected regions to municipalities that remained unscathed. We empirically reveal a pronounced uptick in both outgoing and incoming transfers between the affected and non-affected regions. Our estimations indicate a positive and significant impact on these interregional transactions after a natural disaster.

Finally, we have conducted rigorous robustness exercises to confirm the validity of our findings. Our examination encompassed three dimensions that could be associated with PIX adoption: the impact of the coronavirus pandemic, the dynamics within touristic cities, and the influence of the number of bank agencies. Our investigation regarding the pandemic's effect highlights the strength of our results, even considering the different degrees of mobility restrictions in Brazilian municipalities during our analyzed period. Furthermore, focusing on coastal cities, a subgroup recognized for receiving considerable tourist influx during the summer and for being more susceptible to natural disasters (Kron, 2013), we continue to identify positive effects on financial technology adoption post-natural disasters, rejecting the argument that tourism dynamics could be a strong driver of our results. Ultimately, we stratify our sample based on the median number of bank agencies, revealing a discernible pattern where areas boasting a higher density of bank branches wield a more pronounced influence on PIX adoption. This phenomenon suggests that a higher presence of bank branches increases awareness and acquaintance with electronic transactions, fostering individuals and firms to adopt such technologies, particularly in adverse circumstances.

This paper contributes to two branches of the literature. First, our work is related to the literature on adopting new payment technologies (Wright et al., 2017; Riley, 2018; Chodorow-Reich et al., 2020; Agarwal et al., 2020). Crouzet et al. (Forthcoming) examine retailers' adoption of electronic wallet technology after the 2016 Indian Demonetization. They developed a dynamic model of technology adoption with complementarities and found that the shock resulted in a persistent increase in the number of merchants using the digital payment platform. The analysis reveals state dependence on adoption and shows that complementarities played a significant role, accounting for approximately 45% of the long-term adoption response. The study's findings highlight the impact of temporary shocks on technology adoption and the importance of complementarities in driving the adoption process. In the Brazilian context, Mariani et al. (2023) examines the impact of criminal raids on physical bank branches and the subsequent diffusion of financial technology. The researchers find that these raids deplete cash supplies in the branches but do not affect credit or deposits. In response, customers increase their usage of non-cash payments, particularly the PIX instant payment technology. The study reveals that PIX transactions and user numbers rise within affected municipalities and in unaffected areas. Our research extends the discoveries of Mariani et al. (2023) by investigating different types of shocks that can stimulate the adoption of new technologies among both firms and individuals. In addition, we document a heterogeneous adoption pattern by firms in different sectors and inflows of transfers coming from other municipalities to the locations affected by natural disasters.

This paper is also related to the noteworthy body of literature examining the implications of natural disasters on the economy. Natural disasters can impact economic growth (Noy, 2009; Cavallo et al., 2013), labor markets (Kirchberger, 2017; Karbownik and Wray, 2019; Hoang et al., 2020), financial markets (Czura and Klonner, 2023), foreign direct investment (Friedt and Toner-Rodgers, 2022) and various other aspects (Cavallo and Noy, 2009; Kellenberg and Mobarak, 2011). Our contribution to this literature is examining the adoption of new financial technology in disaster-stricken areas, shedding light on how individuals increase their utilization of this technology in such circumstances. Furthermore, our findings suggest that an inflow of funds through this new technology could drive this behavior change.

The rest of this paper is structured as follows. Section 2 describes the empirical context of PIX and natural disasters in Brazil. Section 3 provides an overview of our data. Section 4 outlines our empirical approach for assessing the impact of natural disasters on PIX adoption. Section 5 presents our estimation results and discusses their implications, and Section 6 presents the robustness of our exercise. Finally, section 7 concludes with our final remarks.

2 Empirical context

PIX, an instant payment scheme launched by the BCB in November 2020, has achieved remarkable success among the Brazilian population. Its primary objectives were to enhance efficiency, competition, and digitalization of the payment market, promote financial inclusion, and address gaps in existing payment instruments. BCB operates the PIX system and defines the rulebook, ensuring standardized, competitive, safe, and inclusive payment processes. In accord with Duarte et al. (2022b), as of February 2022, 67% of Brazilian adults, or 114 million individuals, had made or received PIX transactions, with 9.1 million companies also participating. PIX quickly became a popular choice for various digital transactions, expanding the digital payment user base by attracting 30% of the adult population without previously engaged in account-to-account transfers.

