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Instant Payments and Banks: the Impact of Pix on Bank Branches in Brazil

Pagamentos Instantâneos e Bancos: o Impacto do PIX sobre as agências bancárias no Brasil

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Abstract: This article examines the impact of the launch of the instant payment system Pix by the Banco Central do Brasil (BCB) on the number of bank branches in Brazilian municipalities. Using novel monthly data that capture Pix transactions at the municipal level and applying a staggered difference-in-differences approach, the study finds a negative and statistically significant effect of PIX adoption on the number of local bank branches. The paper contributes to the literature by assessing the economic impact of an instant payment system using an impact evaluation methodology and by focusing on quarterly, municipality-level data on Brazil's Pix system.

Keywords: Pix, Instant Payments, Bank Branches, Difference-in-Differences.
JEL Classification: E42, G21, E58.

Resumo: O presente artigo tem por objetivo verificar o impacto do lançamento do sistema de pagamentos instantâneo pelo Banco Central do Brasil, o PIX, sobre o número de agências bancárias presentes nos municípios brasileiros. Fazendo uso de dados mensais inéditos, que permitem identificar as movimentações de PIX nos municípios brasileiros, e aplicando o método de diferenças-em-diferenças escalonado, este estudo encontra um efeito negativo e significativo da adoção do PIX sobre o número de agências bancárias municipais. O estudo inova ao avaliar o impacto de um sistema de pagamentos instantâneo sobre a economia, através de metodologia própria da análise de impacto e ao considerar como foco de análise dados trimestrais e municipais sobre o sistema da pagamentos instantâneos brasileiro, o PIX.

Palavras-chave: PIX, Pagamentos Instantâneos, Agências Bancárias, Diferenças-em-Diferenças.
Classificação JEL: E42, G21, E58.

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1. Introduction

Instant payment systems have become widespread across a significant number of countries. According to the Prime Time for Real Time Report 2022 by ACI Worldwide, 63 countries—including Brazil—have implemented some form of instant payment system through Pix.

Pix was launched in November 2020 and is available to all users (individuals, businesses, and government entities) with a bank account. The system can be accessed via mobile devices, online banking, or in-person bank services. Users are identified through a unique key, which can take one of five forms: a Individual Taxpayer Identification Number (CPF), a Corporate Taxpayer Identification Number (CNPJ), a mobile phone number, an email address, a 25-character random code, or the user's bank account information (branch and account numbers). Pix transfers are free of charge for individual users but may incur fees for business users. As an instant transfer system, Pix is managed and operated by the Banco Central do Brasil (Central Bank of Brazil - BCB), which oversees its infrastructure and transaction processing (VIVIANA; TOMBINI; ZAMPOLLI, 2020).

Despite its recent introduction, Pix has seen widespread adoption among both individuals and businesses in Brazil. It is estimated that, in 2022 alone, Brazilians conducted approximately 8.7 billion transactions via Pix (Prime Time for Real Time Report 2022, 2023). Furthermore, according to Febraban (2022), there were approximately 51 million users registered with Pix in 2022. By 2026, Pix is expected to contribute up to 2.08% of Brazil's GDP, with an estimated 82.4 billion instant transactions processed annually. In terms of payment composition, instant payments are projected to account for 42.8% of all transactions in the country, according to the Prime Time for Real Time Report 2022 (2023).

Despite the widespread adoption of Pix by both individuals and businesses as a means of instant payment, few studies have examined its effects on real or monetary aspects of the economy. The scarcity of research on the economic impact of Pix may be attributed to its recent implementation, as well as to the lack of data with the appropriate level of granularity required for this type of analysis.

In light of this gap, this study aims to assess the impact of Pix usage on the number of bank branches across Brazilian municipalities. For this purpose, the staggered difference-in-differences method is used, based on Callaway and Sant'Anna (2021). Furthermore, the paper introduces a novel dataset with monthly frequency and municipal-level coverage of all Pix transactions, spanning from its launch in November 2020 through October 2022. The underlying hypothesis is that greater use of Pix by residents in a given municipality may render physical bank branches increasingly redundant, thereby contributing to a reduction in the number of branches operating in that locality.

Beyond this Introduction, the paper is structured into four additional sections. The section Instant Payments and the Economy: A Contextual Overview reviews the literature on instant payments and the relationship between them and the real and monetary economy. The Methods section details the staggered difference-in-differences method and the used database. The Results section presents the main result of the work and implements different heterogeneity and robustness analyses. The Conclusion section brings the study to a close.

2. Instant Payments and the Economy: A Contextual Overview

2.1. Digital Payments: Current Landscape and Key Challenges

Instant payments can be defined as payments made in real-time through a predictable system with an operation history, where funds are made available instantly to end consumers. In addition, instant payment is predictable, occurs instantly and has the history of the operation, similarly to paper money. In contrast, neither direct debits nor electronic money share these characteristics with instant payments (MORA; HEDMAN; AVITAL, 2020).

The real-time aspect of instant payments, however, necessitates considering infrastructure issues, not only within the financial system—particularly concerning the monetary authority—but also for end-users, namely: individuals, businesses, and the government. For example, Greene et al. (2014) consider, that the implementation costs of an instant payment system can be summarized as system implementation costs, as well as its maintenance. An instant payment system needs to be homogeneous across different financial institutions and for different users. Lastly, the speed of each payment is of paramount importance to the system's users. Indeed, the expediency of payment, coupled with the low cost of the instant transaction, can lead to the benefits of adopting an instant payment system outweigh its associated costs.

