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Faster digital payments: global and regional perspectives

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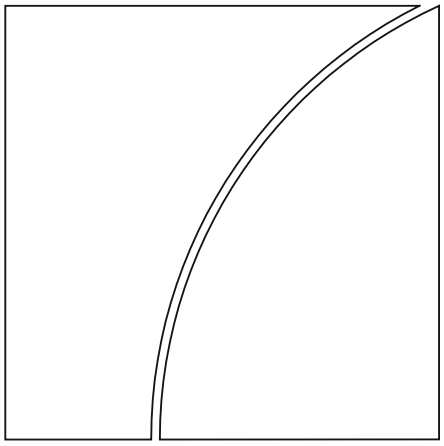

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Faster digital payments: global and regional perspectives

Edited by José Aurazo, Jon Frost and Anneke Kosse

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Foreword

Innovation in payments is proceeding rapidly, with particularly notable progress in Latin America and the Caribbean. Indeed, in just a few short years the use of fast payments has grown exponentially in several countries in the region, and central bank initiatives are driving further innovation. The launch of fast payment systems, the use of aliases such as quick response (QR) codes and mobile phone numbers, and the integration and interoperability of private systems have all proven effective in increasing adoption of digital payments. End users are looking for faster, interoperable, costless and user-friendly payment instruments. Going forward, there is significant promise in regional payment networks, and new initiatives around open banking and central bank digital currencies.

The BIS, as the bank for central banks, convenes dialogue among central banks, conducts cutting-edge research and, most recently, carries out projects to put new technologies into practice through the BIS Innovation Hub. Through its regional bodies, such as the Consultative Council for the Americas (CCA) and the CCA consultative groups, the BIS brings together central banks from North and South America to discuss a range of pressing issues, including around digital innovation, and to develop joint reports that can serve central banks in their work. Through its outreach in the region, the BIS also collaborates with non-BIS shareholder central banks and regulatory and supervisory authorities, helping to advance dialogue and sound policy in the region.

The workshop on fast payments held on 21–22 May in Mexico City was one example of the collaboration between the BIS and the World Bank. Given the high relevance of the topics discussed at the workshop, we determined to publish related papers in this area in a special volume in the *BIS Papers* series.

We hope that this volume will provide useful insights for central banks, regulators, private sector practitioners, academic researchers and interested readers of all backgrounds.

Alexandre Tombini

BIS Chief Representative for the Americas

A revolution in digital payments: faster, user-friendlier and cheaper

José Aurazo, Carlos Cantú, Jon Frost, Anneke Kosse and Carolina Velasquez[1]

December 2024

Abstract

Digital payments are a promising tool to improve people's payment experience and financial health. This is especially true for fast payments, which allow for immediate availability of final funds to the beneficiary. Often combined with new functionalities, fast payments can offer enhanced convenience compared with other payment instruments. They can also be cheaper for individuals and businesses, especially when provided by or in collaboration with the public sector and on a cost recovery basis. This chapter provides a high-level overview of key insights and issues discussed at the Workshop on "Fast payments in Latin America" organised by the Bank for International Settlements and the World Bank and held in Mexico City in May 2024. In particular, it draws out some common themes on financial inclusion, the role of central banks, domestic and cross-border interoperability and new functionalities, and gives an overview of the other chapters in this volume.

JEL classification: G23, G28, L51, L96, O16, R11.

Keywords: Fast payments, digital payments, fast payment systems, financial inclusion, interoperability, digital innovation.

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1. Introduction

The retail payments landscape in Latin America and the Caribbean (LAC) is going through revolutionary changes. At the heart of this revolution is the introduction of fast payment systems (FPS) and the adoption of fast payments (Randall et al (2024)). Fast payments, also referred to as instant, real-time, immediate or rapid payments, allow for transaction messages to be transmitted and final funds to become available to the beneficiary in real time or near real time, and as near as possible to 24 hours a day and 365 days a year (24/365) (CPMI (2021); World Bank (2021a)). FPS enable swift processing of retail transactions to ensure the immediate availability of funds for the recipient. In this chapter, we use "FPS" as an umbrella term that encompasses the underlying technical infrastructure, participating payment service providers (PSPs), end user-facing services and underlying rules that govern the processing and delivery of fast payments (Frost et al (2024)).[2]

Over 15 jurisdictions have implemented an FPS in LAC (see Table 1 for some examples). Brazil's Pix was implemented in November 2020 and is a notable example of a central-bank owned FPS (Duarte et al, 2022); over 90% of the adult population in Brazil received or initiated a Pix transaction between July 2023 and July 2024. Costa Rica has seen a similar success story with SINPE Móvil, which was implemented in May 2015, with nearly 80% of adults using it by August 2024. In Mexico, the central bank launched Cobro Digital (digital collection, "CoDi") and Dinero Móvil (mobile money, "DiMo") in 2019 and 2023 respectively, building upon the large-value Sistema de Pagos Electrónicos Interbancarios (Interbank Electronic Payments System, "SPEI"). By September 2024, the number of validated CoDi accounts had grown to 20.3 million. In Peru, the Automated Clearing House (ACH) implemented a fast payment service in November 2020. This happened in parallel with the rise of digital wallets (eg Yape and Plin), which also allow immediate transfer of funds. These developments have boosted the uptake of fast payments in Peru, which reached 157 such payments per adult in 2023.

In Bolivia, the central bank implemented QR BCB Bolivia – a standardised and interoperable QR code – for fast payments in 2022. In December 2020, the Central Bank of Argentina launched Transferencias 3.0, which comprises different fast payment services provided by the private sector, including payments initiated with QR codes. End users in Uruguay have been able to send and receive fast payments using "Toke", which is also based on QR codes, since September 2024. In 2025, Colombia plans to implement "Bre-B", which is a new central bank-owned service that interconnects financial institutions offering fast payments, such as institutions using the (private sector) FPS Transfiya and Entre-cuentas. In Central America, the countries of Costa Rica, the Dominican Republic, El Salvador, Guatemala, Honduras and Nicaragua have seen a rapid increase in digital cross-border payments, thanks to their regional real-time gross settlement (RTGS) system, Sistema de Interconexión de Pagos (System of Payment Interconnection, "SIPA") and the Transfer 365 FPS.

[2] The use of the term "fast payment systems" can vary. It sometimes refers only to the infrastructure underlying the delivery of fast payments, its governing rules and participants (see CPMI (2016, 2021)). Our interpretation is wider and includes the end user-facing services offered by multiple participants, such as the mobile payment app built on top of these infrastructures, and the rules governing these.

Overview of FPS implemented in LAC, selected jurisdictions Table 1

	Name of FPS[1]	Launch date	Payment initiation methods			
			Account details[2]	QR codes[3]	Email[4]	Mobile number[5]
Argentina	Transferencias 3.0	Dec 2020	X	X		
Bolivia	QR BCB Bolivia	Dec 2022		X		
Brazil	Pix	Nov 2020		X	X	X
Chile	Transferencias Electronicas de Fondos	2008	X			
Colombia	Transfiya	Dec 2019				X
	Entre-cuentas	Jan 2023		X		
Costa Rica	SINPE Móvil	May 2015				X
El Salvador	Transfer 365	Jun 2021	X			
	Transfer 365 – Móvil	Jun 2022				X
Mexico	SPEI	Aug 2004	X			
	CoDi	Sep 2019		X		
	DiMo	Feb 2023				X
Peru	Transferencias Interbancarias Inmediatas	Nov 2020	X			X
	Yape	Feb 2017		X		X
	Plin	May 2020		X		X
Uruguay	Toke	Sep 2024		X		

[1] The use of the term "fast payment systems", or FPS, can vary. See footnote 2. [2] End users can transfer funds using bank account details. [3] End users can pay by scanning QR codes. [4] End users use an email address to send and receive money. [5] End users send or receive money using their mobile phone numbers.

What has been driving these developments? In LAC, the implementation of FPS is often viewed as a tool to achieve public policy objectives. Fast payments have the potential to drive financial inclusion, reduce transaction costs and stimulate economic activity by providing individuals and businesses with convenient and affordable payment solutions and faster and cheaper access to funds (Aguilar et al (2024)). The implementation of an FPS has also been associated with improved access to credit (Aurazo and Franco (2024)). Through these and other benefits, greater use of fast payments could also improve financial health, which is defined as the extent to which a person or family can successfully manage their financial obligations and have confidence in their financial future (Cantú et al (2024)). In particular, it could give users the ability to pay and be paid more efficiently, save for the future and thus better withstand shocks.

Central banks traditionally play a pivotal role in the payment system to safeguard trust in their currency and ensure the safety, efficiency and integrity of payments. Generally, they have been involved in payments as operators, overseers and catalysts (CPSS (2003a)). Driven by the potential of fast payments to support some key public policy objectives, LAC central banks have been a key facilitator in the provision and adoption of fast payments, particularly by modernising the payment infrastructure and other complementary policies.

Despite the rapid adoption of fast payments in LAC, there are still many open questions. How can fast payments contribute to a digital economy? How can central banks and other public authorities further support the growth of fast payments? What specific design choices have worked well in practice, and under what circumstances? What lessons can be learned from observations from individual jurisdictions? How can central banks and other public authorities regulate, supervise and oversee FPS and the PSPs offering fast payment services, and what are the challenges?

The BIS and the World Bank organised a Workshop on "Fast payments in Latin America" in Mexico City on 21–22 May 2024 to share information, knowledge and experiences between central banks. The workshop brought together participants from 13 central banks, as well as the BIS, the World Bank and the Centro de Estudios Monetarios Latinoamericanos (CEMLA).[3] This volume collects related research, including papers presented at the workshop. It includes assessments of a range of successful experiences, such as Pix in Brazil, SINPE Móvil in Costa Rica and the Unified Payments Interface (UPI) in India.

This first, overview chapter provides a high-level summary of the key insights and issues discussed at the workshop. Section 2 discusses the link between fast payments and financial inclusion, and Section 3 explores the role of central banks in fast payments in LAC. Section 4 sheds light on initiatives in LAC to foster domestic and cross-border interoperability of fast payments. Section 5 dives into other value-added services. Finally, Section 6 concludes and gives an overview of the other chapters in the volume.

2. Fast payments and financial inclusion

Digital payments are associated with greater access to transaction accounts (Graph 1.A). Such access is a core indicator of financial inclusion (CPMI and World Bank (2016)). Digital payments are also associated with greater borrowing from financial institutions (Graph 1.B). Greater use of *fast* payments has led to greater adoption of transaction accounts and use of digital payments in general. Thus, it has been a key driver for financial access and has served as a gateway to broader financial inclusion.

As more individuals and businesses adopt fast payments, those that are still unbanked may see greater value in doing the same, due to network effects. Consequently, they become more likely to open (and regularly use) a transaction account. Given the two-sided nature of payment markets, decisions by individuals and businesses (eg merchants) can become mutually reinforcing (Julien et al (2021)). Fast payments can also help people and businesses to overcome challenges and reduce costs associated with cash handling and cash management. Also, subject to customer consent, financial institutions may use insights generated from fast payments to develop and offer personalised financial products, such as credit cards,

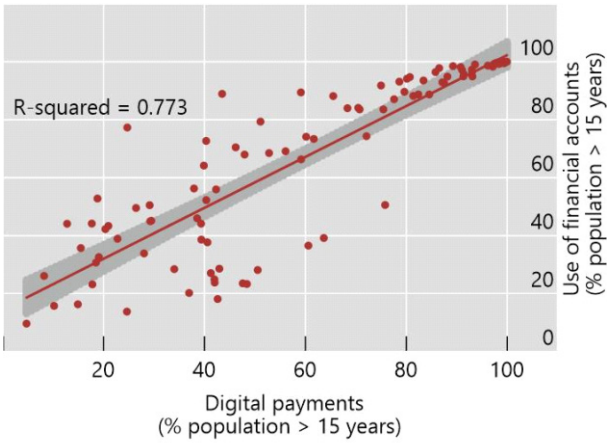
[3] Participants came from the central banks of Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Honduras, Mexico, Peru and Uruguay, and from the BIS, World Bank and CEMLA. With many thanks to Ines Avalos, Irasema Aguilar and Karla Fernandez (BIS) and to Holti Banka, Maria Teresa Chimenti, Guillermo Alfonso Galicia Rabadan, Jose Antonio Garcia Garcia Luna and Douglas Randall (World Bank) for making the workshop possible.

loans and insurance policies. Indeed, Aurazo and Franco (2024) find that the implementation of an FPS is associated with improved access to credit. For instance, in Peru, the widespread use of Yape has enabled formerly unbanked people to access credit from financial institutions.

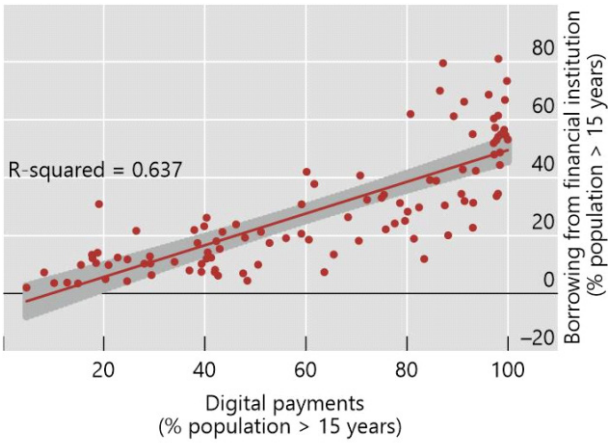
In Chile, due to the early introduction of the Transferencias Electrónicas de Fondos (TEF) FPS in 2008, the share of the population with a transaction account increased from 42% in 2011 to 87% in 2021. Around 70 million Brazilians who had not made a digital transaction before used Pix for the first time to make a digital payment. In Peru, the growth of digital wallets has gone hand in hand with a rise in the share of adults having a transaction account and an explosion in the number of fast payments – from six transactions per adult in 2020 to 157 in 2023.

Digital payment use is associated with greater access to accounts and credit Graph 1

A. Digital payments are linked to higher account access …



B. … and access to credit in the financial system



Sources: Aguilar et al (2024); World Bank, Global Financial Inclusion (Global Findex) Database; BIS.

The benefits of fast payments go beyond mere access to the financial system. Fast payments may also affect interest rates through their potential impact on monetary policy transmission. As more people acquire loans and hold deposits, the interest rate channel of monetary policy can be strengthened (Mehrotra and Yetman (2014)). To the extent this second-round effect of greater use of fast payments materialises, they could contribute to increasing the effectiveness of monetary policy and the ability of central banks to support price stability.

3. The multifaceted role of central banks in fast payments

Central banks' involvement in payments has historically been an integral part of their mandate to ensure trust in money and the safety and efficiency of the payment system (CPSS (2003b); BIS (2020)). While the exact responsibilities and activities of central banks differ across jurisdictions, they are generally involved in the development and evolution of FPS as operators, overseers or catalysts, or a combination of these (CPSS (2003a); CPMI (2016)).

As operators, central banks typically own and manage critical payment infrastructures, such as RTGS systems that settle large-value interbank payments. Over the past decade, many central banks have extended their operator role in the area of fast payments. Various approaches have been taken, ranging from limited operational involvement[4] to the full provision of an FPS (CPMI (2021)).

As overseers, and in some cases also regulators, central banks generally set standards and ensure proper governance and risk management to guarantee that FPS are safe, secure, resilient and efficient. Central banks as overseers may also set out oversight expectations or requirements regarding FPS rules governing access to the payment infrastructure to ensure safety and promote competition. Depending on its mandate, a central bank may regulate fees for participants and end users.