The main usage of PIX has been person-to-person (P2P) transfers, offering a simple and free option for individuals to send money to friends and family or for daily transactions. The BCB made P2P transfers free of charge for individuals, while payment service providers (PSPs) pay a nominal fee for transaction processing. To ensure security and access, PSPs verify users' identities digitally, allowing them to use aliases like phone numbers or email addresses for transactions. PIX has achieved a record of 33.2 transactions per capita, surpassing peer jurisdictions.

Duarte et al. (2022b) argue that PIX's success can be attributed to two key factors: mandatory participation of larger institutions and governance arrangements to set rules. The BCB mandated participation in PIX for banks and payment institutions with more than 500,000 transaction accounts, creating a critical mass of users and incentivizing network growth. Governance arrangements, including open APIs, have played a vital role in securely transmitting data for various transaction types. Additionally, PIX's development was user-centric, focusing on the specific needs of households and businesses. The BCB collaborated with private PSPs to define use cases, standardize interfaces, and expand offerings.

In Brazil, natural disasters are predominantly influenced by external Earth dynamics, resulting in phenomena such as floods, landslides, soil/rock movements, and storms. These events are typically associated with intense and prolonged rainfall during specific seasons, corresponding to summer in the south and southeast regions and winter in the northeast. Brazil has a history of being significantly affected by floods. In contrast, Brazil experiences relatively low seismic activity, with most tremors falling in the 2 to 4 Richter scale range.

Tominaga et al. (2009) argue that the increased incidence of natural disasters in Brazil, particularly since the 1960s, is attributed to rapid urbanization and the unregulated expansion of cities into geologically and geomorphologically unsuitable areas. In accord with the authors, anthropogenic activities like deforestation, excavation, landfilling, changes in drainage patterns, and inadequate infrastructure in these regions elevate the risk of instability. When these areas become densely populated with precarious housing, disasters like landslides and floods can lead to catastrophic economic and social losses. The most affected Brazilian states include São Paulo, Rio de Janeiro, Minas Gerais, Espírito Santo, Santa Catarina, Paraná, Bahia, Pernambuco, Alagoas, Sergipe, Paraíba, and Ceará. This rise in natural disasters is closely linked to environmental degradation and increased human vulnerability.

3 Data

In this section, we describe our database. We analyze the Brazilian municipalities using a monthly dataset covering the period from July 2021 to April 2022, during which we observe 16,460 natural disasters.

To acquire information about credit dynamics, we accessed the Monthly Banking Statistics by Municipality data made available by the Central Bank of Brazil. This database reports the monthly position of the balance sheet items of commercial banks. Specifically, our analysis utilizes the accounts of Credit Operations, Loans and Securities, and Saving Deposits.

For data regarding the quantity of PIX transactions, we obtained access to two different datasets provided by the Central Bank of Brazil through the Lei de Acesso à Informação (FOIA-like). In the first PIX database, we encompass all transactions involving PIX operations, both sent and received. These transactions are aggregated based on the economic sector classification (CNAE[3]). However, a network connection detailing the interrelation between these sent and received transactions is absent within this dataset. It's important to note that this first database exclusively comprises information about company transactions.

In the second PIX database, we possess a comprehensive record of the sent-received relationships related to PIX operations, i.e., a network dataset encompassing information from Individuals and Legal Entities. These records are aggregated by CNAE, with individuals represented as a distinct category. However, in this database, connections involving fewer than ten operations in a specific CNAE sector have been omitted due to anonymity considerations. We conducted sectoral analysis with the first database containing exclusively enterprise data. Conversely, analyses involving individual entities were carried out using the second database.

Our exogenous shock, natural disasters, is provided by the Ministry of Integration and Regional Development of Brazil, through the Integrated Information System on Disasters. Since this database contains disasters that are not necessarily natural and possibly endogenous, such as for accidents involving trucks with hazardous liquids, we only used the types of disasters listed in the Brazilian Atlas of Natural Disasters, namely: Mass Movements, Erosion, Floods, Runoff, Floods, Cyclones/winds, Local Storm/Convective - Hail, Drought/dry, Local Storm/Convective - Tornadoes, Cold Waves, Frosts, and Forest Fires.

[3] **CNAE Sectors:** Sector A: Agriculture, Livestock, Forest Production, Fishing and Aquaculture; Sector B: Extractive Industries; Sector C: Manufacturing Industries; Sector D: Electricity and Gas; Sector E: Water, Sewerage, Waste Management, and Remediation Activities; Sector F: Construction; Sector G: Retail; Repair of Motor Vehicles and Motorcycles; Sector H: Transportation, Storage, and Postal Services; Sector I: Lodging and Food Services; Sector J: Information and Communication; Sector K: Financial, Insurance, and Related Services; Sector L: Real Estate; Sector M: Activities Professional, Scientific, and Technical Activities; Sector N: Administrative and Support Services; Sector O: Public Administration, Defense, and Social Security; Sector P: Education; Sector Q: Human Health and Social Services; Sector R: Arts, Culture, Sports, and Recreation; Sector S: Other Services; Sector T: Domestic Services; Sector U: International Organizations and Other Extraterritorial Institutions.