Regarding the costs and benefits of instant payments, Duffie et al. (2019) identify several considerations: user privacy concerns, anti-money laundering measures, transaction efficiency, monetary policy transmission (a more macroeconomic concern), financial stability, the competitiveness and profitability of banking operations, and financial inclusion. Moreover, instant payments are theoretically expected to reduce transaction costs for businesses, concurrently facilitating access to new markets and the expansion of existing ones (ZUNZUNEGUI, 2018).

The monetary authority fulfills a crucial role in maintaining financial system stability, fostering financial inclusion, continuously improving financial standards, ensuring consumer protection, and cultivating a competitive environment, particularly within the context of instant payments. Specifically in the realm of mobile banking and mobile services, often associated with instant payments, achieving these objectives presents implementation challenges, thereby posing new demands for the regulatory agent (COUSINS; VARSHNEY, 2014).

Furthermore, Cousins and Varshney (2014) emphasize that the role of the monetary authority in the context of instant payments may extend beyond mere regulation. An instant payment system might be centralized at a particular point (as opposed to a decentralized system), and the monetary authority is a natural candidate for this centralization. Another pertinent discussion concerns the practical processing of payments within the system. An instant payment would involve automatic fund transfers between users. However, in the 2010s, a nearly instant payment system was more common, where funds between financial institutions were reconciled two or three times a day, based on transfers previously made by their respective users (ZHILING et al., 2015).

Additionally, the monetary authority should collaborate with financial institutions to ensure ease of access, openness, isonomy, and transparency within the instant payment system. It must also maintain system security and demand compliance from financial institutions utilizing the instant payment service (ZUNZUNEGUI, 2018).

On a national level, each country encounters unique challenges in establishing an instant payment system. India, for instance, launched its instant payment system, the Unified Payment System, in 2017. By 2022, the country had processed 48.6 billion instant transactions (GOCHHWAL, 2017; Prime Time for Real Time Report 2022, 2023). Chavda and Solanki (2014) indicate that, as of 2014, Indian banks faced certain difficulties in adopting new banking technologies, including instant payments. Simultaneously, these authors highlight that the adoption of various innovative banking technologies generates gains for all involved agents—namely, financial institutions and consumers.

Regarding Europe, countries are still in the process of developing instant payment systems. According to Salmony (2017), establishing national instant payment networks in Europe is a complex undertaking; however, some observations can be made regarding such systems: (i) the success of instant payments will stem from diverse applications, meaning it is unlikely that a single service will satisfy the demands of all users; and (ii) the infrastructure of the instant payment system must benefit all stakeholders and not exist merely for its own sake. The author concludes that if difficulties arise in establishing instant payment systems in certain countries, a pan-European instant payment system appears even more challenging given current technological capabilities and usage patterns. Hartmann et al. (2019) analyze the adoption of instant payments by European Union countries. For the authors, the support of authorities and an adequate governance structure is crucial for the penetration of instant payments in the eurozone.

In the US case, Shy (2012) states that the American transfer market was until 2012 highly decentralized. At that time, this market consisted of various groups of banks and fund transmitters operating in isolation. Zelle, launched in 2017, and FedNow, planned to commence operations in 2023, aim to rectify this decentralization within the American payment system (Prime Time for Real Time Report 2022, 2023).

Regarding Latin America, Viviana, Tombini, and Zampolli (2020) identify the primary challenges for an instant payment system in the region as: (i) poor interoperability and the fact that limited competition within the banking system increases end-user costs; and (ii) restricted access to digital payments. In the case of Colombia, Arango-Arango, Ramirez-Pineda, and Restrepo-Bernal (2021) argue that the adoption of instant payments is limited because Colombians tend to prefer paper currency over any other payment method, including credit cards.

Globally, the implementation of an international instant payment system presents significant challenges, primarily because this system has yet to be fully established in most countries. Furthermore, as Bech, Shimizu, and Wong (2017) indicate, instant payment systems tend to perpetuate existing inequalities between nations, being considerably more prevalent in developed economies than in developing ones. Bech and Hancock (2020) additionally assert that this concentration in developed countries is attributable to their greater access to information technology and higher levels of financial literacy when compared to developing countries.

2.2. Impacts of Instant Payments on the Economy and on the Survival of Bank Branches

Studies on the effect of instant payments, both on the monetary economy and on the real economy, are quite incipient. This is primarily because, until the 2010s, their operational mechanisms were anchored in traditional bank transfers. However, the most relevant challenge for instant payments lies in technology and consumer access to that technology.

Kibe (2021), for instance, analyzes the relationship between mobile payments and the output of small and medium-sized enterprises (SMEs) in Kimusu County, Kenya. The author identifies a positive relationship between mobile payments and the growth of SMEs. Concurrently, the cost of mobile banking transactions negatively correlates with payments made via mobile devices. Lastly, a negative relationship exists between the duration of mobile banking transactions and the sales process of SMEs.

Banka (2016), in turn, examines the case of the instant payment system in Guyana. The author concludes that electronic payments are more cost-efficient than those based on paper currency.

Astari and Wibowo (2022) analyze the effect of payments based on alternatives to paper currency (including instant payments) on Indonesia's primary sector. They employ the error correction vector for quarterly data from 2010 to 2014 and find that in the short run, instant payments influence only the mineral sector, whereas in the long run, instant payments, e-money, and credit cards affect the same sector. In the case of agriculture, credit cards, checks, and instant payments impact it in the short run, while only checks do so in the long run.

Chitimira and Magau (2021) analyze regulatory aspects related to the adoption of instant payments in South Africa. They state that the use of instant payments relies on users having internet access and at least one mobile device. Therefore, its adoption may be small for low-income users or financially excluded users. To address this, the authors suggest that policies promoting financial and technological inclusion are necessary.