In their role as catalysts, central banks generally foster the development of – or migration to – new or enhanced retail payment solutions, and promote the adoption of consistent technical standards. Central banks have the power and ability to help the market overcome coordination challenges by bringing together all stakeholders, from both the public and private sector, and to incentivise the market to act. This role has been particularly significant in fast payments, where central banks have stepped in to ensure that new systems are interoperable, efficient and accessible.

The traditional operator, overseer and catalyst roles are not mutually exclusive; rather they are often mutually reinforcing. Many central banks have taken on multiple responsibilities to ensure a robust, efficient and inclusive payment system. The Central Bank of Brazil (BCB), for example, has been instrumental in Pix's development, acting as operator, regulator and catalyst. As the operator, the BCB developed and operates the core infrastructure of Pix, ensuring its reliability and accessibility. As a regulator, it mandated participation of large institutions and implemented a regulatory framework to ensure the system's safety and security.[5] As a catalyst, it promoted interoperability and competition to ensure that Pix operates efficiently and inclusively, eg by mandating unified application programming interfaces (APIs), user interface guidelines and authentication requirements.

In Mexico, the central bank also owns and operates the FPS, SPEI. In its role as operator, the Bank of Mexico ensures the system's reliability, security and operational integrity by managing its infrastructure. In this role, it also monitors the performance of SPEI and implements technological innovations to enhance its accessibility and functionality. For example, CoDi and DiMo were introduced, respectively, to promote QR code-based fast payments, and to allow end users to initiate payments using mobile phone numbers instead of account numbers. As overseer, the Bank of Mexico ensures compliance with relevant regulations and risk management frameworks to promote operational safety and soundness.

The Central Bank of Costa Rica has played a pivotal role in the introduction of SINPE Móvil. As both an operator and a catalyst, it has been instrumental in promoting the system's development and ensuring its widespread adoption. In its operator role, the central bank established the necessary infrastructure and regulatory framework to facilitate secure and efficient fast payments. It has also set technical

[4] For example, this could include final settlement of inter-PSP obligations across accounts held by the PSPs within the central bank-operated RTGS system.

[5] For more details, see this resolution issued by the Central Bank of Brazil.

standards and requirements for participating financial institutions.[6] As a catalyst, it encouraged collaboration between the public and private sector, engaging with financial institutions and fintechs to expand accessibility of financial services. This combination of roles has allowed SINPE Móvil to contribute to enhancing financial inclusion and offered a more affordable and accessible payment option for individuals and businesses.

The Central Reserve Bank of Peru has promoted the uptake of fast payments by facilitating dialogue between financial institutions and fintechs, a function that aligns with its catalyst role. In addition, the central bank has acted as regulator by mandating interoperability between the largest digital wallets, Yape and Plin (see also next section),[7] between these wallets and other payment instruments, and among PSPs. This effort expanded the reach of fast payments and allowed more institutions, including e-money issuers, to offer them.

Similarly, in Uruguay, the central bank has played a catalyst role in modernising the payment system by encouraging competition and fostering the introduction of new payment instruments, such as those based on QR codes and mobile payments. This approach has helped Uruguay enhance financial inclusion while promoting innovation in its payment landscape.

In other countries, the central bank has issued regulation to ensure the robustness and efficiency of FPS. For instance, in February 2022 the Central Bank of Chile issued a regulation to create, regulate and oversee retail payment ACHs.[8] In 2023, Colombia's central bank was empowered to regulate the retail payment system (Article 104, Law 2294). This enabled the central bank to enforce interoperability between fast payment services (see next section).

As operators, overseers and catalysts, central banks face various challenges arising from the rapid pace of technological change and evolving payment landscape. Issues like fraud and consumer protection have long been a concern, and are not new. Nonetheless, central banks that operate an FPS may have to further strengthen efforts to address these risks. For instance, given the actions of bad actors, central banks may need to enhance their fraud detection mechanisms and ensure the implementation of robust security standards – particularly if they were previously not responsible for operating an FPS or other type of retail payment system (World Bank (2023)). Additionally, central banks face the challenge of balancing private sector interests conflicting with the broader public good.

4. Domestic and cross-border interoperability

Domestic interoperability across payment instruments, schemes or systems enables the transfer of funds between different types of accounts, such as a bank account and an e-money account, regardless of the PSP offering the accounts. Such

[6] See here the regulatory framework of SINPE Móvil.

[7] See this circular issued by the Central Reserve Bank of Peru.

[8] For more details, see this central bank circular.

interoperability can help overcome market fragmentation and increase competition between large and small players, which may ultimately lead to lower end user fees (see Bianchi et al (2023)). Domestic interoperability may also improve end users' payment experience to the extent that they no longer need to have multiple payment instruments or accounts to meet most if not all of their payment needs.

Fostering interoperability requires careful consideration of potential unintended consequences. Some unintended effects may relate to a decline in coverage. For instance, in the mobile money market, mandatory interoperability may reduce telecom infrastructure coverage, particularly in rural areas where investment costs are higher (see Brunnermeier et al (2023)). Similar risks may arise in the payments market more generally, for instance mandatory interoperability between PSPs might decrease the presence of physical access points (eg automated teller machines (ATMs), bank branches), especially in rural areas. This may be particularly relevant where different business lines cross-subsidise one another. Finally, where interoperable payment services substitute for card payments, there can be differences in fraud protections and customer rewards, which may influence use.[9]

Various LAC jurisdictions are promoting or even enforcing interoperability in their payment markets. In Colombia, the central bank has introduced a new regulation to establish mandatory interoperability between the fast payment platforms currently available in the country. It will also implement "Bre-B", a brand name to identify interoperable fast payments enabled by PSPs, in which it will implement a centralised directory. Similarly, in Peru, the central bank issued a regulation in October 2022 to mandate interoperability between Yape and Plin and with other payment instruments and PSPs.

In Bolivia, the central bank has issued a standardised QR code system called QR BCB Bolivia to facilitate fast payments. It has also mandated interoperability across all digital payment channels by requiring PSPs to support QR code payments for their digital banking platforms and wallets. Similarly, in April 2024, the Central Bank of Argentina issued a regulation requiring all digital wallets provided by commercial banks and other PSPs to be compatible with all QR codes available in the market and vice versa (see also next section).

Jurisdictions in the Americas have taken some initiatives to foster cross-border payment system interoperability. Cross-border interoperability (or interlinking) allows banks and other PSPs from different jurisdictions to transfer payments, such that end users can seamlessly transact with each other regardless of their geographic location or choice of PSP.[10] In Central America, the regional initiative SIPA allows for cross-border interoperability by interlinking the RTGS systems of six jurisdictions in the region. SIPA payments are cheaper and faster than other available cross-border payment methods, such as services offered by international money transfer operators. In addition, in June 2023 the same Central American jurisdictions launched Transfer365 CA-RD, a system for instant cross-border payments. Since then, the

[9] Especially credit cards often give rewards to users, paid for by merchant discount rates. While these rewards can encourage card use, changes in the size of rewards have been found to have only small effects in practice (see Ching and Hayashi (2010); Arango et al (2015)). In some economies with widespread use of fast payments (eg Brazil), credit and debit card payments have continued growing.

[10] See Boar et al (2021) for a discussion on interoperability between payment systems across borders.

initiative has rapidly achieved scale in terms of both number and value of cross-border payments. It is particularly popular for payments from El Salvador to Guatemala, which is in part driven by trade and business-to-business payments.

Various other cross-border initiatives are being explored in LAC to address the high costs and long processing times of cross-border payments. For instance, Brazilians can pay with Pix at some merchants in Uruguay (since December 2023), Paraguay (since February 2024) and Argentina (since April 2024) through isolated private solutions. Another potential solution to improve cross-border payments in the Americas is to interlink jurisdictions' FPS. But there are key challenges and barriers to overcome first. For instance, anti-money laundering/combating the financing of terrorism (AML/CFT) regulations vary across jurisdictions. In addition, cross-border interlinking is more likely to be successful if FPS are widely used and available in all participating jurisdictions, and it may require implementation of common standards, eg harmonised messaging formats. The BIS Innovation Hub project Nexus is a prominent example of how to interlink domestic FPS to enable instant cross-border transactions. Nexus is a collaboration of the central banks of India, Malaysia, the Philippines, Singapore and Thailand, and the BIS Innovation Hub Singapore Centre.[11]

5. The role of further value-added services

Many FPS provide value-added services that deliver enhanced value to participants and a better user experience than traditional payment methods. Examples include request to pay (RTP) functionality, proxy lookup functionality, scheduled payments and QR code payments (CPMI (2021); World Bank (2021b)). Through implementation of value-added services, an FPS can expand its use cases. Standardisation of value-added services can also enable interoperability between different payment platforms and instruments. Central banks, depending on their mandates and degree of involvement in the provision of fast payments, can play a critical role in promoting the development and harmonisation of these services, such as by setting rules for participation and ensuring that overlay service providers adhere to operational standards (World Bank (2022)).

One of the most prominent examples of a value-added service is payment initiation via QR codes, which has gained widespread popularity among both merchants and consumers. QR codes offer a low-cost and user-friendly solution for consumers and businesses to initiate fast payments.

Central banks in LAC are actively promoting the introduction and use of QR codes to propel fast payments and promote digitalisation. In Argentina, the central bank has launched an interoperable QR code system as part of Transferencias 3.0 to expand its use cases. This service allows users to make payments by scanning any QR code using any digital banking app or digital wallet. Interoperability is ensured not only at the user interface level but also in the back end, allowing payments to be processed by any financial institution or PSP, regardless of who generated the QR

[11] For more details, see Project Nexus: enabling instant cross-border payments.

code. This effort has enhanced interoperability and contributed to the growth of digital payments in Argentina.

SINPE Móvil, the FPS launched by the Central Bank of Costa Rica, has enabled peer-to-peer transfers using mobile phone numbers as aliases. To expand the service, the central bank is now incorporating QR code functionalities, allowing users to send and receive payments without needing payee account numbers or mobile phone numbers. Other new features, such as RTP, are being explored to facilitate more complex payment use cases. These can include invoice and bill payments, recurring payments and subscriptions, and embedded payments in business-to-business (B2B) transactions.

The Bank of Mexico has also been actively promoting value-added services. The launch of CoDi in 2019 enabled users to make and receive fast payments via QR codes and near field communication (NFC) technology. Building on this initiative, the central bank introduced DiMo in 2023. DiMo expands the ways to send transfers by allowing users to make fast payments using only a recipient's mobile phone number. DiMo also allows participation by non-bank players, such as fintechs, to further drive adoption of digital payments.

In Peru, the central bank issued a regulation to establish a common standard for QR code payments in 2020. In addition, PSPs in Peru are required to register with the BCRP QR Registry if they provide wallets that allow for QR code payments and/or if they issue QR codes.

6. Conclusion and overview of chapters

By making available the research presented at the workshop on "Fast payments in Latin America" and related work, this volume sheds light on various aspects of fast payments and jurisdiction experiences, with a specific focus on the LAC region. The rest of the volume is organised as follows:

The first chapter, by Jose Ornelas and Matteus Sampaio, looks in greater depth at Pix in Brazil, and its complementarities with other means of payment. In particular, the authors find that Pix increases the use by individuals and businesses of the four most common payment services in Brazil. They also find that Pix has contributed to an increase in the number of bank accounts and the use of and access to credit, benefiting both banks and non-bank financial institutions. Their findings indicate that the implementation of new payment systems like Pix yields advantages not only for businesses and individuals but also for the broader banking and payment industry.

The second chapter, by Douglas Araujo, Carlos Cantú, Allan Chinchilla, Cecilia Franco, Jon Frost and Andrea Oconitrillo, looks into the experience of SINPE Móvil in Costa Rica. The authors find that higher SINPE Móvil use has been correlated with lower cash withdrawals, a greater number of users and lower average transaction values. Using a synthetic controls approach comparing Costa Rica with peer jurisdictions, they show that wide adoption of SINPE Móvil led to lower non-interest expenses for Costa Rican banks. This suggests that payment innovation can enhance bank efficiency.

The third chapter, by Giulio Cornelli, Jon Frost, Leonardo Gambacorta, Sonalika Sinha and Robert Townsend, looks into the experience of UPI in India. The authors argue that the strong growth of UPI relates to the ease of development of applications, and an open, technology-agnostic architecture that enables transactions across multiple third-party application providers. They also argue that the system has been strengthened by active partnership with the private sector. Appropriate regulatory conditions have been critical in laying the foundation for this success, and in addressing challenges that have arisen.

Adoption of new technology is, fundamentally, a sociological process. Understanding this process requires an interdisciplinary approach. In the absence of laboratories and controlled experiments, the best means to understand how to promote the adoption of fast payments, and digital payments more generally, is to compare experiences across different jurisdictions. Dialogue between authorities from different jurisdictions can help to give them access to effective practices and lessons from similar projects.

This volume represents a snapshot of current research on this evolving topic, with a focus on the LAC region, as part of a broader research agenda at the BIS, World Bank and central banks, and among academic researchers across the region. The authors of these chapters will continue to contribute new work in this area, in the hopes of supporting sound policymaking and valuable research insights for a wide audience.

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Payment technology complementarities and their consequences on the banking sector: evidence from Brazil's Pix*

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Abstract

In this paper, we employ an instrument and individual-level banking data in Brazil to examine the effects of a novel payment technology, Pix, on the use of other payment technologies and its impact on the banking sector. We find evidence that Pix increases use of the four most common payment technologies in Brazil among individuals and firms. Furthermore, our empirical evidence suggests that Pix contributes to an increase in the number of bank accounts, their use and access to credit, benefiting different types of banks. The findings indicate that the implementation of new payment technologies yields advantages not only for firms and individuals but also for the broader banking and payment industry.

JEL classification: D14, E42, E51, E58, G20, O1, O16, O33, Q54.

Keywords: Natural disasters, instant electronic transfers, Pix, payment technologies.

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1. Introduction

For a long time, payment technologies have been known to bring an array of different benefits to society. The payment literature is filled with evidence of the positive effects of new payment technologies on welfare, consumption and economic growth from technologies such as mobile money, instantaneous transfers (eg Pix, Zelle, UPI, Swish) and card payments (see eg Jack and Suri (2014), Higgins (2019), Bachas et al (2018), Bachas et al (2021), Balyuk and Williams (2021), Crouzet et al (2023), Dubey and Purnanandam (2023) and Chodorow-Reich et al (2020)). That is why more than 100 countries are experimenting with instantaneous payment technologies (Duffie (2022) and Frost et al (2024)).

However, new payment technologies have faced opposition from sceptical players in the government and banking industry. They fear that an easy, cheap and instantaneous way of transferring money could decrease the barriers to switching banks and substitute more profitable payment methods, thus increasing competition, decreasing profits and disrupting the banking industry (Bogaard et al (2024), Fed Board (2022) and BIS (2020)). For example, the United States Congress passed a bill to stop the development of the digital dollar, and the biggest banks in the country delayed their participation in the new payment technology developed by the Federal Reserve, called FedNow (Feltman (2019), Marek (2024), Marek (2023) and Versprille (2022)).[1] However, these players seem to underplay the complementarities between payment technologies and financial services. For example, to use payment systems or financial services, individuals need to pay the fixed cost of learning how to use bank accounts. Thus, an improved payment method can make individuals face these fixed costs, increasing the use of bank accounts, financial services and other payment methods.[2] The opposing forces of substitution and complementarity play a crucial role in determining the effects of new payment technologies on the banking sector.