As additional control variables, we utilized nighttime luminosity and population data. Population data was collected from the Brazilian Institute of Geography and Statistics (IBGE), while the nighttime luminosity indicator was created using Black Marble products, made available by NASA (Román et al., 2018). To identify the geographical region of each Brazilian municipality, we used georeferenced data maintained by the Database of Global Administrative Areas (GADM - gadm.org).

4 Empirical Strategy

We start by exploring a Difference-in-Differences approach to estimate the effects of natural disasters on financial technology adoption. In particular, we estimate the following econometric model:

$$Y_{mt} = \alpha_m + \gamma_t + \beta D_{mt} + X'_{mt}\Theta + \epsilon_{mt}, \tag{1}$$

where Y_{mt} represents the outcome of interest, which in our main specification is given by the number of PIX transactions *per capita* at the municipality m and time (year-month) t.[4] The variable D_{mt} is an indicator variable for whether unit m has been treated by time t, i.e., indicates 1 (one) for the time after which we observe the first calamity in municipality m, and zero otherwise (i.e., whether the municipality never suffers any calamity or if the calamity is not the first occurrence in the municipality). Thus, the parameter of interest, β, measures the average reduction/increase in the number of transactions made by PIX after the occurrence of a calamity. The coefficients α_m control for municipality-specific (time-invariant) heterogeneities at the municipality level while the γ_t controls for aggregate shocks that may have similarly affected PIX adoption across municipalities over time. The vector X_{mt} includes a set of control variables relevant to the analysis, such as the natural logarithm of per capita credit availability (Credit), the natural logarithm of the population (Population), and the natural logarithm of nightlight radiance (Luminosity). Finally, the term ϵ_{mt} represents idiosyncratic error to which we assume the classical assumptions.

In addition to the main specification, we adopt an event study framework that al-

[4] We also use other outcomes of interest, such as credit operation, savings deposits, loans, and securities, in our analysis.

lows effects to vary over time and is commonly used to assess the standard parallel pre-treatment trends assumption. The event study model is outlined by:

$$Y_{mt} = \alpha_m + \gamma_t + \sum_{j=-8}^{+8} \beta_j D_{mj} + X'_{mt}\Theta + \epsilon_{mt}. \tag{2}$$

In Equation (2), each β_j coefficient captures the average differences in Y_{mt} in municipalities j months before/after the calamity, relative to the baseline at one month after the calamity $j = -1$, which is omitted from the model as the reference category. The event study specification allows us to not only test for the persistence of the calamity shocks by allowing its effects to vary by time, but also determine whether pre-treatment trends were similar prior to the calamities. In particular, we expect the estimated β_j's for the prior months to be statistically indistinguishable from zero to validate our empirical strategy.

Considering our setting of staggered treatment adoption and given that once a municipality participates in the treatment, it remains treated, we adopt the recently developed estimator of Callaway and Sant'Anna (2021), which accounts for variation in treatment timing and adequately assesses the impact of the staggered calamity events. To exploit only appropriate natural disaster variation, the authors propose an approach to implement *DiD* methods in situations of differential treatment timing.

Let G_m be the time period when unit m becomes treated (often groups are defined by the time period when a unit becomes treated; hence, the G notation). A natural way to estimate the parameter of interest is to define group-time average treatment effects:

$$ATT(g,t) = E[Y_t(g) - Y_t(0)|G = g]. \tag{3}$$

This is the average effect of participating in the treatment for units in group g at time period t. Now let C_m be an indicator variable for whether unit m is in a never-treated group. Thus, when we impose the parallel trends assumption, based on these "never-treated units", we have that, for all $t \geq g$:

$$ATT(g,t) = E[Y_t - Y_{g-1}|G = g] - E[Y_t - Y_{g-1}|C = 1]. \tag{4}$$

Following Callaway and Sant'Anna (2021), we finally aggregate the group-time average treatment effect to highlight treatment effect dynamics given by the estimator outlined as follows:

$$\theta_D(e) := \sum_{g=2}^{\mathcal{T}} \mathbf{1}\{g + e \leq \mathcal{T}\} ATT(g, g+e) P(G = g | G + e \leq \mathcal{T}). \quad (5)$$

The parameter $\theta_D(e)$ measures the average effect of experiencing the calamity for the group of municipalities exposed to the treatment for exactly e periods.