Kozachenko (2019) examines the use and dissemination of Near Field Communication Mobile Payment (NFC MP) in Portugal. The author finds that user attitudes and user convenience directly impact the adoption of this payment method. Furthermore, NFC MP was perceived by users as offering the following benefits: (i) ease of use; (ii) handheld technology; (iii) secure transactions; (iv) compatibility with billing devices; and (v) highly secure transactions.

Khiaonarong and Humphrey (2022) investigate the substitution among various payment instruments (cards, checks, paper money, and instant payments) using a sample of 12 developed and developing countries that possess an instant payment system, employing a Seemingly Unrelated Regressions model. The authors conclude that: (i) cards tended to replace checks; and (ii) instant payments tended to replace all other means of payment, i.e., check, paper money, and cards.

Polasik et al. (2020) analyze the impact of the Payment Services Directive 2 (PSD2) on PayTechs[1]. The authors find that PSD2's impact was more pronounced in the initial years of the directive's implementation. Furthermore, the adoption of PSD2 by the European Union led to an increase in the number of new financial start-ups acquiring a PayTech license. Still focusing on Europe, De Portu (2022) proposes a pan-European digital payment system. This system, which they term Euro-PaID, would feature centralization, user privacy, ease of use for end-users, and manageability for financial institutions. The authors contend that despite implementation difficulties, such a system could standardize the European banking system.

In terms of risks to the financial system, Mayo, Fozdar, and Wellman (2022) developed a network-based game. This game models financial agents and users within an instant payment system to analyze the inherent risks. The specific risk examined is that of a payer initiating a transfer without sufficient funds. This issue is more critical for nearly instant payment systems, as it assumes the bank processes the operation before verifying the existence of funds to settle banking transactions performed within a relevant time interval. Regardless, the authors identify a trade-off between executing payments instantly—thereby attracting more clients—and the inherent risk associated with such settled operations.

Regarding the impact of instant payments on India's economy, Camacho and Silva (2022) analyze the short- and long-run relationships between variables for India using a

[1] Fintechs focused on payment services.

panel ARDL model. The authors conclude that, for India, the volume of credit and credit card transactions are complementary to the adoption of instant payments. Concurrently, mobile banking transactions, as well as mobile plan subscriptions, impacted the use of instant payments in the short run. Rooj and Sengupta (2020) employ a Bayesian VAR model for India to analyze the relationship between economic growth and the volume of instant transactions. The authors find, by controlling for relevant exogenous and endogenous variables, a bidirectional causality, i.e., economic growth causes an increase in the volume of instant transactions and vice versa. Finally, Rooj and Sengupta (2021) utilize monthly instant payment data in India to forecast the country's quarterly consumption. The authors conclude that using this higher-frequency data improves quarterly consumption forecasts.

The survival of firms is strongly linked to the process of economic growth, holding significant interest for investors, creditors, local development, and the State (Giovannetti; Ricchiuti; Velucchi, 2011). Numerous studies investigate firm survival in Brazil and globally (PINHO, MARCELO, CÔRTES, MAURO ROCHA, FERNANDES, 2002; BARTELSMAN; HALTIWANGER; SCARPETTA, 2004; FREITAS; SALLES, 2011; ANAVATAN; KARAOZ, 2013; CAVALCANTE, 2015; TUMELERO; DOS SANTOS; KUNIYOSHI, 2016; LÖFSTEN, 2016; ANDERSSON; XIAO, 2016; PROKOP; HUGGINS; BRISTOW, 2019).

The survival of bank branches within a municipality is relevant, as they constitute an important driver of development, growth, and resilience for local economies (OTAKE, 2017). They are also responsible for granting credit at the most local level, often managing and possessing a peculiar non-negligible informational set. Concurrently, it is frequently through bank branches that individuals gain greater access to more sophisticated and profitable financial and investment products. Finally, the practical implementation of the BCB's monetary policy—which banks tend to follow—occurs at the frontline bank branch when interest rates are increased or reduced.

The closure of a bank branch can contribute to the discarding of local agent information, which is relevant for credit providers, while simultaneously reducing the capillarity of monetary policy, potentially diminishing its efficacy. The positive impacts of greater bank branch capillarity on GDP growth have been observed at the municipal level (OTAKE, 2017) and by directly examining a subset of bank branches, specifically credit cooperatives (JACQUES and GONÇALVES, 2016). The identified effect is positive from both perspectives.

Thus, the survival of bank branches may be particularly related to the survival of micro and small enterprises, which are crucial for local development. Access to credit and new technologies is fundamental for the development and survival of new businesses (Roberts; Myrrha, 2016). The lack of access to bank credit, insufficient working capital, and financial problems are cited as some of the main causes of difficulties faced by micro and small enterprises in Brazil (Krauter; Sousa, 2019). Difficulties in accessing bank credit

intensify as the number of branches in a municipality declines. In conclusion, the survival of bank branches, particularly in small municipalities, can be fundamental for maintaining local development. Despite the positive impacts that instant payments can generate on a country's economic growth, their indirect impacts in small localities, disseminated through a reduction in the number of bank branches, cannot be overlooked.

3. Methods

3.1. Staggered Difference-in-Differences

The employed method is the Staggered Difference-in-Differences approach, as developed by Callaway and Sant'Anna (2021). This method consists of the following model:

$$\#\ of\ bank\ branches\_i = \alpha + \delta_i + \gamma_t + \beta D_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where: $\#\ of\ bank\ branches\_i$ represents the number of bank branches in municipality i at quarter t; α is the intercept; δ_i denotes the municipality i fixed effect; γ_t represents the time fixed effect; and $D_{i,t}$ is the treatment variable.