Given the importance of payment technology and the resistance that it faces, this paper estimates the effects of a new payment technology on other payment methods and, more broadly, in the banking sector. For this, we study Pix, the new instantaneous bank transfer launched in November 2020 by the Central Bank of Brazil (BCB). Pix cost only USD 4 million to develop, generated a cost savings of USD 5.7 billion in 2021 alone and is expected to help generate 2% of Brazil's GDP by 2026 according to an ACI Worldwide study.[3] Pix is a technology for instantaneous bank-to-bank transfers [4] that quickly exploded in popularity in Brazil with 149 million people and 15 million firms using it as of December 2023. In contrast to the US Fed's approach, the BCB

[1] When FedNow launched in July 2023, just 35 out of over ten thousand financial institutions joined. By July 2024, this number had increased to around 800.

[2] One simple example is an attractive credit card offer. To enjoy this offer, individuals will be willing to pay the fixed cost of establishing a bank account which could lead them to deposit more money, acquire loans, and have access to a debit card.

[3] See ACI Worldwide study https://www.aciworldwide.com/wp-content/uploads/2022/04/Prime-Time-for-Real-Time-Report-2022.pdf

[4] All transactions for individuals are free. Banks can only charge fees for firms' transactions. During the beginning of Pix, most banks would not charge fees. As of December 2023, important Brazilian banks continue to make transactions for free for firms.

required all major banks to adopt Pix,[5] making it ubiquitous in the country. At the same time, in figure 1, we see that the proportion of cash transactions dropped from 42% in 2020 to 22% in 2023 and money in circulation dropped 10% during the same period. We also witness a growth in the use of other payment methods and financial services performed by banks, while the access channel used by the population to access bank services has shifted from physical access to cellphone access. At the macro level, we see that the introduction of Pix seems to decrease the use of cash and accelerate the digitalisation of payments and banking in Brazil.

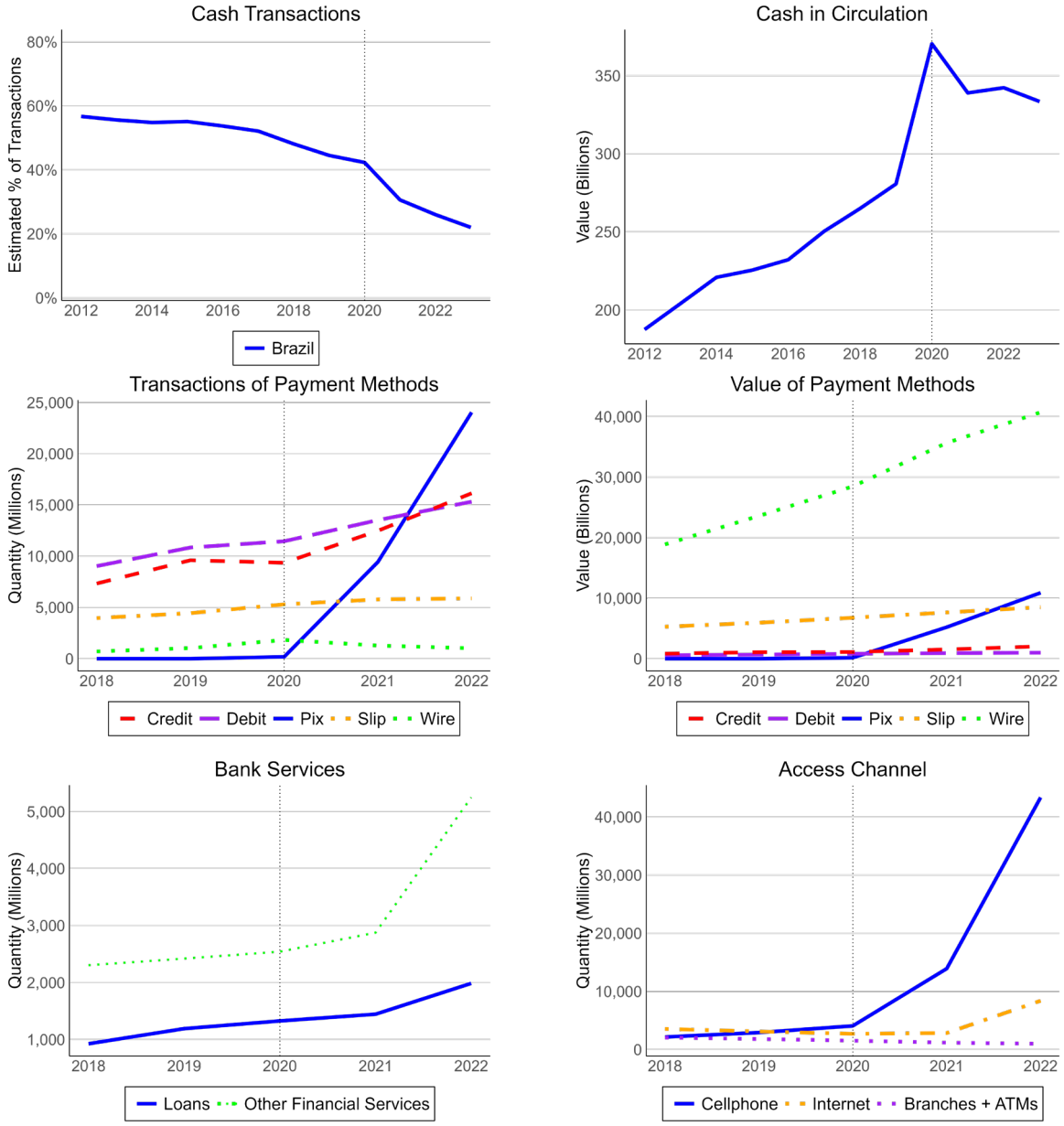
In order to formally study the effects of Pix on the payment and banking sector, we leverage private individual-level data on the uses of payment and bank services for the entire population of citizens and firms in the country through the BCB. In the case of payment methods, the challenge is to empirically separate the substitutability or complementarity of Pix on other methods from changes in consumer preferences. In the case of the banking sector, we face the challenge of omitted variable bias. To solve those challenges, we use an instrumental variable approach, and floods as our instrument. We argue that floods can be a great instrument for several reasons. First, like most weather events, floods can be considered random draws from the climate distribution when controlling for the endogenous ex ante risk of flood in a municipality. Second, floods are a common and recurring natural disaster in Brazil, affecting 84% of the municipalities between 1991 and 2022, giving us statistical power. Third, floods are sudden and swift, making them difficult to predict. Fourth, we expect a strong first stage impact of floods on Pix use through the informal insurance channel, as has been shown by other researchers. In particular, several studies show the crucial role that instantaneous transfer methods play during shocks (Jack and Suri (2014), Blumenstock et al (2016), Riley (2018)). Finally, we do not expect floods to affect other payment methods in Brazil because they are not suitable for informal insurance. Compared to Pix, they are more expensive, harder to use, slower and available through fewer banks during fewer hours. Moreover, since the last payment method introduced in Brazil was decades ago, if floods were to affect long-term use of other payment methods, they would have already done so.

However, instead of blindly believing the exclusion restriction of our instrument, we begin our work by studying the effects of floods on our main variables before the launch of Pix. Our goal is to show that prior to Pix, the exclusion restriction used to hold. For our analysis, we examine the use of payment methods, bank accounts and bank services at the municipal level using a staggered differences-in-differences design. In this case, our empirical strategy relies on the parallel trends assumption based on never-treated units, which translates to our variables following a parallel trend when controlling for municipality and time x flood risk fixed effects in the absence of treatment (flood). Our municipality fixed effect captures fixed spatial characteristics, and our time-fixed effect interacted with flood risk allows us to capture any common trend, so as to untangle idiosyncratic shocks to areas while permitting differential trends for municipalities with similar probability of floods.

[5] The Central Bank imposed that any financial institution with more than 500 thousand accounts must join Pix. As such, 38 financial institutions were required to join and more than 700 other banks and financial institutions choose to join at the launch.

Time series of macro variables in Brazil

Figure 1



Source: BCB

We show that floods obey the exclusion restriction in the period before the introduction of Pix, meaning that floods do not affect the use of other payment methods, bank accounts or bank services prior to the launch of PIx. This increases our confidence in the validity of our instrument. We also graph the effects of floods in our variables after Pix is introduced to find that floods spark a continuous growth in the use of Pix with the number of active users of Pix increasing to more than 3%, and the number of transactions and value transacted among individuals and firms increasing 4-5%. Moreover, we show that after Pix was launched, use of other payment methods, bank accounts and banking services displayed a similar pattern, remaining stable immediately after a flood and then showing signs of growth after a

few weeks. This pattern is consistent with our exclusion restriction assumption that floods do not directly impact our variables. It is also consistent with people and firms slowly switching to digital payments and services after they become active Pix users.

To better quantify the effects of Pix, we turn to our instrumental variable approach. We study the effect of an increase of 1% in the number of active Pix users on the use of other payment methods. We find an increase of 5.7% in the number of payment slip transactions, of 4.5% in the number of bank wire transactions and of 1.2% in the number of firms accepting debit cards. We also find that an increase of 1% in the number of active Pix users in a municipality leads to an increase of 0.45% in the number of people creating a credit relationship, a 0.25% increase in the number of people creating a relationship with a new bank and a 0.80% increase in the number of people opening bank accounts for the first time.

Moreover, we expand our results on the creation of bank accounts by studying the behaviour of people and firms that already have bank accounts. First, instead of counting bank accounts, we count the number of accounts that are actively used using transaction data. This is especially relevant to Brazilians since they have a massive number of bank accounts due to employers being able to dictate employees' choice of bank. By the end of 2023, Brazilians averaged 6 accounts per person, a big growth from 3.5 accounts in 2020. We find that the number of active bank accounts grows more than 4% for people and 2% for firms following a flood. Second, we study self-transfers, which are defined as transfers between accounts owned by the same person or firm but in different banks. Since Brazilians have so many bank accounts and each bank account has its different benefits and comparative advantages, we believe that self-transfers are a good proxy for the optimisation of bank accounts. We document a growth of active users of self-transfers of more than 4% for people and firms following a flood.

To address the belief that instantaneous payment technologies would make traditional brick-and-mortar banks obsolete and that digital banks and fintechs would take over, we study how the benefits to the banking sector are distributed among those two types of banks. First, we study Pix transactions to find that for individuals, the growing popularity of Pix was shared almost equally between digital and traditional banks. For firms, we present evidence that seems to indicate that traditional banks were favoured over digital banks. This is consistent with the fact that traditional banks are more established and can offer more complex services to firms. Second, we study the growth in the number and active use of bank accounts. We find evidence that the growth of new accounts seems to favour digital banks, while the growth in active use of accounts seems to favour traditional banks in the case of firms. This is consistent with the fact that smaller digital banks have more room to grow their number of accounts, while traditional banks have more to gain from an increase in the number of active users.

Finally, we study the mechanism that makes Pix popular after a flood. We investigate whether people would use Pix as an informal insurance tool after a natural disaster. We study remittances, which we define as a transaction between two people in different municipalities. We find that, during the week of the flood, there is a significant drop in the outflow of money, while the number of inflow transactions increases, together with the number of people outside the municipality that are sending money to people inside the municipality affected by the disaster. We document a permanent change in behaviour following the flood, with remittances

growing around 2-4% after a year, and a network effect of Pix, with people outside the municipality increasing their use of Pix to send money.

Taken together, our results suggest that the introduction of Pix in Brazil has led to a financial revolution, with significant growth in bank accounts, bank services and other payment methods. We also find the crucial role that Pix plays during an economic shock, acting as an informal insurance tool. Moreover, we shed light on the benefits that different types of banks receive from Pix, with digital banks expanding their number of accounts and traditional banks expanding their number of active accounts. Our results suggest that fears of displacement of other payment methods and disruption of the banking sector are unfounded, with much to be gained not only by people and firms but also by the payment and banking sectors.

Our research directly contributes to the policy debate on whether new low-cost instantaneous payment systems could hurt the payment and banking industry. This debate has delayed or completely stopped the development of new payment technologies in several countries. Our work contributes to this debate by showing the complementarities between Pix and other payment methods while also showing the increase in the use of bank accounts and bank services.

Academically, we make three major contributions. First, we add to the payment literature by studying the benefits and complementarities of different payment methods. Many papers discuss the benefits of payment methods on welfare, consumption and economic growth (eg Jack and Suri (2014), Suri and Jack (2016), Riley (2018), Aron (2018), Balyuk and Williams (2021), Koont et al (2023), Wang, Bian et al (2023), Brunnermeier et al (2023), Garratt et al (2022), Haendler (2022), Aker et al (2020), Brunnermeier et al (2019) and Dubey and Purnanandam (2023)). Another related literature on payment adoption studies how shocks can help overcome adoption barriers such as coordination failures, fixed costs and lack of trust (eg Rosenstein-Rodan (1943), Rochet and Tirole (2006), Katz and Shapiro (1986), Huynh et al (2022), Higgins (2019), Bachas et al (2018), Bachas et al (2021), Chodorow-Reich et al (2020), Crouzet et al (2023), Lahiri (2020), Gupta et al (2020) and Breza et al (2020)). We add to the literature by not only showing how a shock can increase the popularity of a payment technology but also that it can complement different payment methods, increasing the use of other beneficial payment methods and accelerating the digitalisation of the economy.

Second, we add to the bank competition literature by studying the effects of a payment method in the banking sector. A growing literature studies the effects of new technologies in the banking sector (see eg Ouyang (2021), Yannelis and Zhang (2023), Beaumont et al (2022), Babina et al (2023), Parlour et al (2022), Gopal and Schnabl (2022), Di Maggio and Yao (2021), Chava et al (2017), Ghosh et al (2022), Erel and Liebersohn (2022), Buchak et al (2018), Berg et al (2022), Sarkisyan (2023) and Argentieri Mariani et al (2023)). We add to the literature by showing that instantaneous payment methods can lead to the expansion of bank accounts, account use, access to credit and bank services. In addition, we expand our research to show how these benefits are spread across different types of banks.

Third, we add to the literature on natural disasters and informal insurance by studying the role of Pix as an informal insurance tool. Informal insurance networks have been studied by an extensive literature to bring an array of benefits, especially for the most vulnerable families (eg Jack and Suri (2014), Dell et al (2014),

Blumenstock et al (2016), Riley (2018), Balyuk and Williams (2021)). We add to the literature by showing that shocks can lead to a long-term change in informal insurance behaviour and that the use of a new informal insurance tool is spread to other municipalities through people's networks.

The remainder of the paper is organised as follows. Section (2) describes the institutional background, informing in more detail the payment technologies in Brazil and our instrument, floods. Section (3) describes our main data sources. Section (4) describes our empirical strategy. Section (5) presents our main results. Section (6) presents our robustness checks. Section (7) concludes.

2. Background

In this section, we familiarise the reader with the Brazilian banking and payment landscape, discuss the history of floods in Brazil and compare the Pix initiative with other countries.

2.1 Payment technology in Brazil

Like many countries, Brazil until recently lacked a modern way to transfer money between bank accounts and make payments. Almost 20 years after the last major innovation in this area, the BCB developed Pix in November 2020 with the goal of allowing users to make transfers and payments in a few seconds, 24 hours a day, seven days a week. In essence, Pix is an instantaneous transfer method between bank accounts that is completely free for individuals.[6] Firms may incur a small percentage fee for transactions that varies among financial institutions.[7] But some of the most important financial institutions in Brazil still do not charge fees for Pix transactions.

To use Pix, senders initiate a transaction by inputting the receiver's key into their bank mobile app. The key uniquely identifies the receiver and takes the form of a phone number, email, random key, quick response (QR) code or tax identification number.[8] The receiver can also initiate a transaction by generating a dynamic QR code with embedded identifiers and the value of the transactions. This allows for payments to be instantly verified without the need for a manual check of bank balances, thus facilitating in-person and online purchases.