5 Results

In this section, we present the results of the effects of natural disasters on the adoption of PIX. As discussed in the data section, the database allows analyzing PIX transactions according to the type of economic agent (whether household or firm) and according to payments and receipts. Thus, we begin this section by presenting the main results of adopting PIX by type of economic agent. Next, we show the results of the effects of the PIX on other financial system variables to isolate the impact of the natural disaster on the adoption of the PIX. We also conduct additional analyses to assess if the other banking transactions played a role in the surge of PIX adoption. Finally, we perform a series of robustness exercises.

5.1 Adoption of instantaneous payment method - PIX

Figure 1 presents the effect of natural disasters on the adoption of PIX by households and companies according to receipts and payments. In the regression, we employ the fixed effect of time and municipality in addition to the control variables associated with credit availability (Credit), population (Population), and luminosity (Luminosity). As we discussed in the methodological section, these variables are in logarithms.

The estimations assume that the adoption of PIX in places that have experienced natural disasters (treatment effects) is constant over time, which may not always be the case.

Treatment effects may change over time due to policy changes, economic conditions, or seasonal effects. The multiple periods DID method proposed by Callaway and Sant'Anna (2021) allows the treatment effect to vary over time, providing a more accurate estimate of the causal effect of an intervention or treatment. In Figure 1, we observed no pre-treatment trend for companies, but after the shock, the effect was positive and generally increased over time. For individuals, there is a small pre-trend, two periods before the shock, which may indicate that individuals anticipate the natural disaster. In any case, the effect of the natural disaster is also positive and increases over time for individuals. The calamity variable presents the effect of the natural disaster on adopting PIX. The cumulative impact observed eight months after the event is positive and significant for households and firms at the 1% significance level. The result also holds for the amount of PIX sent and the amount of PIX received. The cumulative impact on the increase in the quantity of PIX used is not negligible, with estimates ranging from 6.4% to 8.9% for firms and 7.8% to 8.3% for households.[5]

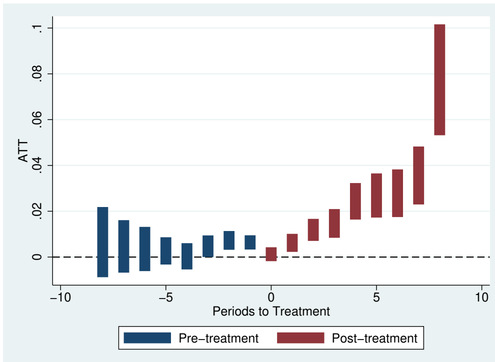
The distinction between outgoing and incoming transfers is essential, as these categories may not necessarily mirror each other, given the possibility of transactions involving both businesses and individuals. Furthermore, in order to receive or pay through instantaneous payment technology, both the payer and payee must have access to these types of payment technologies and be willing to use them.

One important consideration is distinguishing between the impact of a natural disaster on the overall utilization of the financial system and its effect on specific payment methods, such as instant payment methods like PIX. Figure 2 shows that the natural disaster appears to have led to a contraction in credit operations. Specifically, there was a decrease in loans, securities, and savings following the shock. This suggests that individuals have drawn on their savings and avoided taking out new loans after the disaster. Therefore, it cannot be concluded that adopting new technologies like PIX is associated with expanding credit available within the financial system.

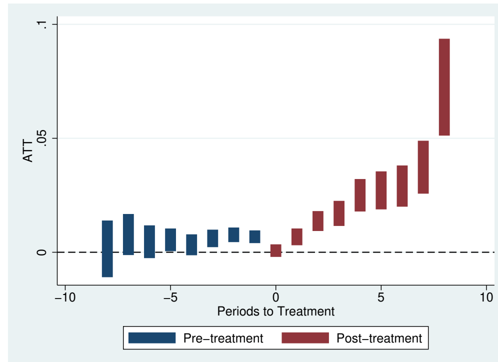
Certain sectors are more likely to experience an increase in the use of PIX than others.

[5] In the online appendix, we explore some additional exercises. We show no discernible pattern in the number of disasters over time and no correlation between city size and natural disasters.