The treatment variable is constructed as follows:

$$D_{i,t} = I\{PIXpercapita \geq 2{,}75\}$$

The cut-off of 2.75 for Pix per capita indicates the average monthly instant payment transactions observed in India, the country with the highest level and penetration of instant payments, according to the Prime Time for Real Time Report 2022 (2023). Therefore, the average number of instant payment operations for the country where this banking technology is most well-established is considered a criterion for determining Pix penetration in Brazilian municipalities. This cut-off is flexibilized in the robustness analysis presented in the Results section.

Municipal fixed effects play a crucial role in controlling for the impact of the treatment variable on the number of bank branches by accounting for idiosyncratic characteristics of the municipalities, such as economic, social, and institutional attributes. Concurrently, time fixed effects also capture common trends across all municipalities regarding shared variations in the number of bank branches. The coronavirus pandemic represents a global shock occurring simultaneously for all municipalities. It is assumed this shock is accounted for by both time and municipality fixed effects.

Additionally, Pix was launched after the onset of the coronavirus pandemic (October 2020 vs. March 2020, respectively). Therefore, any average changes in the number of bank branches in Brazilian municipalities were already incorporated into the model through the time fixed effect. Any further municipal and state specificities related to the local economy and the public health environment are duly considered within the municipality fixed effects.

For the effect captured by the parameter β to genuinely reflect the impact of increased Pix usage per capita on the number of bank branches, exogenous treatment is assumed. In practical terms, this hypothesis indicates that the use of Pix in municipalities occurred exogenously. This assumption is reasonable given that Pix was launched nationally on the same date, November 2020, and its use required only the possession of a bank account. Thus, it appears reasonable to consider it an exogenous variation.

Furthermore, as Baker, Larcker, and Wang (2022) indicate, the Callaway and Sant'Anna (2021) staggered difference-in-differences estimator is the most flexible of its kind. It permits the use of covariates and allows the "not-yet-treated" group to serve as the control group. Simultaneously, the Callaway and Sant'Anna (2021) difference-in-differences estimator also offers more robust modeling options, such as outcome regression, inverse probability weighting and doubly robust estimation.

Additionally, it is assumed that the treatment here is binary and, once administered, it is permanent. Essentially, once a municipality is treated, it does not "forget" its treatment. In practical terms, when a municipality reaches the Pix per capita transaction threshold of 2.75, it does not subsequently decrease below this level of per capita operations. Therefore, in comparison to the traditional difference-in-differences estimator, the Callaway and Sant'Anna (2021) estimator also accounts for the treatment being permanent, though it can occur in different periods for the observation units. The difference-in-differences literature has undergone significant advancements and flexibilities in the early 2020s. Callaway, Goodman-Bacon, and Sant'Anna (2021) propose an interesting methodological direction for the present study by allowing the treatment to be a continuous variable. Despite this work's advancement, it is still in the publication phase and not yet implemented in any statistical software, unlike the Callaway and Sant'Anna (2021) estimator[2].

Additionally, the average treatment effect can be defined as:

$$ATT\hat{}(g,t) = E\hat{}[Y_{it} - Y_{i,g-1}|G_i = g] - E\hat{}[Y_{it} - Y_{i,g-1}|G_i = \infty] \quad (2)$$

[2] The authors are aware that the Callaway and Sant'anna estimator (2021) is implemented in the R and Stata softwares. Additionally, according to Google Scholar, despite its recent publication, the article has already accumulated over 2000 citations (as of February 3, 2023), affirming the impact and widespread use of this estimator within the scientific community.

If the number of groups is small relative to the number of observations, then it is possible to report the metric from Equation (2) directly. When dealing with a large number of groups or periods, a direct estimation might be counterproductive. In such cases, a more carefully chosen estimation of averages becomes necessary. Callaway and Sant'Anna (2021) suggest three aggregations: group-time average effects, event-study estimands, and calendar time effects. This study presents all three metrics in the main model.

3.2. Data

Two datasets were used for the analysis: monthly data on the number of Pix transactions and their total value per municipality; and the number of existing bank branches in each Brazilian municipality. The origin and treatment of these data are explained in more detail below.

Regarding the Pix transaction data, both the number of operations and their corresponding values were obtained from the BCB via the Freedom of Information Act in January 2023. This information, provided monthly, details Pix operations and values based on the originating municipality of the transaction, thus reflecting the transaction's source. These records are available for the period spanning November 2020 (Pix launch date) to October 2022.

Information regarding the number of bank branches in Brazilian municipalities is available for an extensive period (since 1988), derived from BCB's ESTBAN data (2023). From these monthly municipal and branch datasets, a variable representing the number of bank branches in each municipality per month was constructed.

Estimates for the municipal population, crucial for building per capita variables, were sourced from the Brazilian Institute of Geography and Statistics (2022), providing updated figures for each Brazilian municipality for the year 2021.

Finally, for tractability of the estimation, the analysis was conducted at a quarterly frequency. This encompassed the period from Q1 2018 to Q4 2022, with quarterly average variables constructed accordingly for this estimation.