Pix gained popularity due to its speed, convenience and smaller fees, and for being present in most banks (nearly 800) in Brazil since its inception. By 20 December 2023, 149 million people and 15 million firms had used Pix, and it became the most

[6] We use term "bank account" to refer also to payment accounts used by fintechs and payment institutions.

[7] In this paper, the terms "financial institutions" and "banks" are used interchangeably. These terms encompass financial institutions in general (including banks and credit unions) and payment institutions.

[8] Those are CPF for individuals and CNPJ for firms. These numbers are not as sensitive as their US equivalents, social security number (SSN) and employer identification number (EIN). CPF and CNPJ are how we uniquely identify everyone in our research.

popular transaction method in Brazil, surpassing cash, according to a McKinsey study (Bretas (2023)). In 2023, USD 3.5 trillion, almost twice the Brazilian GDP, were transferred in 42 billion Pix transactions, averaging 200 transactions per capita.

Overall, there seems to be a clear substitution from cash to Pix, but it is hard to tell whether Pix substitutes for other payment methods. We investigate the other four most popular payment methods in Brazil: bank wire (TED), payment slip (Boleto), credit card and debit card. Bank wire (TED or electronic funds transfer) is a system similar to Pix that permits fund transfers between bank accounts. For the transfer, users would need all bank information from the recipient, the transfer could take from a few minutes up to the end of the day and it only works during business hours.[9] Additionally, there are around only 100 institutions able to do TED compared to more than 800 institutions able to do Pix, and users are usually charged an expensive flat fee for transactions, so the method is more common for large transfers, especially between firms.

Boleto is a payment method that consists of a voucher with a unique barcode. It differentiates from TED because of it has a smaller flat fee, it does not require a bank for the sender and it allows for instructions inside the voucher, eg extra fees for late payment. Boleto is a very popular person-to-business (P2B) payment method, often used for utility bills and online purchases. However, this instrument takes up to 3 days to clear, it only works during business hours and there is a limited number of banks that offer this service.

Credit cards are a very useful payment method that allows consumers and firms to make secure transactions in person and online. Firms incur fixed costs to set up card payments and large percentage fees are taken for each transaction. Firms may also have to wait for 30 days to receive their money, usually with the option to pay extra fees to receive the money in a day. Users usually need access to a credit line with a bank and need to pay annuities. Debit cards are similar but firms pay smaller fees compared to credit cards and receive the money earlier, and users do not need a credit line and have their money discounted from their bank account right away.

2.2 Floods

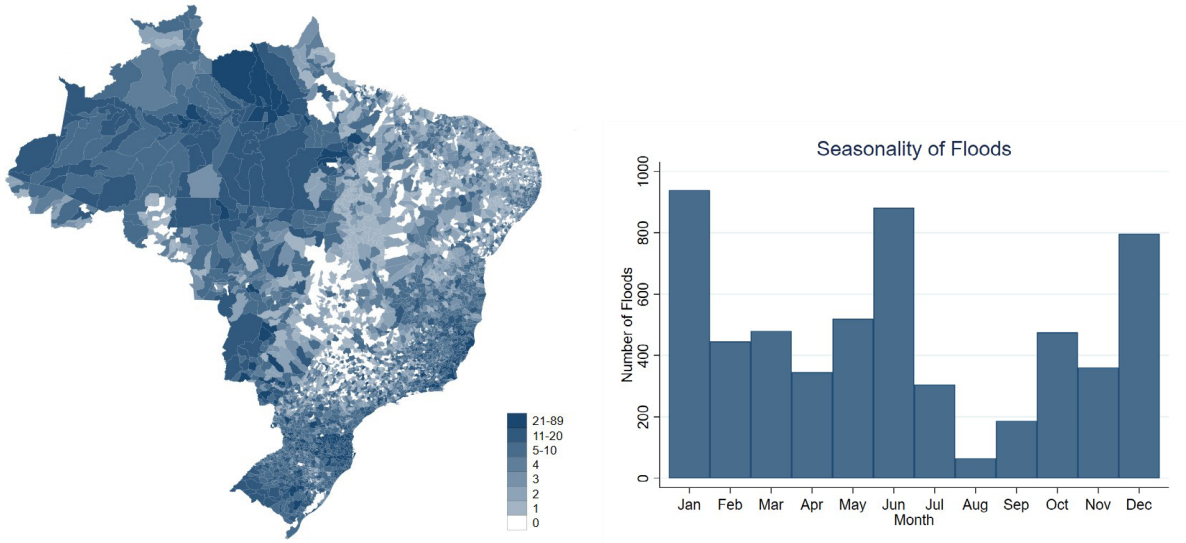
According to the World Health Organization, floods are the most frequent type of natural disaster in the world with 2 billion people affected between 1998 and 2017. In Brazil, floods are one of the most common natural disasters along with droughts. They happen suddenly and swiftly and affect most parts of the country, with 84% of municipalities being impacted between 1991 and 2022. More than 6000 disasters occurred in the last 10 years, with floods happening all year long – see figure 2. It is estimated that they caused more than 2,000 deaths, 140,000 hospitalisations and USD 16 billion in losses. Of those losses, only 1.2% were covered by federal assistance. It is also important to note that in Brazil, the money given by the government following a natural disaster cannot go directly to the people affected; instead, it must be used for "civil and defence" expenses (eg infrastructural projects).

[9] Business hours are usually defined as 8 am to 5 pm on business days. Transfers outside those hours will only be processed the next business day, thus incurring extra days to the normal clearing time.

To identify when a flood occurred, we use the natural disasters reports by the National System of Civil Protection. Those reports are filled by municipalities to inform federal authorities of damages.[10] The federal authorities then access the veracity of the information and help the municipality with logistic and financial support. We collect data on municipalities that were able to claim State of Emergency or State of Public Calamity due to floods from 1991 to 2022.

Floods in Brazil

Figure 2



a) Floods by Municipality - 1991 to 2022

(b) Floods by Month - 2013 to 2022

Source: SINPDEC.

3. Data

To study payment methods, we collect identifiable individual-level data on Brazil's top 5 most used payment methods: Pix, payment slip (Boleto), bank wire (TED), credit card and debit card. For Pix, we collect transaction-level data from the Instant Payments System (SPI) from its launch in November 2020 to December 2022.[11].From there, we generate weekly data for transactions, value transacted and unique users. In order to investigate informal insurance, we collect data on remittances between people outside the flooded municipality and people inside it, thus being able to see how this mechanism plays a role in the expansion of Pix following a flood. Moreover,

10 There are subtle differences between the classification of a flood by the federal authorities depending on the cause of the flood. For simplicity, we aggregate those disasters under the term flood. They are "Alagamentos" (overflow of water at certain areas), "Inundações" (overflow of water from a body of water), "Enxurradas" (water running off at high speed), and "Tempestade Local/Convectiva" (local storms/convective storms with possibly intense rain, hail, wind, and lightning).

11 SPI has all transactions except transactions internal to the banks.

we investigate which banks are being used the most to make Pix transactions and whether people are using Pix to self-transfer funds from one type of bank to another.

For payment slips, we collect all individual transactions from the Interbank Payments Chamber (CIP)[12] from 2019 to 2022. We aggregate the data weekly at the municipality level to generate the number of transactions, value transacted and unique users.

For bank wires, we collect all transactions from the Booking Transfer System (STR) and Funds Transfer System (SITRAF) from 2019 to 2022.[13] Similarly, we aggregate data weekly at the municipality level to generate the number of transactions, value transacted and unique users.

For credit and debit card acceptance, we collect data on the volume of transactions at the firm and date level[14] from CIP from 2019 to 2022. Note that, differently from Pix, Boleto and TED, we do not have transaction-level data for credit and debit cards. Thus, we will only know which firms accepted card payments, and the total value transacted at that date. Therefore, we will construct a measure of how many firms are accepting card payments, and the total value transacted in each municipality and week.

For financial services data, we collect data on every credit relationship between financial institutions and individuals and firms from the Credit Information System (SCR) from 2019 to 2022. This dataset identifies the lender (bank) and the borrower (firms and individuals) in each credit relationship. The data set reports a set of loan and borrower characteristics, including loan amount, type of loan, credit line, interest rates and repayment performance. Since the use of credit cards is a form of loan, we are also able to access the number of people and firms with credit cards, and their total credit card balance.

To study people and firms' behaviours toward bank accounts, we collect data on bank account opening and closing dates by institution and account holder from the Client Registration in the National Financial System (CCS) from 2019 to 2022. With this dataset, we are able to see, based on their unique ID, which individuals and firms opened or closed bank accounts each day for each bank ID, when they opened their first account and their current stock of accounts.

As mentioned before, our flood data come from natural disaster reports filed by municipalities to the National System of Civil Protection. We collect data on municipalities that were able to claim a State of Emergency or State of Public Calamity due to floods and were verified by the government from 1991 to 2022. We use this dataset to determine when a flood occurred in order to use it as our instrument.

We collect monthly balance sheet data from each bank branch in the country. This dataset is known as ESTBAN (Estatística Bancária Mensal), which is compiled by the BCB every month. We use the confidential version of this dataset to have access

12 CIP is a non-profit civil society clearinghouse that is part of the Brazilian Payments System that operates the SILOC (Sistema de Liquidação Diferida das Transferências Interbancárias de Ordens de Crédito), where the Boletos are cleared.

13 STR is operated by the BCB, while SITRAF is operated by CIP. STR and SITRAF do not register transactions internal to the bank.

14 This dataset does not include store-branded cards nor meal vouchers.

to extra variables, such as deposits by people and firms, loans, physical cash inventory and assets.[15] Our data span all months from 2019 to 2022.

Municipality-level data are compiled from multiple sources, with the Brazilian Institute of Geography and Statistics (IBGE) and Anatel being the main ones. From these databases, we can create control variables that vary over time to complement our fixed effects such as the municipality's population, GDP, taxes collected, education statistics and internet access.

4. Methodology

4.1 Staggered differences-in-differences

The first step to evaluate the effect of Pix on other payment methods is to find a good instrument, and we believe that floods can be this. (We will discuss this further in the next section). To increase the credibility of our exclusion restriction, we show that, prior to Pix, floods did not affect the use of other payment methods. We also show that the effect of floods on other payment methods is not immediate. This is consistent with the idea that floods affect the use of Pix first, and then the use of other payment technologies later.

For this, we use a methodology called staggered differences-in-differences, where floods are the event that triggers Pix adoption. One of the reasons why we would expect floods to affect the use of Pix is because of informal insurance. The literature has shown that people form informal insurance networks so that if a member of that network suffers a shock, others insure them by sending money. For example, Blumenstock et al (2016) showed that, after a natural disaster, people make transfers to people affected by the shock; Jack and Suri (2014) showed the importance of transfer technology in increasing their informal insurance network. We expect Pix to be used in those situations because of its lower price, speed and convenience. Compared to other payment methods, the only one that could be used in the case of remittances is TED; however, the high flat price of TED transactions combined with its hard-to-use interface, limited availability, unpredictable transfer duration and sparse number of participating banks makes TED an improbable candidate for informal insurance. We also believe that floods should not change long-term behaviour towards older technologies because of the high frequency of floods in Brazil. Our rationale is that if people and firms were to change their behaviour towards older technologies because of a flood, they would have done so already.

Like most weather events, floods can be considered random draws from the climate distribution in a given spatial area. We follow the literature on extreme weather events, summarised in Dell et al (2014), to evaluate the effect of floods in a municipality in Brazil. In this literature, it is assumed that the occurrence of a flood is a random event when comparing regions of similar probability of flooding. Thus, the

[15] Our cleaning of this data is similar to Bustos et al (2020), we define bank deposits as the sum of deposits in checking accounts, savings accounts, and term deposits as reported by the ESTBAN dataset of the Central Bank of Brazil.

likelihood of being flooded ex-ante is endogenous and controlled for, while being flooded is exogenous and allows identification.

The main assumption of this approach is conditional parallel trends based on never-treated units. This assumes that, without treatment, treated units would move parallel to never-treated ones. Due to our municipality and time x flood risk fixed effects, our assumption translates to similar municipalities with similar flood risk moving parallel in the absence of a flood.

$$y_{m,t} = \sum_{k \neq -1} \beta_k Z^k_{m,t} + \mu_m + \theta_{Risk,t} + \epsilon_{m,t} \qquad (1)$$

In equation (1), $y_{m,t}$ is the variable of interest measuring the use of a type of payment technology or the use of a banking service in municipality m at time t (eg log Pix users or log quantity of bank accounts). Municipality-fixed effects μ_m capture fixed spatial characteristics, untangling the impact from various potential sources of omitted variable bias. Time fixed effects interacted with flood risk $\theta_{Risk,t}$ allow us to capture any common trend to untangle idiosyncratic shocks to areas while permitting differential trends for municipalities with similar probability of floods. In our case, we define flood risk using ex-ante flood occurrences from 1991 to 2018. We then divide municipalities into quintiles based on those numbers. The first quintile contains the municipalities that were never flooded, and the fifth quintile contains the most flooded municipalities. This allows us to compare municipalities with similar probabilities of getting flooded to each other and allows for differential trends in those groups to account for the endogeneity in the risk of floods. $Z_m{}^k{}_{,t}$ is a dummy that equals 1 if municipality m was hit by a flood k weeks ago. ϵ_{mt} is the error term. For our primary analysis, we decided to use a simpler two-way fixed effects (TWFE) regression model without control variables. We believe it is better to show the most straightforward results first, and then change the model and add controls later to see if the results are robust.

We analyse two different periods, namely "before Pix" and "after Pix". The period "before Pix" consists of January 2019 until 16 November 2020, and the period "after Pix" consists of 16 November 2020 until 20 December 2022. As a robustness check, we also use the period from March 2020 until 26 November 2020 as "before Pix", and the period from 16 November 2020 until June 2021 as "after Pix". This is to test whether the results are robust during the Covid period. We include all weeks before and after the shock. However, we only graph results from -26 to +52 weeks. We also show results by balancing the sample, so that every treated municipality has equal weight in the data points shown. We use data on all municipalities and cluster the standard errors at the municipal level.

4.2 Instrumental variable

Once we show that floods affect the use of Pix, we move on to establish that it is reasonable to believe the exclusion restriction, that is, that floods do not affect other payment technologies directly. We believe this assumption for three reasons. The first is that other payment technologies are not suitable for informal insurance, they are expensive, hard to use and slow. The second is that it is reasonable to believe that if

floods affected the use of payment technologies, it would have done so already since floods are very common and the other technologies have been around for decades. Third, we have evidence that floods did not affect the use of other payment technologies before Pix was introduced. Thus, we can use floods as a suitable instrument for the increase in use of Pix and not the others.

$$y_{m,t} = \delta Pix_{m,t} + \mu_m + \theta_{Risk,t} + \epsilon_{m,t} \quad (2)$$

$$Pix_{m,t} = \beta Z_{m,t} + \mu_m + \theta_{Risk,t} + \epsilon_{m,t} \quad (3)$$

In equation (2), $y_{m,t}$ is the variable of interest measuring the use of a type of payment technology or the use of a banking service in municipality m at time t. Municipality-fixed effects μ_m, and time fixed effects by subgroup $\theta_{Risk,t}$ are added. $Pix_{m,t}$ measures the use of Pix in municipality m at time t. In equation (3), $Z_{m,t}$ is the instrument, a dummy that equals 1 if municipality m was hit by a flood on a time before or equal to t, and 0 otherwise. We use the same periods as before and we cluster errors at the municipality level.