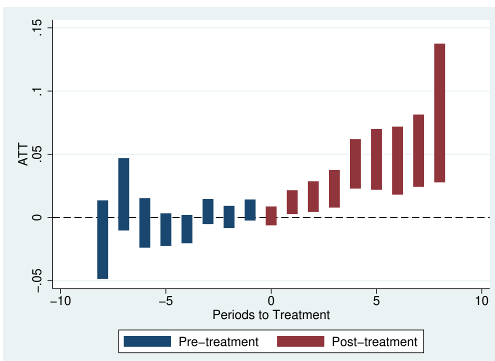
Figure 1: DID estimation - The impact of natural disasters on the number of transactions using PIX



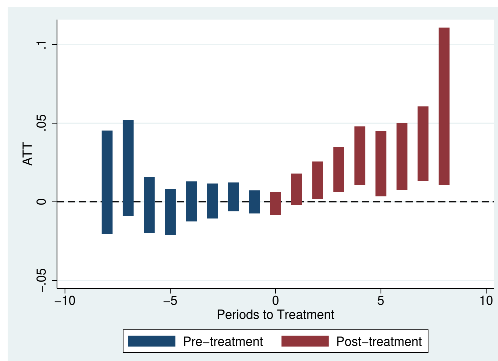
(a) Household - Transfer received



(b) Household - Transfer sent



(c) Firms - Transfer received



(d) Firms - Transfer sent

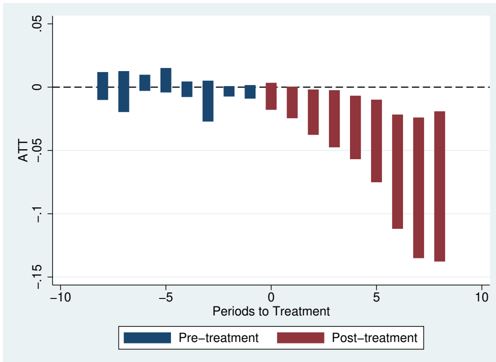
Note: In this figure we apply the Callaway and Sant'Anna (2021) method to estimate the impact of natural disaster on financial technology adoption. Here we split our dataset in (i) transfers received by household (1a), (ii) transfers sent by household (1b), (iii) transfers received by firms (1c), and (iv) transfers sent by firms (1d). In the regression, we employ the fixed effect of time and municipality in addition to the control variables associated with credit availability (Credit), population (Population), and luminosity (Luminosity).

Overall, natural disasters can impact the ability of companies to operate, and they often rely on technology to mitigate disruptions. The adoption of fintech solutions can help businesses recover more quickly and effectively, resulting in increased demand for fintech solutions in certain sectors. Our analysis, depicted in Figure 3, indicates that the human health and social services, commerce, and information technology sectors are among those with a higher susceptibility to the adoption of fintech solutions.[6]

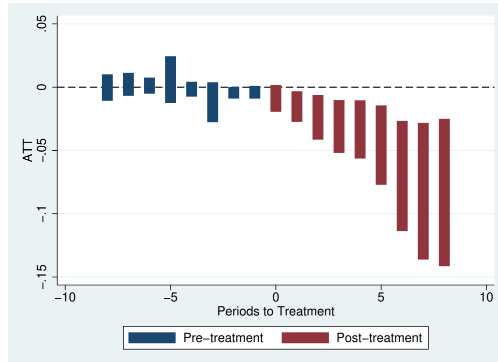
The human health and social services sector typically experiences a surge in demand after a natural disaster, which can result in an increased need for financial transactions.

[6] In the online appendix, we show all results for all 21 sectors available in our sample.

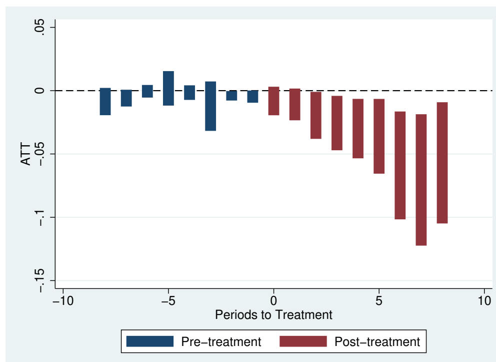
Figure 2: DID estimation - The impact of natural disasters on the credit side