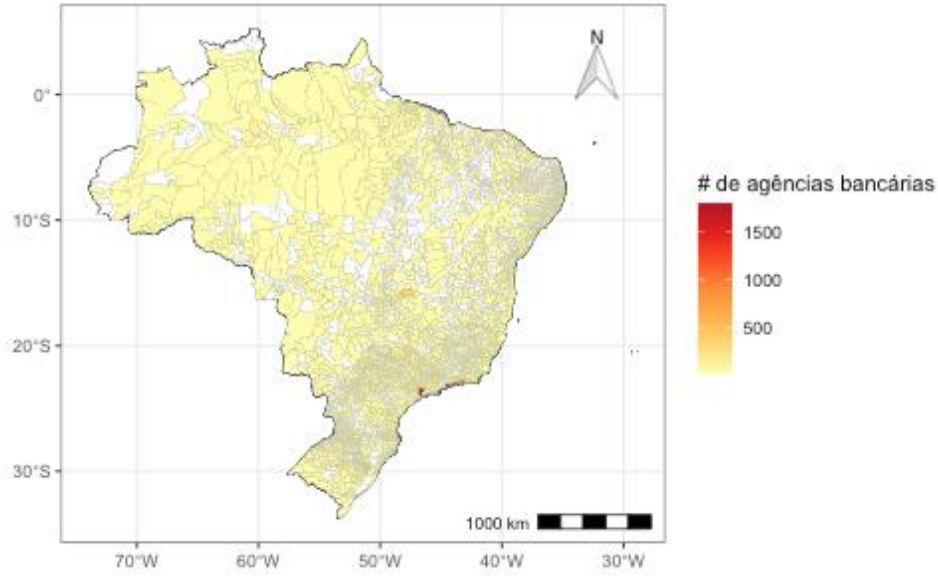
4. Results

The following four subsections present the main findings of the analysis. Before detailing the estimation results, however, a descriptive overview of the variables is provided through maps, graphs, and summary tables.

4.1. Variables description

Figure 1 displays the location of bank branches in Brazilian municipalities during the last considered period, namely the fourth quarter of 2022.

Figure 1. Number of Bank Branches per Municipality (Q4 2022)

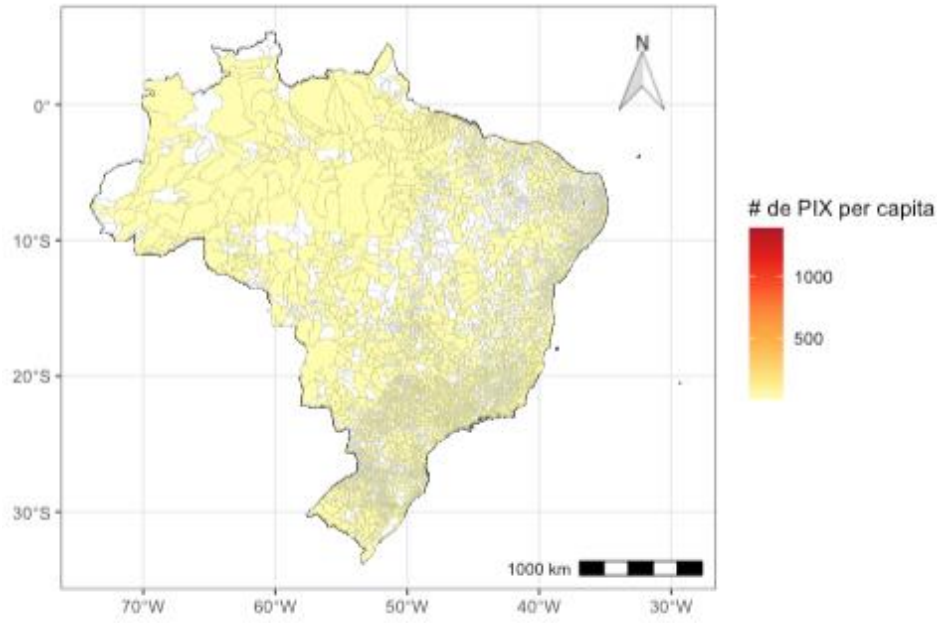


Source: own elaboration based on data from the BCB.

The number of bank branches tends to be higher in large cities, especially in capitals. Specifically, São Paulo, Rio de Janeiro, Brasília, and Belo Horizonte stand out on the map in **Figure 1** as having the largest number of bank branches within their territorial limits.

Next, **Figure 2** displays a map illustrating the average number of Pix operations per capita per month (normalized by municipal population size) for each municipality during the last quarter of the analysis, specifically Q4 2022.

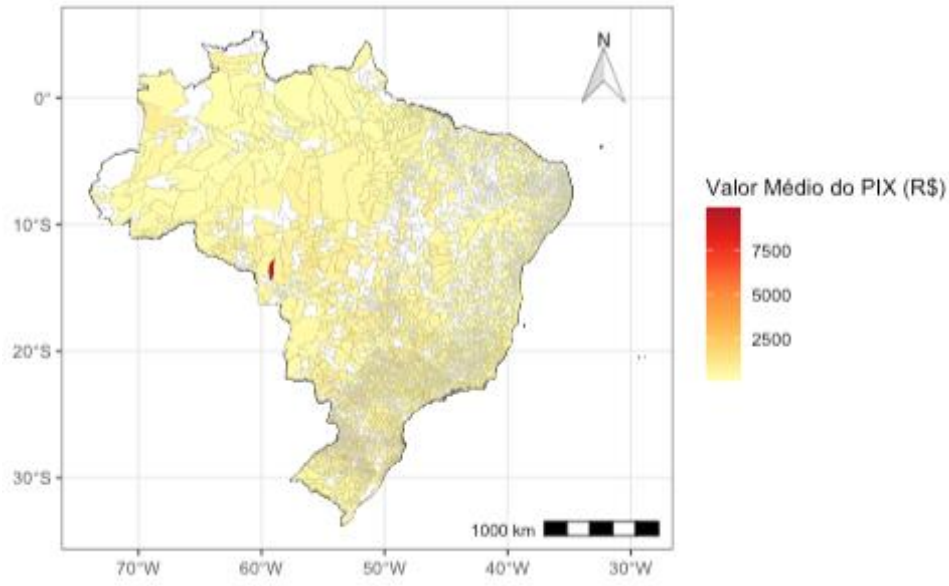
Figure 2. Number of Pix Operations per Capita per Municipality (Q4 2022)



Source: own elaboration based on data from the BCB.