5. Results

5.1 Effects of floods on Pix

The advantage of the staggered differences-in-differences approach is that, rather than believing assumptions blindly, we can see them playing out. Our main variable of interest is the active number of Pix users in a municipality. We define this as 1 if a person received or sent money using Pix in a given week and 0 otherwise. The idea behind the choice of this variable is that floods would increase the use of Pix through a channel of informal insurance (we will explore this channel in Section 5.4). In turn, once people pay the fixed costs of using Pix, such as setting up an account and learning how to use the app, they will continue to use it. Moreover, since those fixed costs are shared with other payment methods, we expect that the increase in the use of Pix would increase the use of other payment methods as well.

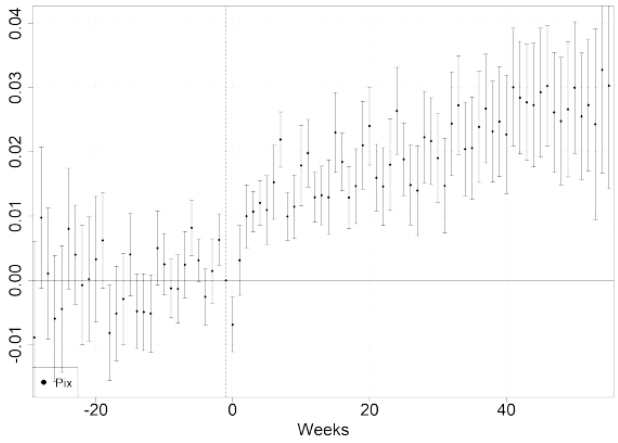
For this analysis, we run equation (1) on the logarithmic quantity of active users of Pix. Figure 3 shows the staggered differences-in-differences graph on the left. In the figure, we show that the number of people using Pix drops significantly during the week of the flood, which is consistent with a drop in commercial activities during a natural disaster; however, an upward trend begins a week after the disaster and continues over the course of the year. In the graph, we can see that the number of active Pix users increases to more than 3% after 52 weeks. On the right-hand side of figure 3 we show the results of the first stage of our IV approach where we performed equation (3). In the table, we find consistent results with floods increasing users by 2.2%.

We provide a more detailed analysis of the effect of floods on many Pix variables in figure 8 in the online appendix. In this analysis, we distinguish transactions received and sent by people and firms. In the graphs shown in the figure, it is possible to see

that the drop in the use of Pix on the week of the flood is mostly due to a drop in the number of transactions sent. This behaviour is consistent with the need to save money during a natural disaster. Another interesting result is the fact that the number of transactions sent by people increases more than the number of transactions received, whereas the number of transactions received by firms increases more than the number of transactions sent. Meanwhile, the growth in total value sent and received is similar. This is consistent with people using Pix to purchase many small-ticket items and services from firms, while firms perform a few high-ticket transactions to pay suppliers and workers' salaries. In numbers, we see an increase of 4-5% in the number of transactions and value transacted among people and firms.

Log active users

Figure 3



	Dependent variable:
	Log Pix Users OLS
Flood	0.022***
	(0.006)
Mun. FE	*Yes*
Time x Region FE	*Yes*
Observations	614,163
R^2	0.995
Note:	*p<0.1; **p<0.05; ***p<0.01

Overall, we find that floods have a positive, progressive and long-lasting effect on the use of Pix by people and firms. The effect is almost immediate, with usually a drop during the week of the flood and then a continuous growth in use in the following weeks. This is consistent with the idea that people use Pix as a form of informal insurance. Firms are quick to adapt as well, with growth, especially in the number of transactions received, which is consistent with people using Pix to purchase goods.

5.2 Effects of Pix on other payment methods

In this subsection, our goal is to establish a causal link between the number of active users of Pix and the use of other payment methods. The way we do this is two-fold. First, we show the effect of floods on other payment methods before and after Pix was introduced. The goal here is to demonstrate that before Pix, floods did not affect the use of other payment methods, whereas after Pix, floods had a positive effect on the use of other payment methods. Thus, if you believe that not much changed in Brazil to alter the aftermath of floods on payment technology in the periods before and after Pix besides Pix itself, you would expect that the effect of floods on other payment methods would be similar in both periods had Pix not been created. Therefore, the growth in the use of a payment method after a flood would be caused by the increase in the number of users of Pix. Second, we use floods as an instrument

for the increase in the number of users of Pix. The main assumption, in this case, is the exclusion restriction: floods will not affect the use of other payment methods directly. This assumption is impossible to test and it would require the reader to believe blindly in it; however, since we have data from before Pix existed, our staggered differences-in-differences act as a reasonable test to see whether this assumption is plausible.

For this task, we direct your eyes to the estimates in black in figure 4. The estimates in black are the results of equation (1) on the log transactions of bank wire, payment slip and the log number of firms accepting credit and debit payments. (We do not have transaction-level data on card payments and the number of firms accepting card transactions is defined by having a positive amount of total value transacted that week). The period we studied to create these estimates is from January 2019 until November 2020, when Pix was created. What we find is that, with the exception of highly noisy debit card data, we see no evidence of a systematic change in behaviour toward payment methods after a flood.

Alternatively, in the estimates in red of figure 4, we show the results of the same equation but for the period after Pix was introduced, from November 2020 until December 2022. We find that the use of other payment methods is systematically affected by floods after Pix. We show that during the period near the natural disaster, estimates are flat, but there seems to be a growth in the use of those payment methods after several weeks. This growth is shown in all alternative methods and this delayed increase is consistent with the idea that once familiarised with Pix, people and firms gradually learn to use other payment methods over time.

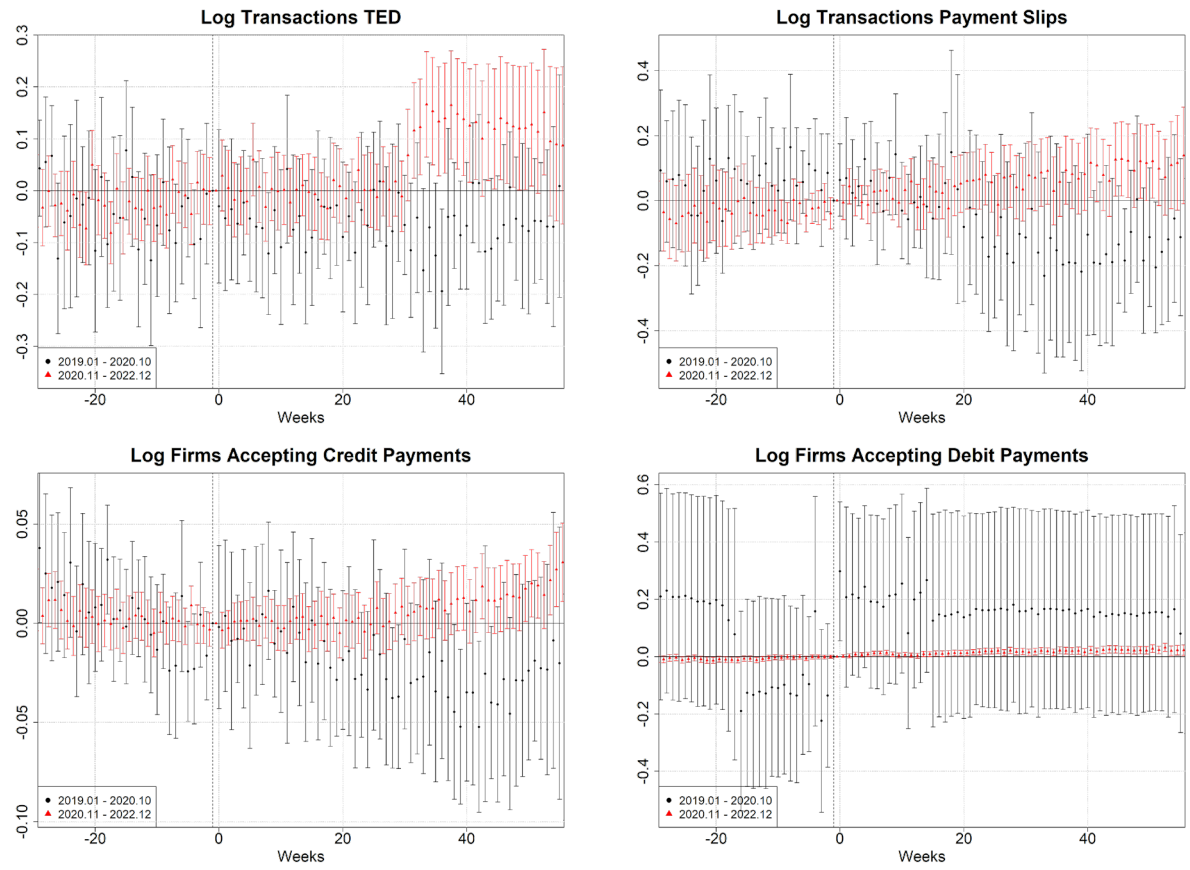
In the IV approach, we display in table 1 the results of the same variables shown in figure 4. We find consistent results with a 1% increase in the number of active users of Pix in a municipality leading to an increase of 5.7% in the number of payment slip transactions and 4.5% in the number of bank wire transactions. We also find that the number of firms accepting debit card increases significantly by about 1.2% while credit card acceptance does not change significantly.

Due to the richness of the data, we can offer a more detailed analysis of each payment method. For payment slips, our results are presented in figure 9 in the online appendix. We study four main variables, log transaction of payment slips (already analysed in the previous paragraphs), log value (the sum of all money transacted) and log active users for people and firms (constructed as the number of unique people and firms that sent or received money using payment slips). As seen before, the variables show a similar pattern. The before Pix estimates in black seem to be flat, while the after Pix estimates in red show a modest positive effect of floods on the use of payment slips over time. Running the IV approach on those variables, we find that a 1% increase in the number of active users of Pix in a municipality leads to a 10.7% increase in the value transacted using payment slips, a 1.7% increase in the number of active firms and an insignificant change in people actively using it.

Table 1

	Dependent variable:				
	OLS			IV	
	Log Pix Users	Log Trans. Wire	Log Trans. Slip	Log Credit Acceptance	Log Debit Acceptance
	(1)	(2)	(3)	(4)	(5)
Flood	0.022***				
	(0.006)				
Log Pix Users		4.538***	5.737**	−0.132	1.182***
		(1.109)	(2.922)	(0.285)	(0.371)
Mun. FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Time x Region FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	614,163	614,163	614,163	614,163	614,163
R^2	0.995	0.853	0.874	0.994	0.991
Note:					*p<0.1; **p<0.05; ***p<0.01

Figure 4



For bank wire transfers, additional results can be found in figure 10 in the online appendix. As before, we found no evidence of floods affecting bank wire before Pix was created. In the period after Pix, in red, we start to see an increase in the use of Wire only after several weeks. We see a clear increase in the number of transactions

and total value transacted. This is consistent with people and firms learning how to use the technology after Pix over time. The pattern in the figure is reflected in the results of the IV approach. We find a growth of 4.5% in the number of transactions and 7.0% in the value transacted, while we do not see a significant change in the number of firms using Wire to receive or send money.

For credit and debit card payments, additional results can be found in figure 11 in the online appendix. These data are not as rich as the other payment methods. As such, we only have the total value transacted in a day to each firm, from which we create a dummy to determine whether a firm accepted card payments that week. The estimates for them are a little more erratic than the other payment methods with a lot of noise, but there seems to be no effect of floods on the number of firms accepting credit and debit cards, and the total value transacted before Pix. In the period after Pix, we see a similar partner from before, a delayed increase in the number of firms accepting credit and debit cards, and the total value transacted. In the IV approach, we find a 1.2% increase in the number of firms accepting debit cards, while we do not find a significant effect on the total value transacted of debit and credit cards, nor on the number of firms accepting credit cards.

Overall, we see a similar pattern for all payment methods, no effect of floods on the use of payment methods before Pix, and a delayed increase in the use of payment methods after Pix.

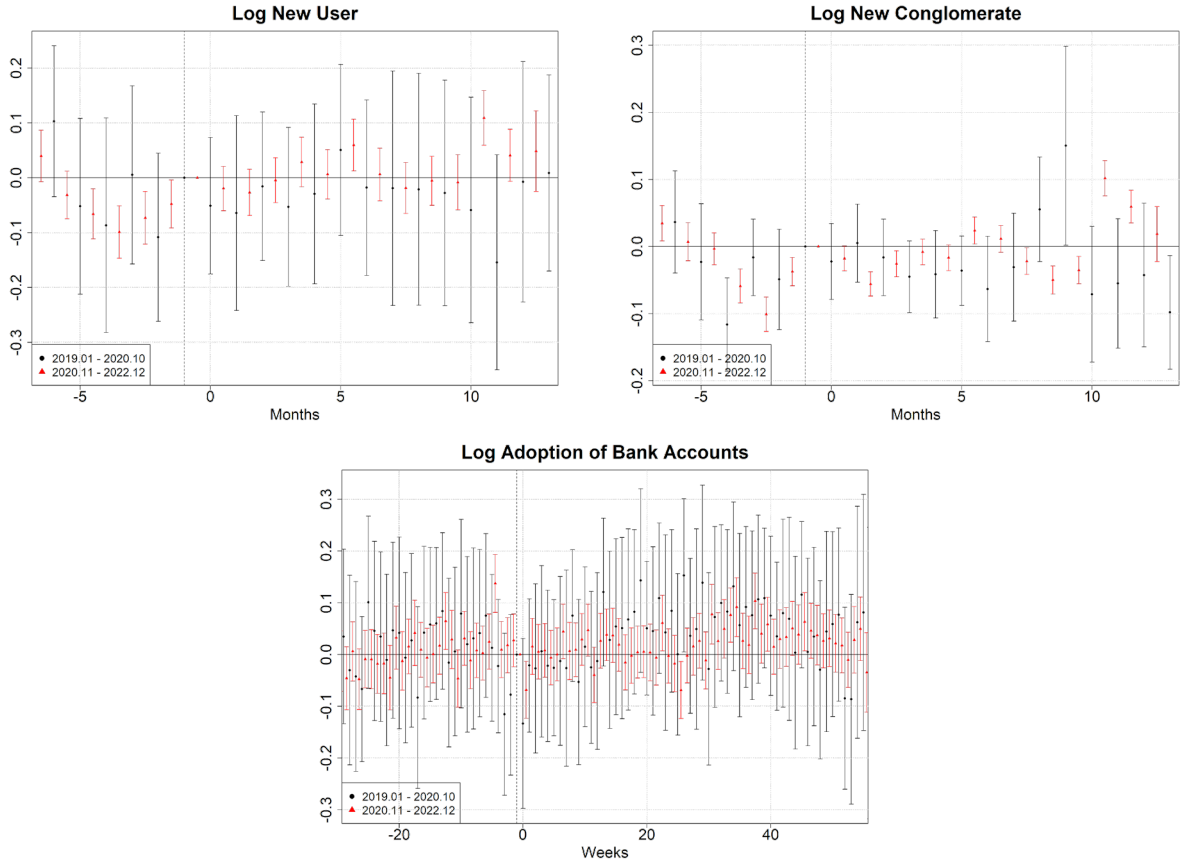
This is consistent with the idea that people and firms learn how to use Pix first and then gradually learn how to use other payment methods. The graphs also increase our confidence that flood can be a valid instrument in our analysis. With that, our IV approach points to the fact that the increase in the number of users of Pix is causing an increase in the use of other payment methods. This result is in contrast to the more natural idea that Pix would substitute other payment methods; instead, we find that Pix is complementary to other payment methods.