(a) All credit operation



(b) Loans and Securities



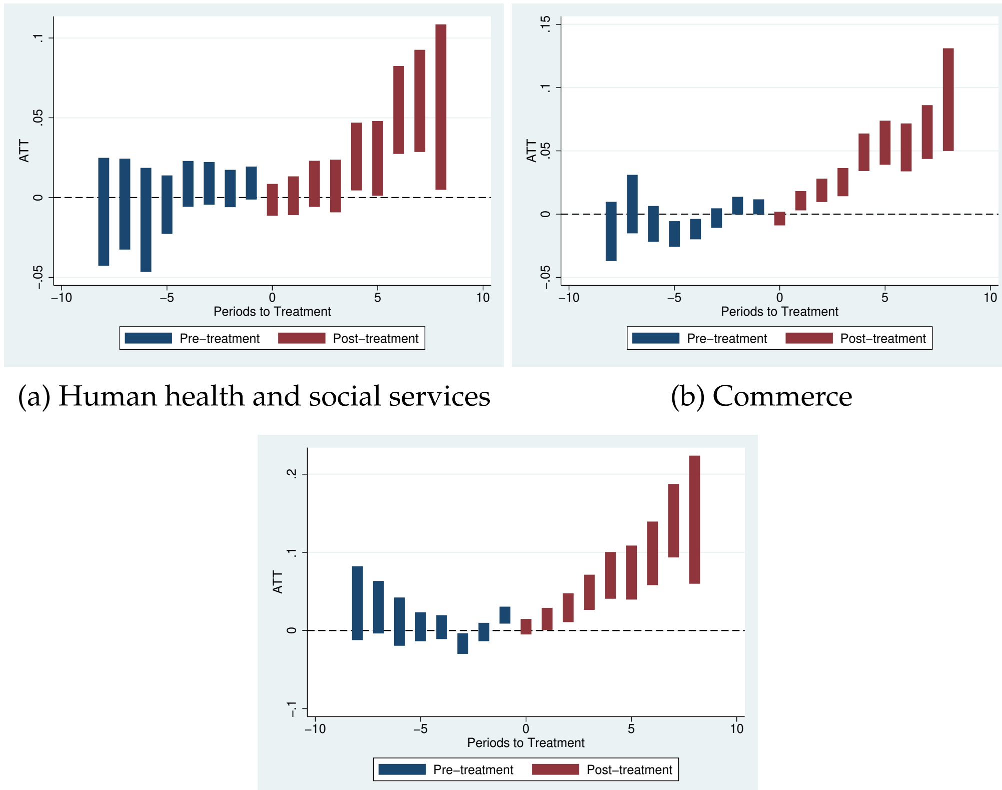
(c) Savings deposits

Note: In this figure we apply the Callaway and Sant'Anna (2021) method to estimate the impact of natural disaster on credit operations. Here we split our dataset in (i) all credit operations (2a), (ii) loans and securities operations (2b), and (iii) savings deposits (2c). In the regression, we employ the fixed effect of time and municipality in addition to the control variables associated with population (Population), and luminosity (Luminosity).

Similarly, the retail sector is positively impacted by the adoption of fintech as there is often an increase in demand for essential items such as food, water, and medical supplies during these events. The IT sector is also significantly affected by natural disasters. These events can disrupt the normal flow of business and cause companies to seek technology solutions, such as cloud-based services, remote work tools, and disaster recovery solutions. This increased demand for IT services and expertise often leads to a rise in payment rates for IT professionals.

Natural disasters can have a significant impact on financial technology adoption for several reasons. Firstly, physical damage to payment infrastructure such as bank branches, ATMs, and point-of-sale terminals can make it challenging for people to access their

Figure 3: DID estimation - The impact of natural disasters on transfer received for specific sectors



(a) Human health and social services

(b) Commerce

(c) Information technology

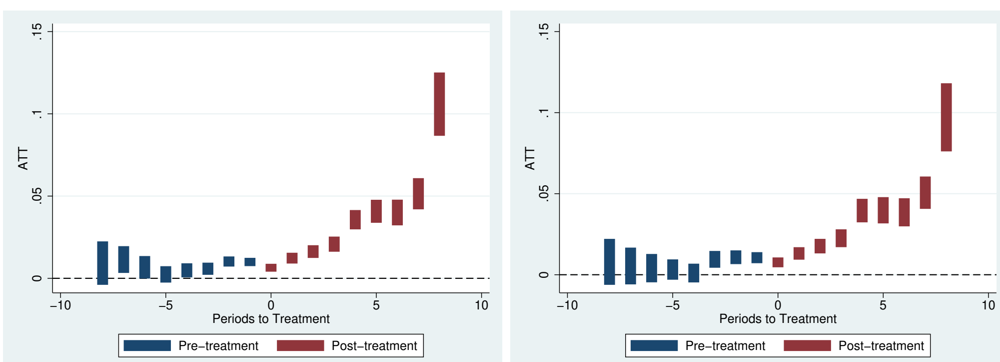
Note: In this figure we apply the Callaway and Sant'Anna (2021) method to estimate the impact of natural disaster on transfer received for specific sectors. In the regression, we employ the fixed effect of time and municipality in addition to the control variables associated with credit availability (Credit), population (Population), and luminosity (Luminosity). Here we present the results for (i) Human health and social services (3a), (ii) Commerce (3b), and (iii) Information technology (3c).