The number of Pix transactions per capita tends to be quite similar across Brazilian municipalities. Further on, **Figure 3** presents the average value of Pix transactions for each Brazilian municipality, considering Q4 2022.

Figure 3. Average Pix Transaction Value per Municipality (Q4 2022)

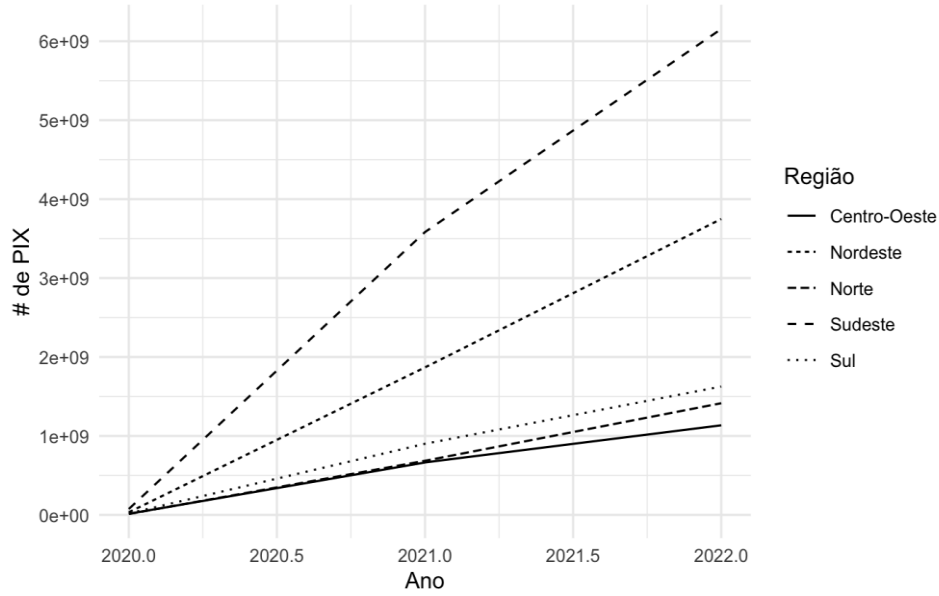


Source: own elaboration based on data from the BCB.

Figure 3 highlights municipalities with a higher average Pix transaction value. Notably, the municipality of Campos de Júlio in Mato Grosso stands out.

Figure 4 illustrates the evolution of the number of Pix transactions by administrative region since the launch of the instant payment system.

Figure 4. Number of Pix Transactions by Region

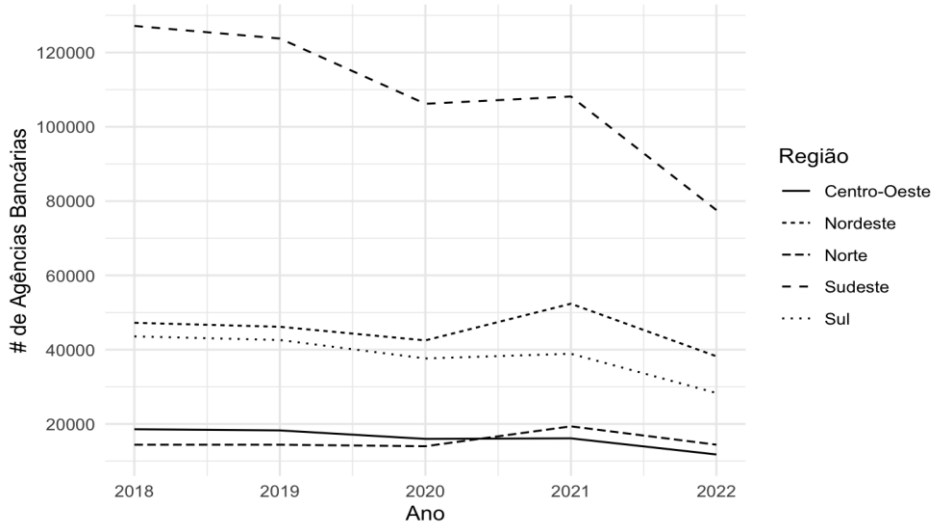


Source: own elaboration based on data from the BCB.

There is a pronounced growth trend in the number of Pix transactions across all Brazilian regions; economically larger regions typically exhibit a greater number of monthly transactions.

Finally, **Figure 5** displays the number of bank branches per Brazilian region, according to ESTBAN data.

Figure 5. Number of Bank Branches by region



Source: own elaboration based on data from the BCB.

Figure 5 indicates a declining trend in the number of bank branches across Brazilian regions, according to data obtained from the BCB.

Finally, **Table 1** presents descriptive statistics for the variables utilized in this study.

Table 1. Descriptive Statistics

	Mean	Standard deviation	Minimum	Median	Maximum	# Obs.
# of bank branches	6.131	44.759	1	2	2.333	59721
Population (2021)	59897	295582.7	839	20873	12396372	59721
Pix values per capita	1974.1	10236.3	7.4	1154.8	712651.7	59721

# of Pix transactions per capita	4.01	19.674	0.02	2.71	1392.09	59721

Source: own elaboration based on data from the BCB.

The average Brazilian municipality has 6 bank branches, a population of almost 60,000, conducts 4 Pix transactions per month, and the average Pix transaction value is R$ 1,975, as indicated by **Table 1**.