5.3 Effects of Pix on Banking

Now we move on to analyse the impact of Pix in the banking sector. There is growing fear that free instantaneous transfer technologies have the potential to disrupt the banking sector. We will assess a few variables to see if those concerns have any merit.

Similarly to before, we selected some relevant variables to study the effect of Pix on it. We direct the reader to the estimates in black in figure 5 which are the results of equation (1) on the (1) log number of people creating a credit relationship for the first time, (2) log number of people creating a relationship with a new bank for the first time, and (3) the log number of people opening bank accounts for the first time. The period we studied to create these estimates is from January 2019 until November 2020, when Pix was created. The first two variables are calculated on a monthly time frame, while the third is calculated weekly. In the estimates, we see no evidence of a systematic change in behaviour toward creating new credit relationships or new bank accounts after a flood.

Figure 5



Alternatively, the estimates highlighted in red in figure (5) delineate the outcomes of the same equation for the post-Pix implementation period, spanning from November 2020 to December 2022. We find a few positive estimates weeks after the flood for all three variables. Those results are reflected in the IV approach in table 2 where we find that a 1% increase in the number of active users of Pix in a municipality leads to an increase of 0.45% in the number of people creating a credit relationship, a 0.25% increase in the number of people creating a relationship with a new bank, and a 0.80% increase in the number of people opening bank accounts for the first time.

Due to the richness of the data, we can offer a more detailed analysis of the impact of Pix in the banking sector. First, we explore the impact of Pix on the opening of bank accounts, particularly how this was influenced by a flood both before and after Pix's implementation. In the online appendix, figure (12) shows the results of the staggered differences-in-differences on the log number of bank accounts for people and firms, the log number of people with at least one bank account in a municipality (log banked population), and the log number of people opening bank accounts for the first time (log adoption). According to the figures, the log adoption of bank accounts before Pix was not affected by floods, while after Pix, we see a few positive estimates weeks after the flood. A similar pattern occurs for the log banked

population, as you can imagine since both variables are closely related. The log number of bank accounts for people and firms are very similar and face the same problem since most of the estimates violate the pre-trend assumption despite our fixed effects. The only one that is well-behaved is the log number of bank accounts for firms that rise over time following a flood. Since we face some problems with the pre-trend assumption, the results of the IV approach should be taken with a grain of salt. The results can be viewed in table 6 in the online appendix, where we find that a 1% increase in the number of active users of Pix in a municipality leads to an increase of 0.80% in the number of people opening bank accounts for the first time, a 0.08% increase in the number of people with at least one bank account, an insignificant increase in the number of bank accounts for firms, and a 0.5% increase in the number of bank accounts among individuals.

Second, we study credit relationships between people and firms with their banks. We study three variables, the log number of credit adoption defined as the first time a person or firm creates a credit relationship, the log bank adoption defined as the first time a person or firm creates a relationship with a new bank, and log debt defined as the total amount owed by a person or firm. The results for people are presented in figure 13 in the online appendix, and for firms in figure 14 in the online appendix. There we find very stable graphs showing no evidence that floods affect credit relationships before Pix. After Pix, we also see stable graphs with a few positive estimates during certain months after the flood. The results of the IV approach can be found in table 7 and table 8 in the online appendix. We find that a 1% increase in the number of active users of Pix in a municipality leads to an increase of 0.45% in the number of people creating a credit relationship and a 0.25% increase in the number of people creating a relationship with a new bank. We did not find evidence of a change in the total debt carried by individuals, also, none of the variables for firms were significant.

Third, we use data from Pix to study two interesting variables, the number of active bank accounts and the number of self-transfers. We define the former variable as the number of bank accounts that were used to send or receive money in a given week, and the latter as a transfer from one individual's bank account to the same individual in another account. The goal is to address the possible issue of people and firms creating bank accounts but not using them and to see whether people and firms are optimising their use of bank accounts by using Pix to transfer money between them. To study the number of active accounts, refer to figure 16 in the online appendix. We find the number of active bank accounts growing more than 4% for people, outpacing the growth in active Pix users by around 3%. For firms, the number of active bank accounts grows approximately the same as active users, at a rate of around 2%. To study self-transfers, refer to figure 15 in the online appendix, where we find that the number of people and firms actively performing self-transactions grows to 4-5% after 52 weeks.

Overall, the results of this section suggest that Pix contributes to the growth in bank accounts, access to credit and the expansion of bank products among people. We also find that people and firms are actively using more their bank accounts and optimising their use by performing selftransfers.

Table 2

	Dependent variable:		
		IV	
	Log Credit Adoption	Log Bank Adoption	Log First Account
	(1)	(2)	(3)
Log Pix Users	0.445***	0.224***	0.798**
	(0.112)	(0.065)	(0.373)
Mun. FE	*Yes*	*Yes*	*Yes*
Time x Region FE	*Yes*	*Yes*	*Yes*
Observations	138,325	138,325	614,163
R^2	0.878	0.974	0.851
Note:			*p<0.1; **p<0.05; ***p<0.01

5.4 Additional results

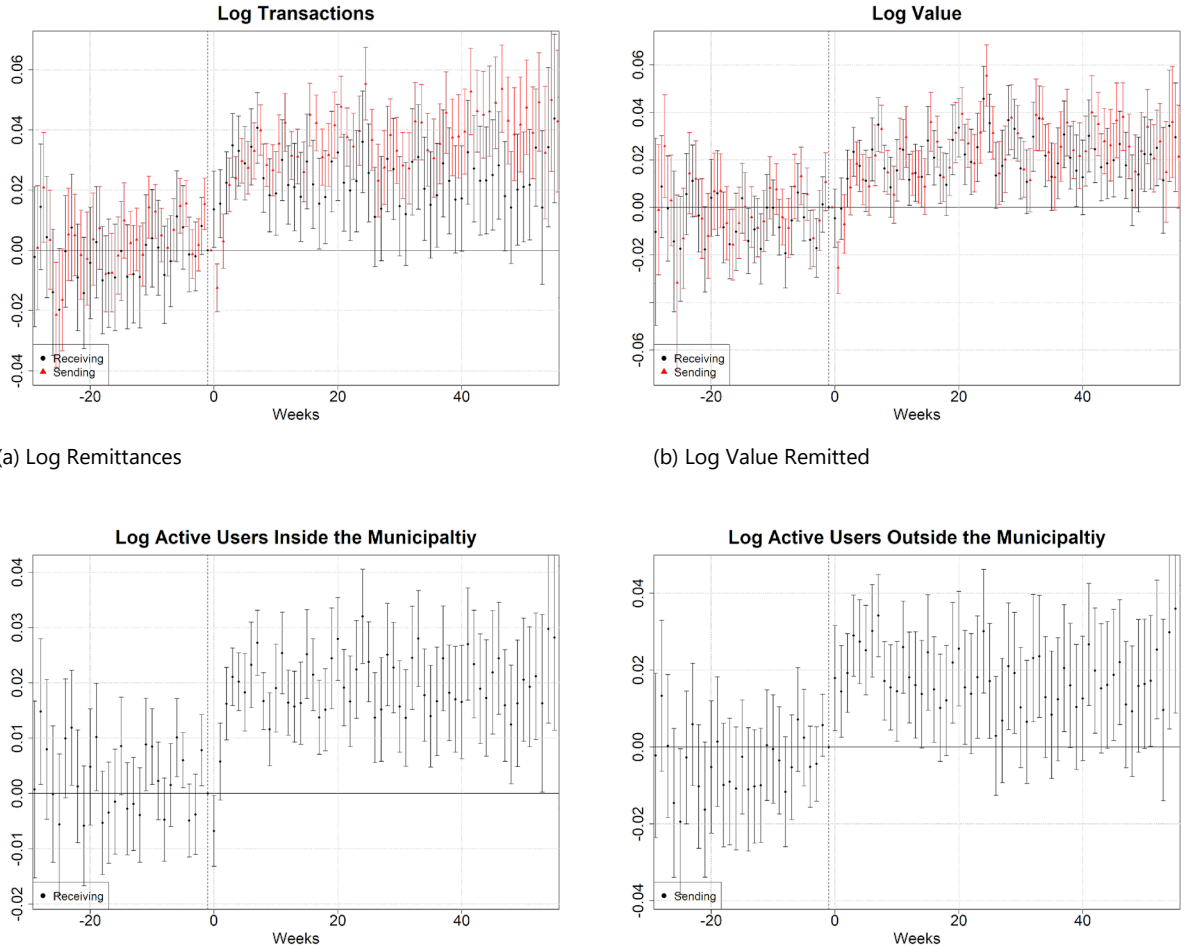
In this section we will analyse two main topics, the first is the role of informal insurance in the growth in popularity of Pix following a flood, and the second is which type of bank, traditional or digital, was more favoured by the growth in popularity of Pix.

5.4.1 Informal Insurance

To study informal insurance, we study remittances, which in this case, we define as a transaction of Pix between a person outside the municipality affected by the flood and a person inside the municipality. Moreover, we define as inflow, a transaction from a person outside the municipality to a person inside the municipality, and as outflow, a transaction from a person inside the municipality to a person outside the municipality.

The main graphs of our analysis are presented in figure 6. In the first two graphs, the estimates in black are the results of equation (1) on the inflow, while the red ones refer to the outflow. We find that in the week of the flood, there is a significant drop in the outflow of money, while the number of inflow transactions increases significantly. This is consistent with informal insurance in which people affected by the flood decrease the outflow while increasing the inflow. The last two graphs show the number of people affected by the flood receiving remittances and the number of people not affected by the flood sending remittances. We find that during the week of the flood, more people outside the municipality send money to people inside the municipality. In all graphs, we see a permanent change in behaviour following the flood, with remittances growing around 24%, and a network effect of Pix, with people outside the municipality increasing their use of Pix to send money.

Figure 6



(a) Log Remittances

(b) Log Value Remitted

(c) Receivers of Remittances

(d) Senders of Remittances

5.4.2 Heterogeneous analysis

In this section, we study the effects of Pix on different types of banks. Since there is a common sense belief that digital banks and fintechs would take over traditional brick-and-mortar banks, we divide banks into two categories, digital banks and traditional banks based on their physical branch presence.

First, we study Pix transactions using equation (1) on the log number of transactions and the total value of Pix for people and firms between those different banks. The results are presented in figure 18 in the online appendix, the estimates in black represent the traditional banks, while in red, the digital banks. We find that for people, the growth in Pix transactions and the total value transacted are almost identical. Thus, indicating that both types of banks were favoured similarly after a flood. Alternatively, for firms the results seem to differ, despite the high noise and pre-trend violation, the estimates show that traditional banks grew more in the number of transactions and total value transacted. This is on par with the idea that

firms benefit much more from traditional banks since they can offer better services and credit.

Second, we look at the number and active use of bank accounts. The results are presented in figure 19 in the online appendix. Regarding the number of bank accounts, we face the same problem as before with some violations to the pre-trend assumption in the case of people. In the case of firms, the estimates are more well behaved, with the growth in digital accounts appearing to be bigger than traditional accounts following a flood, but the results are not significant. The result is on par with firms having established relationships with traditional banks, decreasing potential growth in new bank accounts. While for new digital banks, it is natural to experience bigger growth in accounts. Concerning active use, a pattern consistent with previous observations emerges. Individuals' active use of bank accounts increases at comparable rates for both digital and traditional banks, with estimates adhering to the pre-trend assumption. On the other hand, firms demonstrate a greater increase in active use of traditional bank accounts. However, the estimates do not comply with the pre-trend assumption.

Overall, we find evidence that for people, both types of banks were favoured similarly by the growth in popularity of Pix, while for firms, our evidence is of worse quality, but it seems to indicate that traditional banks have been more favoured by the growth in popularity of Pix.

6. Robustness

Our empirical identification relies on the exclusion restriction assumption. To increase the validity of this assumption, we study the period "before Pix", from January 2019 until November 2020. The idea is that if floods did not affect our main variables before Pix, then it is reasonable to believe that floods would not affect them in the period after Pix, except through Pix. One may argue that studying results from January 2019 until November 2020 as our "placebo" period does not capture fully the effect of Covid and it is possible that our results are driven by the change in behaviour caused by Covid. To check on the possibility that Covid was the main driver of our results, we study the period "before Pix" from March 2020 until November 2020, and the period "after Pix" from November 2020 until June 2021.

The results are reported in Section 8.4 of the online appendix. The findings are very similar, with even stronger results of floods affecting the use of Pix, and Pix affecting our main payment and banking variables. The results are naturally noisier given the loss of observations. However, the main conclusion remains the same: floods do not have a significant effect on our main variables before Pix and Covid does not seem to be the driver of change, Pix does.

7. Conclusion

In conclusion, this paper studies an important aspect of the evolving financial landscape, namely the development of transfer technologies. Although previous

studies have shed light on the positive impact of these transfer systems, the speed of development and the popularisation of these technologies remain slow worldwide compared to Pix. One of the reasons for this reluctance is the fear that these technologies could compete with existing payment technologies and possibly disrupt the banking sector. At the same time, innovation on the payment technology front, such as Pix, has the potential to substitute for cash transactions, pushing people and firms toward using more their bank accounts and other financial technologies.

We overcome the challenge of separating the substitutability or complementarity of Pix on other payment methods from changes in consumer preferences, by using floods as an instrument for the increase in the use of Pix. We find that floods have a significant effect on the use of Pix, while not having a significant effect on the use of other payment methods or in our banking variables before Pix, thus clearing the way for an Instrumental Variable approach.

We discover that floods have a lasting impact on the use of Pix, with a significant increase in the number of people and firms using Pix even after one year. We find evidence that Pix is used for informal insurance, with a significant increase in the inflow of money from people outside the municipality and in the number of people sending and receiving remittances. We also find that the use of Pix by firms is also affected after a flood, with a significant increase in the number of firms accepting Pix as a payment method.

When studying the effects of Pix on other payment methods, we find evidence that Pix causes significant increases in the four most used payment technologies in Brazil: payment slips, Bank Wire, credit card and debit card. We show that following Pix use, people seem to be more open to using other payment methods. Similarly, firms seem to be more open to accepting other payment methods once they start accepting Pix.

In the banking sector, we find that Pix contributes to the growth in bank accounts, access to credit and expansion of bank products among people. We also find that people and firms are actively using more their bank accounts and that they are optimising the use of their accounts by performing self-transfers. Regarding which type of bank was favoured by the growth in popularity of Pix, we find that traditional and digital banks were favoured similarly.

In sum, Pix seems to have brought a financial revolution to Brazil. Since its introduction, access to banking services moved from branches to phones, cash transactions were cut in half, and the whole economy became more digital. In this paper, we were able to unveil the effect of Pix on the payment and banking sectors to shed light on the many benefits that instantaneous transfer systems can bring to individuals, firms and banks. We hope that these findings can encourage the development of new transfer technologies and increase their adoption worldwide.

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Fast payments and banking: Costa Rica's SINPE Móvil

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Abstract

Launched in 2015, the Costa Rican retail fast payment system SINPE Móvil has seen rapid adoption since 2020. As of the second half of 2024, 76% of the Costa Rica´s population older than 15 are active users. The system can be used by natural and legal persons, with each user averaging approximately 180 transactions per year. Higher SINPE Móvil use has been related to lower cash withdrawals, a greater number of users and lower average volumes, suggesting SINPE Móvil has carved a prominent place in retail payments. With a synthetic controls approach comparing Costa Rica to peer countries, we show that wide adoption of SINPE Móvil led to lower non-interest expenses by Costa Rican banks after the pandemic. This suggests that payments innovation can enhance bank efficiency.

Keywords: Digital innovation, fast payments, fast payment systems.