money or make payments using traditional methods. Secondly, transportation and communication systems can be disrupted, making it difficult for people to travel to work or visit physical stores. As a result, more people may turn to remote work and online shopping, which often require instantaneous payment methods. Thirdly, natural disasters can cause people to lose their homes, belongings, and jobs, creating an urgent need for funds to cover basic needs such as food, shelter, and medical expenses. In these situations, instantaneous payment methods such as mobile payments and digital wallets can provide an alternative way to make and receive payments. Other example are aid organizations and governments which need to quickly disburse funds to those in need, and instantaneous payment methods can help facilitate this process without the delays and administrative burden associated with traditional payment methods. In the next section, we explore the transferences from/to other regions that did not suffer from the disaster toward areas affected by the calamity.

5.2 Transfer of resources among municipalities

Following a disaster, the afflicted city experiences an influx (or outflow) of transfers from (or to) other municipalities that did not have a disaster. This can trigger financial technology adoption since citizens need an instantaneous payment method to execute payments faster. The dataset allows for tracking the flow of transferences among households at the municipality level. In Figure 4a and 4b, we present the results of these transferences coming outside and sending abroad of the city affected by the disaster, respectively. As we can see, there is a positive and significant effect after the disaster, indicating that the adoption of new financial technology grows over time.

Figure 4: DID estimation - The impact of natural disasters on transacionts with other municipalities



(a) Receiving from other municipalities (b) Sending to other municipalities

Note: In this figure we apply the Callaway and Sant'Anna (2021) method to estimate the impact of natural disaster on transfer received from municipalities not affected by the natural disaster and on transfer sent to municipalities not affected by the natural disaster. In the regression, we employ the fixed effect of time and municipality in addition to the control variables associated with credit availability (Credit), population (Population), and luminosity (Luminosity).

6 Robustness

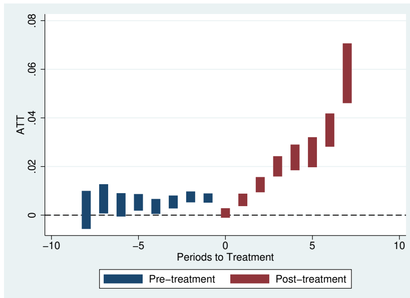
In this section, we assess the robustness of our results by considering the (i) coronavirus pandemic, (ii) touristic cities, and (iii) the number of bank agencies. In all exercises we employ the fixed effect of time and municipality in addition to the control variables associated with credit availability (Credit), population (Population), and luminosity (Luminosity).

(i) Coronavirus Pandemic: To examine whether the coronavirus pandemic affected our results, we present Figure 5a and 5b, which depicts the main results regarding the effect of natural disasters on the number of PIX sent, both with and without the number of deaths from COVID-19. The Figure demonstrates that the results remain consistent and unaffected by the pandemic.

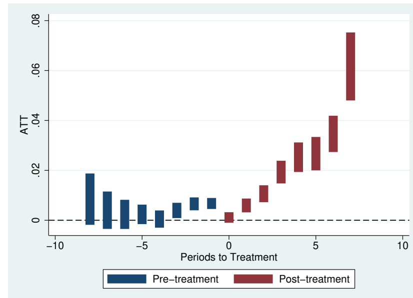
(ii) Touristic Cities: Additionally, we investigate whether touristic cities exhibit different effects. Figure 5c and 5d evaluates cities with coastlines as a proxy for touristic cities and assesses if this factor influences our results. Notably, we still observe positive effects on technology adoption for both groups.

(iii) Bank agencies: Finally, we estimate the impact of natural disasters on transactions using PIX according to the number of Bank agencies. We split our sample into two groups: above and below the median number of Bank agencies per one thousand people. Figure 5e, 5f, 5g, and 5h present the results for household and firms transactions, respectively. According to our results, cities with more Bank agencies have a more significant effect on PIX adoption. Indeed, in areas with a higher presence of bank branches, such as PIX, there may be greater awareness of the benefits and security of electronic transactions. People may be more familiar with electronic payment options and thus more likely to adopt these technologies, mainly in adverse situations.