Of particular interest for this study is the variable "number of Pix transactions per capita." As shown in **Table 1**, this variable exhibits considerable variability, with a median of 2.71 and a maximum value reaching 1,390.

The subsequent subsection will present the primary findings derived from the model developed in this study.

4.2. Impact of Pix on Brazilian Bank Branches

Table 2 presents the estimation results from the staggered difference-in-differences method.

Table 2. Impact of Pix on the Number of Bank Branches in Brazilian Municipalities

	Overall Average	Group-Specific Effects		Event Study		Calendar Time	
Partially Aggregated		g=12	-0.939* (0.356)	e=0	-0.101* (0.017)	t=12	-0.257 (0.162)
		g=13	-4.169 (2.134)	e=1	-0.195* (0.042)	t=13	-0.875* (0.362)
		g=14	-0.599* (0.195)	e=2	-0.309* (0.074)	t=14	-0.716* (0.172)
		g=15	-0.007 (0.006)	e=3	-0.588* (0.138)	t=15	-0.445* (0.116)

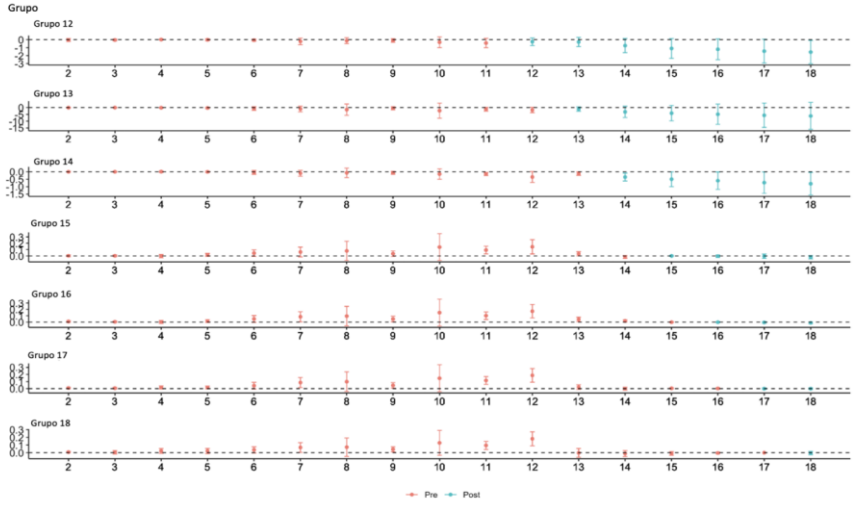
		g=16	-0.007* (0.003)			t=16	-0.341* (0.087)
		g=17	-0.001 (0.004)			t=17	-0.325* (0.098)
		g=18	-0.005 (0.008)			t=18	-0.345* (0.093)
Individual Parameters	0.382* (0.101)		-0.241* (0.057)		-1.284* (0.442)		-0.472* (0.133)

Source: Own elaboration. Note: the * symbol indicates that the confidence interval in the estimate does not contain 0. Standard errors are reported in parentheses.

All results within **Table 2** consistently indicate a negative impact of increased Pix utilization on bank branches. Specifically, using the group-time average treatment effect, it is observed that higher per capita Pix usage contributed, on average, to reducing the number of bank branches in Brazilian municipalities by 0.25. This implies that for every four municipalities with a single bank branch, one would experience a branch closure. This analysis is based on the single metric derived from the appropriate average calculated across the treatment group effects.

Figure 6 displays the treatment effects of Pix usage on the number of bank branches per municipality, aggregated by treatment group.

Figure 6. Pix Treatment Effects on Bank Branches



Source: Own elaboration.

Figure 6 offers an alternative visualization of the results presented in **Table 2**, indicating that once, on average, a municipality's inhabitants increase their Pix usage, there is a declining trend in the number of bank branches within that municipality. This trend is evident as the post-treatment bars (in blue) are entirely located below the zero-effect horizontal line. Consequently, when a given municipality begins to utilize Pix more extensively, a reduction in its number of bank branches tends to follow.

From a public policy perspective, the closure of bank branches can have deleterious effects on the local economy. Beyond merely capturing account holder deposits, bank branches, owing to their more direct client contact, are frequently responsible for credit-related decisions. This, in turn, impacts the local economy by invigorating economic activity and fostering investment sources for the locality. Thus, despite the numerous benefits associated with instant payments, which could amount to at least 2% of Brazil's GDP by 2026 (Prime Time for Real Time Report 2022, 2023), the findings of the present study suggest a cost associated with bank branch closures that should not be underestimated.

The subsequent section implements various analyses in an attempt to consolidate the robustness of the previously displayed results.

4.3. Heterogeneity

This subsection presents the results of additional regressions estimated to better qualify the effect observed in the previous subsection: namely, that greater Pix usage tended to reduce the number of bank branches in Brazilian municipalities. Therefore, the model was considered within the following restricted samples:

- Cities with over 200,000 inhabitants;
- Cities with under 5,000 inhabitants;
- Cities in the North Region;
- Cities in the Northeast Region;
- Cities in the Southeast Region;
- Cities in the South Region;
- Cities in the Midwest Region;
- State capitals.

For simplicity, the results were opted to be reported aggregated into a single, group-specific treatment effect metric. The results of this estimation are displayed in **Table 3**.

Table 3. Heterogeneity of Pix's Impact on the Number of Bank Branches

	Segment	Single Parameter for Group-Specific Effect
Population	Cities with > 200k inhab.	-2.071* (0.544)
	Cities with < 5k inhab.	-0.063 (0.051)
Region	Northern Region	-0.046 (0.03)
	Northeast Region	-0.144* (0.040)
	Southeast Region	-0.431* (0.156)

	South Region	-0.149* (0.067)
	Midwest Region	-0.154 (0.119)
State capitals		-1.05 (2.369)

Source: own elaboration. Note: The symbol * indicates that the confidence interval for the estimate does not contain 0.