JEL classification: G21, G23, O32.

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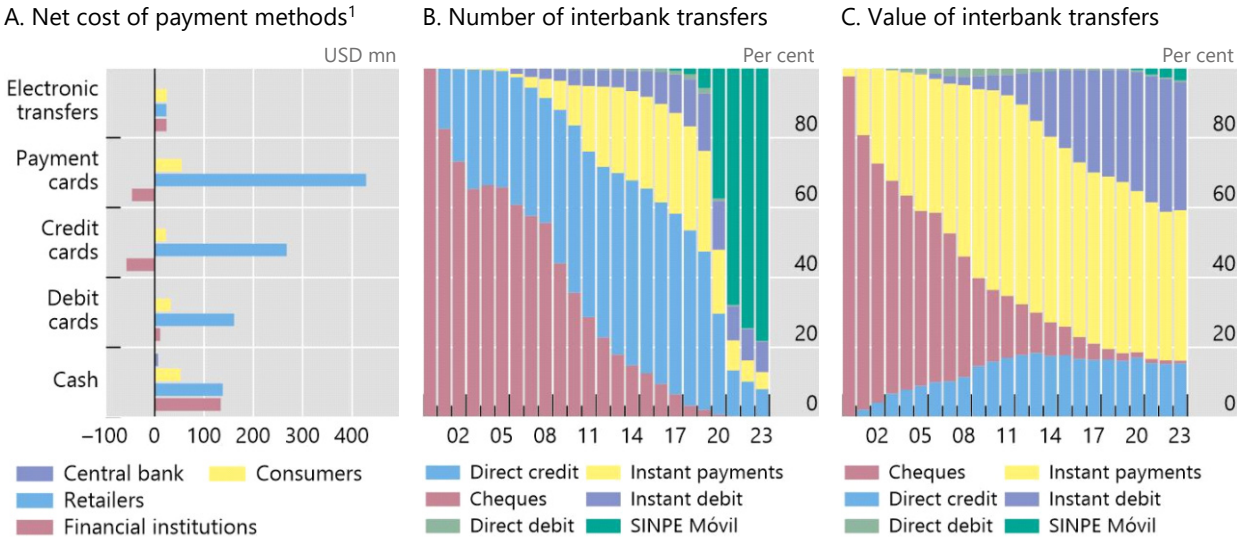
1. Introduction

Digital innovation can have a profound impact on economies and financial systems. In the payments market, new payment methods can alter the availability of funds for payers and payees, the fees paid to intermediaries, the available information about past transactions and much more. For payment intermediaries – notably banks – the adoption of new payment methods can lead to important shifts in payment revenues and expenses. What happens to the banking system when a new method achieves mass adoption across an economy?

In the last several years, Costa Rica has seen a digital revolution in payments with the introduction of a retail fast payment systems (FPS) called SINPE Móvil. SINPE Móvil is operated by the Central Bank of Costa Rica as an open, public infrastructure. All major banks participate, and it is also open to a range of non-banks. Users link their bank (or other) accounts in national currency (Costa Rica Colón) to a mobile phone number. This enables them to make electronic money transfers using a variety of electronic banking channels, such as short message service (SMS), e-banking, mobile web banking, banking apps, online banking or automated teller machines (ATM). It is available every day at all hours and is free of charge up to a certain amount (approximately CRC 100,000 or USD 200 at the time of writing).

Compared with cash and cards, electronic transfers are a low-cost payment method. In Costa Rica, electronic transfers are far cheaper for consumers, retailers, financial institutions and the central bank than other payment methods (Graph 1.A). Cash is the most expensive payment method, particularly for retailers and financial institutions. The total cost of processing cash in Costa Rica amounted to 1% of GDP in 2017 (Cerdas and Rodriguez (2018)). Still, until recently, cash was king, for two reasons. First, it always works at all times, for all individuals, regardless of whether they have a bank account. Second, clearing and settlement are immediate.

SINPE Móvil has carved a prominent place in payments in Costa Rica — Graph 1



[1] Data from 2016. Net costs are calculated as production costs minus fees received in CRC. Exchange rate used was average of 2016.

Sources: Central Bank of Costa Rica; national data.

The debut of SINPE Móvil in 2015 was accompanied by a number of further reforms, such as the introduction of simplified bank accounts. Yet it was not until 2020 that adoption took off, as Costa Rica implemented lockdowns to attenuate the Covid-19 pandemic, and consequently people began to use it more. Transactions with SINPE Móvil then quickly overtook other interbank transfer methods (Graph 1.B). Soon, they accounted for close to 80% of all interbank transfers. By the end of 2022, 52% of the population older than 15 were an active user in SINPE Móvil, and by 2024 this exceeds 76%. Still, SINPE Móvil only represents 4% of the value of all interbank transfers since it is a low-value payment system focused on retail use (Graph 1.C).

This paper explores the experience with and impact of SINPE Móvil. In particular, it assesses the conditions that led to a slow uptake at first, followed by exponential growth. It then looks at how SINPE Móvil evolved to infer whether users are using it in substitution of cash, which would be a powerful sign of its value and a potential source of efficiency for the financial system. To drive this point about efficiency home, we use a synthetic control approach to study the effect of SINPE Móvil on the costs of the Costa Rican banking system. We find that, relative to what Costa Rica would be if SINPE Móvil was not widely adopted, Costa Rican banks had lower non-interest expenses.

This paper contributes to a budding literature on FPS and their impact on macro outcomes. For instance, Natarajan and Balakrishnan (2020), CPMI (2021), Cornelli et al (2024) and Frost et al (2024) look at the design and adoption of FPS. Aguilar et al (2024) look at the impact of digital payments on informality and economic growth, and Araujo et al (forthcoming) document the effects of Brazil's FPS Pix on firm-level outcomes. This paper is most similar in spirit to Alvarez et al (2023), which assesses SINPE Móvil using micro data and finds strong evidence of network effects. In our case, the focus is more on the impact on the banking system. To the best of our knowledge, ours is the first study to explicitly consider how FPS impact on banks' non-interest expenses.

The paper is organised as follows. Section 2 discusses the background, launch and growth of SINPE Móvil. Section 3 discusses the effects on the Costa Rican banking system. Finally, section 4 concludes with some lessons learned on the implementation of SINPE Móvil and its effect on banks.

2. Background, launch and growth of SINPE Móvil

While the success of SINPE Móvil in Costa Rica is recent, the foundations were set far earlier. In 1997, the Central Bank of Costa Rica launched the National Electronic Payments System (SINPE after its name in Spanish).[2] Its first service was clearing and settling cheques, which previously took on average 20 days to redeem (Cerdas and Melegatti (2014)). SINPE had – and still has – the capacity to process operations in real time or deferred, in gross or net form, of low or high values. It can process peer-to-peer (P2P), person-to-business (P2B), business-to-business (B2B), business-to-person (B2P), person-to-government (P2G), government-to-person (G2P) and government-to-government (G2G), and it is open to a wide range of participants. Indeed, types of participants in SINPE include banks, non-bank financial institutions,

[2] *Sistema Nacional de Pagos Electrónicos.*

cooperatives, mutual funds, pension funds, public institutions and other payment service providers (PSPs).

From 2000, Costa Rica put in place an FPS called TFT (now PIN), after its name in Spanish[3] – providing instant settlement and clearing, albeit with a focus on retail transfers of higher amounts. Seeking to boost mobile, small-value transfers, in 2015 the Central Bank of Costa Rica introduced SINPE Móvil, a mobile payment system that allows users to make and receive electronic money transfers by linking their accounts to a mobile telephone number (OECD (2020)).[4] In addition to the use of mobile phones as payment medium, the focus on retail transfers is underscored by the no fee commission (up to a certain limit).

Finally, and complementing SINPE Móvil, the central bank introduced three important reforms to the payment system that contributed to wider adoption of electronic payments and lower use of cash. The first step was to modernise the payments infrastructure. In 2015, the central bank enacted regulation that required the migration of its retail payment infrastructure to the Europay, Mastercard and Visa (EMV) chip and contactless technology. At the same time, banks collaborated with transit authorities to establish the Electronic Payments Systems for Public Transportation, which allowed passengers to pay bus and train fares with contactless cards. Second, in 2016 the central bank approved simplified accounts to expedite bank account opening by only requiring an identification document. The central bank also created a unified account database, integrating data about customers from all their accounts (current, savings and simplified). In another landmark reform, in 2019 the central bank introduced the International Bank Account Number (IBAN) to all accounts. The purpose was to standardise accounts and to identify them at the national and international level.

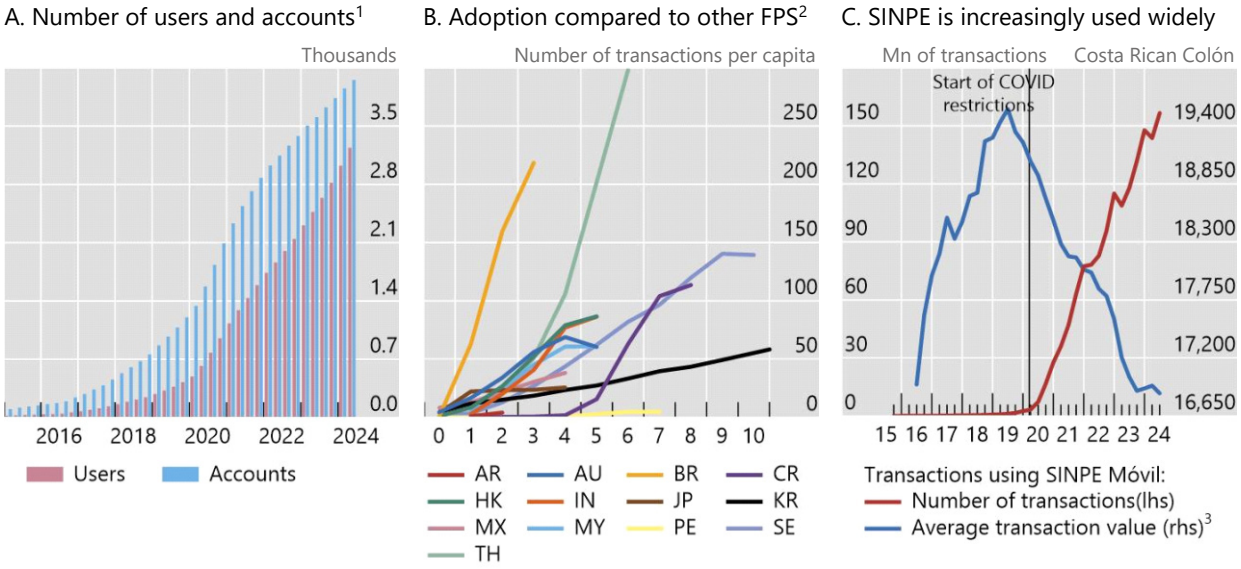
To use SINPE Móvil, clients need to have a transaction account in any of the financial entities that offer the service and an active mobile phone line. While banks in Costa Rica commonly offer US dollar-denominated accounts, only accounts denominated in Costa Rican Colón are eligible for SINPE Móvil, at least for now. Each mobile phone number must be linked to a single account, but the same account can be linked to multiple mobile phone numbers. This allows users to transfer funds knowing only the payee's phone number. Financial institutions and payment service providers have innovated, adding features like quick response (QR) codes and embedding SINPE Móvil in their own apps.

Adoption of SINPE Móvil started slow but then accelerated, particularly during the Covid-19 pandemic (Graph 2.A). By end-2022, there were around 2 million users and more than 3 million accounts. By June 2024, this had risen to nearly 3 million users and 4 million accounts. This makes Costa Rica one of the most active users of fast payments in the world. In terms of transactions per capita, SINPE Móvil holds fourth place in our selection of FPS, behind Thailand's PromptPay, Brazil's Pix (Duarte et al (2022)) and Sweden's Swish. Yet the speed of adoption has been similar to Thailand and Brazil, as evidenced by the slope of the line for these systems' number of transactions (Graph 2.B). As the number of transactions skyrocketed, their average value decreased to around CRC 16,900 (close to $34 USD) by June 2024 (Graph 2.C). This means that consumers increasingly use SINPE Móvil for everyday transactions.

[3] TFT stands for *Transferencias de Fondos a Terceros* while PIN stands for *Pagos Inmediatos*.

[4] Table A1 in the appendix describes SINPE Móvil and compares it with PIN.

SINPE Móvil adoption started slow but then accelerated Graph 2



[1] The numbers regarding SINPE Móvil users and accounts can change over time, as data reporting is further refined. [2] Systems were selected based on data availability. Data are available until 2019, except for CL and DK where data are available until 2018 and CR available until 2022. [3] Four-quarter moving average; 1 USD~ 600 CR Colón.

Sources: Central Bank of Costa Rica; national data; BIS.

Two aspects were key for adoption. First was the partnership between private banks and the central bank. Private banks agreed that the central bank would aggregate their respective mobile phone registry to create an interbank mobile phone registry, which is the backbone of SINPE Móvil. This avoided siloes that would hamper intercommunication between account holders in different banks. The second characteristic contributing to user acceptance is the integration and interoperability within the national payment system. For users, this means that the money they already have in their respective bank accounts can be transferred through SINPE Móvil, without the need to first transfer it to a wallet. This differentiates the system from most of the private wallets and mobile money solutions from telecom companies in Africa, for example (eg Jack and Suri (2014)).

Even with all this favourable groundwork, it took a combination of factors to drive the rise in adoption only five years after SINPE Móvil was created. The onset of the Covid-19 pandemic and the associated lockdowns were major contributors, as many households used SINPE Móvil for the first time to pay for home-delivered meals, groceries and other goods. Also important is the delayed network effect: as more users experimented with and kept using SINPE Móvil, more people were incentivised to adopt it (Alvarez et al (2023)).

3. Effects on the Costa Rican banking system

SINPE Móvil's fast rate of adoption since early 2020 prompts the question: how did it affect Costa Rican banks? Some potential effects of the wide adoption of free, fast retail payments include:

- Greater financial inclusion, given easier access to digital payments, new simplified accounts and the economic opportunities for informal entrepreneurs arising from easier payments by potential clients.
- Lower costs, as banks adjust the size of their *physical* interface with customers to meet a lower demand for cash: all else equal, customers could be serviced with fewer ATMs, bank branches, etc, and banks and firms may face less costs attached to custody and maintenance of cash.
- Lower revenue, as legacy electronic payment methods, for which customers are typically charged a fee, are replaced with SINPE Móvil.

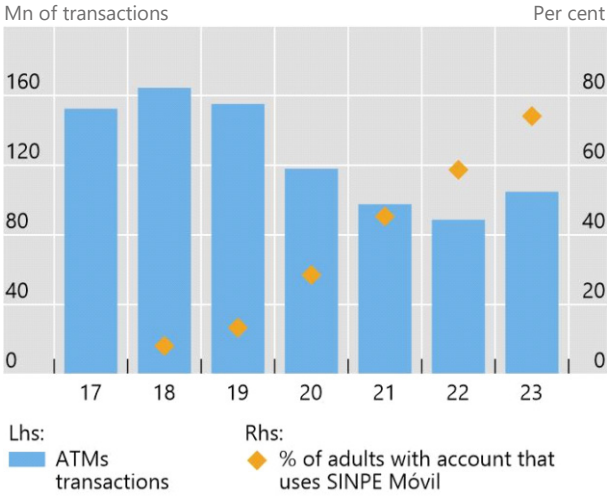
It is not clear *a priori* which of those effects is dominant. In this section, we explore the data to form a picture of the effects of SINPE Móvil on the Costa Rican banking system. Because these analyses span the pandemic period, which likely had considerable influence both on SINPE Móvil usage and on bank outcomes, the results are necessarily tentative. Still, these analyses can be informative about the direction and scale of responses from the banking sector.