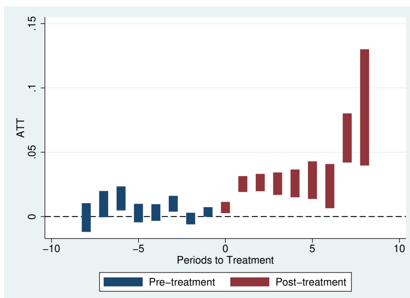
Figure 5: Effect of Natural Disasters on household PIX transactions considering COVID-19 Deaths, Touristic cities, and Bank agencies



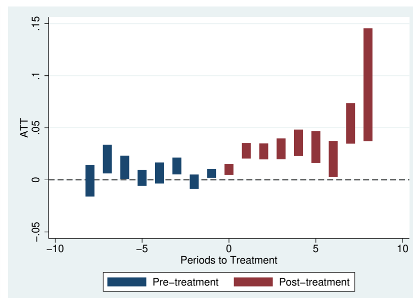
(a) COVID-19 : PIX sent



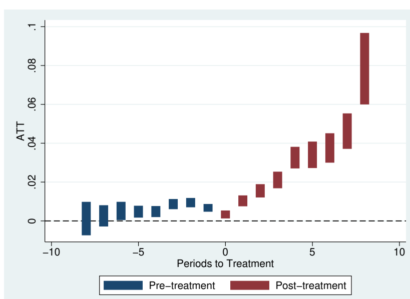
(b) COVID-19 : PIX received



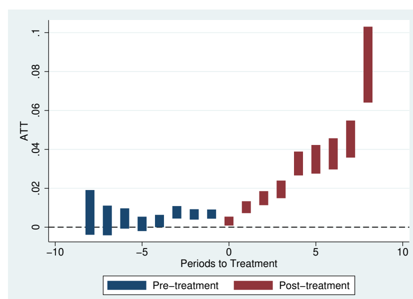
(c) Coastlines: PIX sent



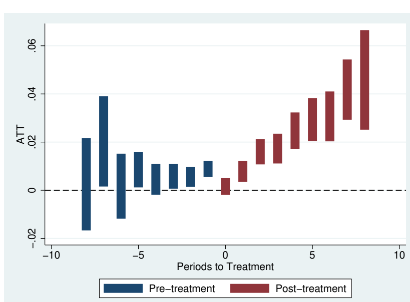
(d) Coastlines: PIX received



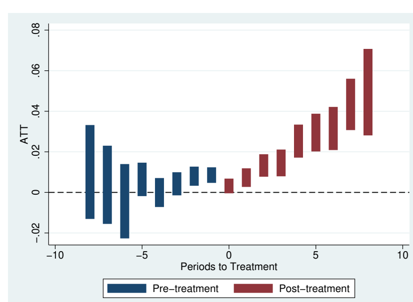
(e) High Bank Ag. - PIX Sent



(f) High Bank Ag. - Received



(g) Low Bank Ag. - Pix Sent



(h) Low Bank Ag. - Received

Note: In this figure we apply the Callaway and Sant'Anna (2021) method to estimate the impact of natural disasters on Household transactions using PIX. Figure 5a and 5b consider the number of COVID deaths. Figure 5c and 5d consider cities on the coast as a proxy to touristic cities. Figure 5e, 5f, 5g, and 5h consider the number of Bank agencies with two samples: above and below the median number of Bank agencies per one thousand people. In the regression, we employ the fixed effect of time and municipality in addition to the control variables associated with credit availability (Credit), population (Population), and luminosity (Luminosity).

7 Conclusion

This study investigates the impact of adverse economic shocks on the adoption of novel payment technology within a developing economy, with a specific focus on the PIX payment system introduced by the Brazilian Central Bank. Leveraging natural disasters as exogenous variables, we analyze their influence on PIX adoption. Our findings reveal a significant and positive cumulative effect of natural disasters on increased PIX usage among households and businesses. This effect grows over time, although variations exist among different industry sectors. This research expands existing literature by exploring technology adoption during economic downturns and highlights the role of financial technology in facilitating transactions during challenging times.

Comprehending the factors influencing technology adoption is critical for policymakers and financial institutions dedicated to advancing financial inclusion and optimizing payment system efficiency. Our research, which elucidates both the catalysts and obstacles in technology adoption, holds the potential to guide the development of strategies to foster the assimilation of innovative payment technologies, particularly in the wake of adverse economic circumstances. These insights carry significance not only for emerging economies such as Brazil but also for policymakers and scholars abroad as they strive to harness the capabilities of financial technology to strengthen economic resilience and sustain economic growth.

This research opens the doors to many other directions and important avenues for future research. First, additional investigation into the drivers of technology adoption, particularly in developing economies, focusing on factors like network effects, trust, and demographics, can deepen our understanding of this complex phenomenon. Secondly, investigating the broader economic impacts of technology adoption during adverse events, such as its influence on local economies and employment patterns, could provide valuable insights for policymakers. Lastly, given the increasing vulnerability to various adverse events worldwide, examining the role of financial technology in disaster preparedness and relief efforts would be valuable, assessing its contribution to efficient fund transfers and financial system resilience during crises.

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