This heterogeneity analysis highlights the differentiated effects of Pix on the number of bank branches across municipalities. The non-significance of Pix's effect on bank branches in cities with small populations (under 5,000 inhabitants) and in state capitals, contrasting with a significant negative effect for cities with over 200,000 inhabitants, may be attributable to several phenomena. Cities with a small number of inhabitants, for instance, rarely possess more than two bank branches; their average number was 1.85 during the analyzed period (2018–2022). Conversely, capitals typically boast superior technological and financial infrastructure. This, combined with higher technological and financial literacy, reduces the need for physical bank branches, causing the introduction of a technical-financial innovation like Pix to have a limited impact in these areas.

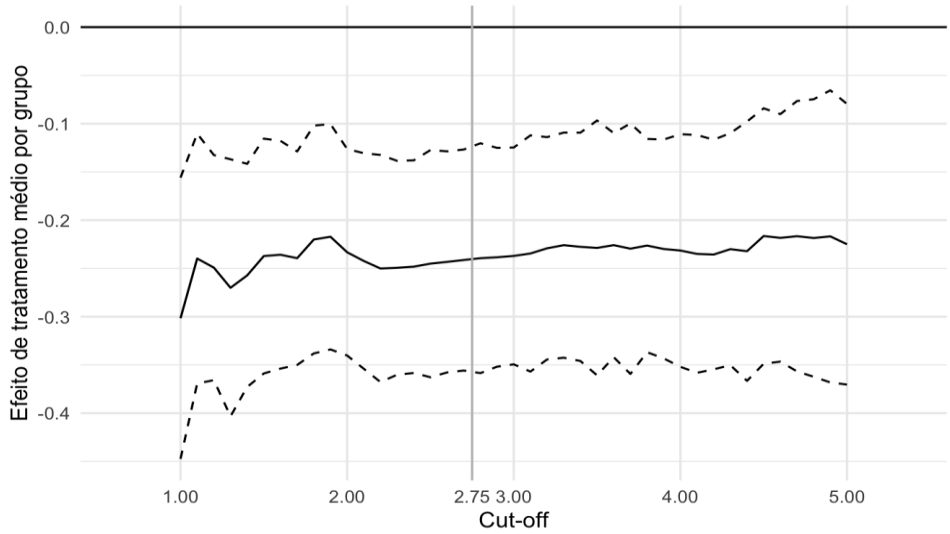
The regional heterogeneity analysis also yielded notable results. Pix's impact on the number of bank branches was significant across the Northeast, Southeast, and South regions, but not in the North and Midwest. This finding is particularly relevant, as it directly and indirectly sheds light on the varying dynamics of bank branch presence across Brazilian municipalities. Consequently, diverse technological and economic conditions likely account for the differential impact of Pix on bank branches in Brazil. A plausible explanation for this observation is greater access to mobile technology among inhabitants in regions where the effect was significant. Given that Pix usage predominantly relies on mobile devices and internet connectivity, this appears to be a reasonable hypothesis.

4.4. Robustness

The choice of 2.75 for the Pix per capita threshold might seem arbitrary, potentially biasing the previously presented results and conclusions. To verify that increased Pix usage genuinely leads to a reduction in bank branches, a small simulation was conducted using alternative treatment cut-offs. The main model was re-estimated with cut-offs varying by 0.1, from 1 to 5, to re-qualify whether a municipality is treated in a given quarter. The

single parameter for the group-specific effect and its confidence interval are plotted in **Figure 7**.

Figure 7. Impact of Pix on the Number of Bank Branches, Considering Different Treatment Cut-offs



Source: own elaboration.

The effect of Pix usage on bank branches is significant and negative across a range of values defining the treatment. Therefore, this article's conclusion—that Pix usage negatively impacts the number of bank branches in Brazilian municipalities—is robust to different definitions of the treatment.

5. Conclusion

This study aimed to examine the impact of a new instant payment technology, Pix, launched in November 2020 by the BCB, on the number of bank branches present in each Brazilian municipality. Using a staggered difference-in-differences method and novel Pix data, the study finds negative impacts of increased Pix usage on the number of existing bank branches in a municipality, corroborating the study's hypothesis.

Furthermore, the study assesses how this impact varies across different aggregation levels. It finds non-significant effects of Pix in state capitals, cities with fewer than 5,000 inhabitants, and cities in the North and Midwest regions. Conversely, Pix negatively impacted the number of bank branches in cities with over 200,000 inhabitants and in the Northeast, Southeast, and South regions.

From a public policy standpoint, this study's findings suggest the monetary authority may need to consider the capillarity of the banking network across Brazil. Given the negative impacts of Pix usage on the number of bank branches in Brazil, this could hinder access to credit for a significant portion of Brazilian consumers and entrepreneurs. In the long term, this might impair the economic capacity of these underserved localities—those without bank branches—to produce and employ new individuals. The results of this study prompt discussions regarding the long-term structure of the banking system, particularly with the increasing penetration of Pix among Brazilian consumers and businesses.

This study is novel in its use of Pix data at the municipal aggregation level and with monthly frequency. It is anticipated that these data, with their various spatial and temporal aggregation levels, will facilitate diverse studies on macroeconomic and microeconomic aspects related to instant payments. Indeed, the centralization of Brazil's instant payment system within the BCB, coupled with the Freedom of Information Act, suggests that Pix-related studies should proliferate in the coming years.

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