Substitution of cash payments

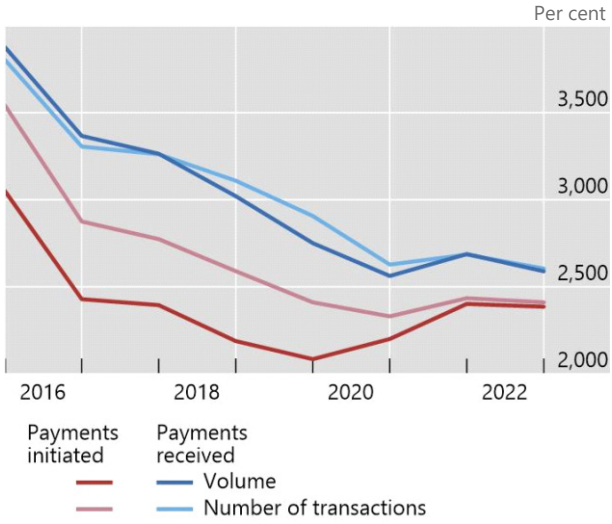
Use of SINPE Móvil has gone hand-in-hand with an increase in access to and use of transaction accounts – one key element of financial inclusion. First, from 2018 to June 2024, the share of population older than 15 with a bank account rose from around 77% to 90%. Notably, 84% of those with at least one bank account is an active user in SINPE Móvil (Graph 3.A). Second, higher SINPE Móvil use is correlated with lower ATM transactions, hinting at a substitution effect: while Costa Rican households performed 155 million ATM transactions and only 6 million SINPE Móvil payments in 2019, these were matched equally at 104 million ATM transactions and 506 million SINPE Móvil payments in 2023 (Graph 3.A). Extrapolating the costs from the Central Bank of Costa Rica, the estimated benefits from reduced cash use are about 0.5% GDP annually (Cerdas and Rodriguez (2018)). Third, uptake of SINPE Móvil was linked to a decline in market concentration in the payments sector. After its introduction, there is a decline in the Herfindahl-Hirschman Index (HHI) for both payments initiated and payments received (Graph 3.B).

SINPE Móvil promoted competition in the financial system Graph 3

A. As SINPE Móvil goes up, cash use goes down



B. The Herfindahl-Hirschman Index of market concentration has fallen



Sources: IMF; Central Bank of Costa Rica; BIS.

Effects on bank expenses

Next we turn to the effects on the Costa Rican banking system. We are interested in particular in first-order effects on bank expenses, given the impressive level at which users substitute cash with SINPE Móvil and how costly operating cash is usually for banks. The broader societal effects of lower cash use can be complex; for example, less tech-savvy customers or those in areas with less stable internet connection might have a strong preference for cash. Yet for the banking sector specifically, lower aggregate costs would be a positive contribution to its efficiency. A more complete analysis would also look at their revenues to check the extent to which lost fee income from lower use of legacy payment methods was compensated by other fees. Such costs could even be offset by lower delinquency rates on credit as SINPE Móvil offers banks more information with which they can assess prospective borrowers. Yet comparable data from other countries at this level of breakdown are not available.

Our focus then is on answering the following question: have banks' non-interest expenses decreased after SINPE Móvil use took off, compared with an alternative reality where SINPE Móvil use remains low as in its early years? To answer this question, we use synthetic controls (SC) (Abadie (2021)), a prominent methodology for comparative case studies. In short, the SC method entails data-driven counterfactual estimates of the outcome of interest (in this case, non-interest expenses divided by gross income) using peer countries. The observed value is then compared with the estimated counterfactual value: what would have happened in Costa Rica in a scenario where SINPE Móvil adoption had not taken off?

In the canonical methodology (Abadie and Gardeazabal (2003) and Abadie, Diamond and Hainmueller (2010)), estimating SC models entails finding the weights $\widehat{\omega}_j$ that approximate ω_j^*, for

$$Y_{1,t}^{\square} = \sum_{j=2}^{N+1} \omega_j^* \, Y_{j,t}^{\square} \text{ for } t < T, \sum_{j=2}^{N+1} \omega_j^* = 1 \text{ and all } \omega_j^* > 0, \quad (1)$$

where $Y_{1,t}^{\square}$ is the outcome variable of interest (in this case noninterest income divided by gross revenues of banks in quarter t), the treated unit is standardised as $j = 1$, T is the intervention date and N is the donor pool size. In the current case, Costa Rica is the "treated" country, ie the one where the intervention occurs, and we consider the first quarter of 2020 as the "intervention date", due to the occurrence of the Covid-19 pandemic, which was a major driver of SINPE Móvil adoption. Once an SC is estimated, the causal effect at time $t > T$ after the intervention is calculated as the difference between the observed outcome variable and the SC, or more formally, $Y_{1,t} - \hat{Y}_{1,t}^{N}$, for $\hat{Y}_{1,t}^{N} = \sum_{j=2}^{N+1} \hat{\omega}_j \, Y_{j,t}^{\square}$.

In our setting, data ending in end-2018 are used to find the best way to combine other countries' banking systems' non-interest expenses to form a counterfactual Costa Rica with low SINPE Móvil use. Data from 2019 to 2022 are then used for calculating the causal effect of widespread SINPE Móvil adoption on the cost efficiency of the Costa Rican banking sector. We use data from the IMF's Financial Soundness Indicators (San Jose and Georgiou (2009)).

While the SC method is popular for its ability to combine peer units in a data-driven way, other steps actually end up requiring many subjective judgment calls. How should one select the peer units? How can we best combine peer units to form a counterfactual, especially for data that may have complex, non-linear dynamics? And how can one objectively judge the quality of fit of the SC compared with actual Costa Rica? We follow Araujo (2024) and combine specific machine learning methods to estimate and judge these SC. This makes the selection of the comparison control countries and estimation of the counterfactual Costa Rica fully data-driven. Another advantage is that the estimation of the counterfactual with machine learning more flexibly accommodates potentially complex data generating functions.[5]

The first step is to select the countries that would serve as a pool of potential controls. A natural comparison group would be the immediate neighbouring countries, Nicaragua and Panamá, but that would be too small a sample and leave out possibly relevant cases. Extending to the whole Central America region plus Dominican Republic would seem adequate, but a question arises on whether or not larger neighbours such as Colombia to the South, and Mexico to the North, should also be included. One could consider the United States, which is by far the largest trading partner, and possibly even the Netherlands or Belgium – other relevant export destinations according to World Bank WITS data. That would still leave out other countries with broadly the same population size and social structure, whose outcomes could be correlated with Costa Rica's. One pragmatic way is to select a common-sense group and conduct robustness checks by including and removing a few other countries, especially as the statistical significance of a result may hinge on including or not a specific unit (Klössner et al, 2018).

A data-driven way is to find which countries are more similar to Costa Rica and to each other *as a group* before SINPE Móvil's take-off. Clustering algorithms do exactly that. These are a class of unsupervised machine learning techniques that, in essence, group together units according to their similarity to each other.[6] This sidesteps subjective judgment in the selection of controls, and also may actually uncover other countries that are relevant but were not initially considered. A

[5] All analyses were conducted with the open-source gingado package (Araujo (2023)).

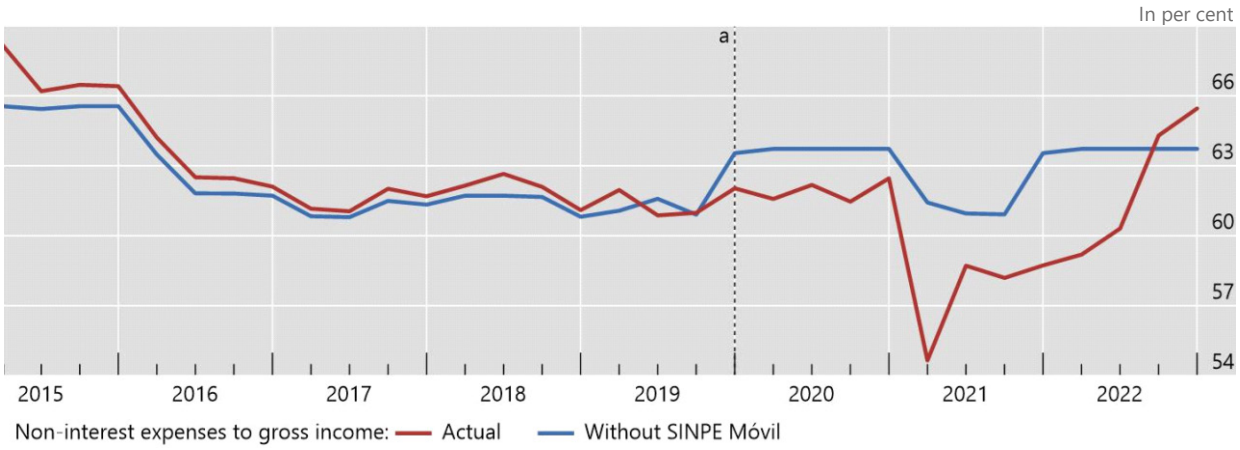
[6] Alternatively, Abadie and L'Hour (2021) propose the use of penalised linear regressions for the selection of control units.

particular method, *affinity propagation* (Frey and Dueck (2007)) combines many useful properties for SC estimation. First, cluster assignments of each country do not depend on the random initialisation of the search algorithm. Second, all units are eventually assigned to a cluster (even if a solitary one). And third, both the number of clusters and the size of each are purely determined by data, not chosen by the analyst. This flexibility allows clusters assignments to be fully determined by data.

In the case of Costa Rica, using only the outcome variable (noninterest expenses of the banking sector), the cluster contains Bosnia and Herzegovina, Ecuador, Guatemala, Honduras, Lithuania, Madagascar, Nicaragua, Nigeria, North Macedonia, Norway, Paraguay, Romania, Rwanda, Ukraine, United States, Vanuatu and Zambia. Granted, this is hardly a list that any analyst would spontaneously come up with. But, it is the list of countries that are more similar to one another in their noninterest expenses according to an objective and flexible methodology. Thus, this choice of donor pool can be transparently defended as being data-driven. Another advantage of this particular pool of countries is how distant most are to Costa Rica, rendering any direct spillover between their banking systems unlikely. In contrast, if the donor pool consisted only or mostly of Central American countries, then other analyses would be necessary to confirm lack of externalities that would invalidate a causal interpretation of the estimates, since this is a comparative case study.

This exercise shows a strong reduction in noninterest expenses of Costa Rican banks after the rapid adoption of SINPE Móvil. The efficiency effects are economically large and seem to last for a number of quarters. Using this cluster as controls to estimate a counterfactual Costa Rica without the take-off of SINPE Móvil, the analyses suggest that SINPE Móvil adoption is indeed associated with a marked reduction in the cost structure of Costa Rican banks (Graph 4) at first. The ratio of non-interest expenses to gross income for the Costa Rican banking system (red line) fell significantly in 2020 and continued to be lower (compared to past values) for eight quarters afterwards. This observed outcome compares favourably with the estimated non-interest expenses for a counterfactual simulation of Costa Rica in which SINPE Móvil use had not taken off (blue line). While the true Costa Rican banking system and the counterfactual simulation tracked each other quite well in the years before SINPE Móvil was widely adopted, a gap opens afterward. This suggests a contribution of SINPE Móvil to higher cost efficiency in the banking system, especially during the Covid-19 pandemic, when ensuring access to banking and payment services was not straightforward.

Bank expenses were notably lower than in the counterfactual[1] Graph 4



[1] Values for series without SINPE Móvil are estimated with a combination of machine learning algorithms. [a] Dashed line represents the cut-off date for the estimation of synthetic controls: data up until that date is used to estimate the control weights, and from 2019 onwards is used for calculating the effect from SINPE Móvil.

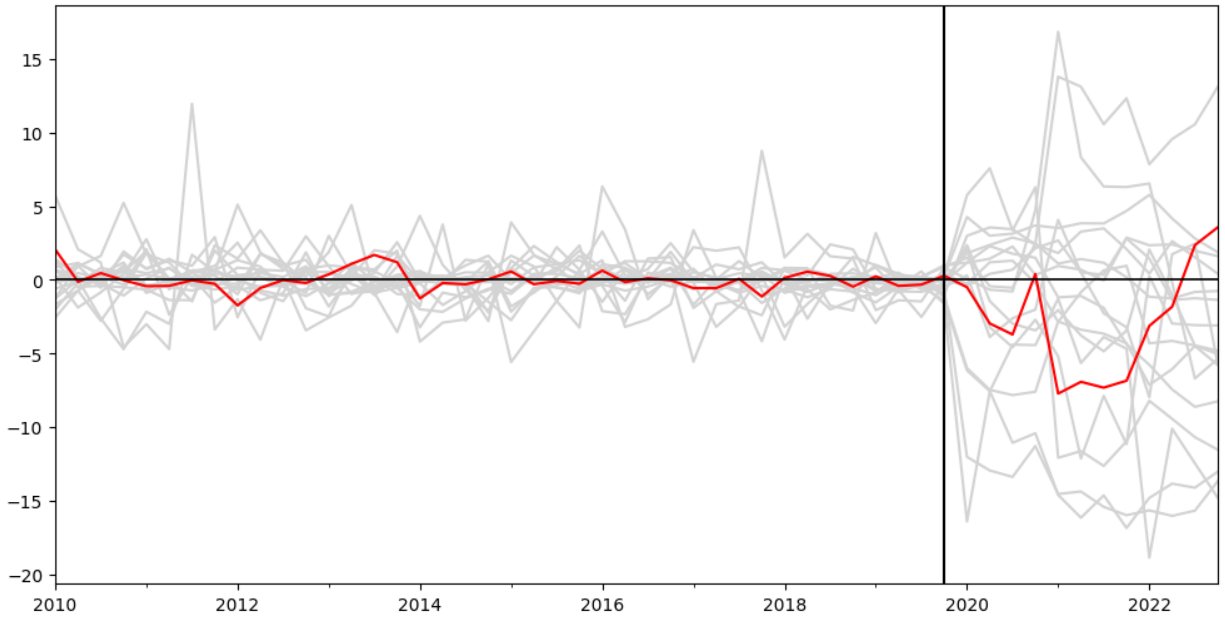
Sources: IMF; Central Bank of Costa Rica; BIS; authors' calculations.

One way to verify the statistical significant of these results is to run so-called *permutation analyses*, ie pretend that each of the control countries without SINPE Móvil adoption were "treated" and see what the post-treatment result would be. If Costa Rica's effect is contained in the range of these placebo calculations, then it suggests that at those periods, the shock is statistically indistinguishable from the effect of other shocks around the same time. Graph 5 presents these permutation analyses. Each line is the difference between the actual country (Costa Rica in red, control countries in grey) and its SC. Note the lower values for Costa Rica during the Covid pandemic time; while these are not strictly out of the range of placebo calculations, they tend to have only a few countries with even lower values. [7]

[7] The analysis period ends in 2022 to more cleanly identify the causal effect of SINPE Móvil's adoption take-off. Noninterest expense increased by more than a counterfactual Costa Rica in 2023. The magnitude of this effect suggests this is another individual "event" happening in the Costa Rican banking system and therefore, could not be separately analysed as part of the effects of SINPE Móvil.

SINPE Móvil adoption lowered bank noninterest expenses by more than most controls Graph 5

In per cent of gross income



Sources: IMF; authors' calculations.

An assessment of the quality of the synthetic Costa Rica helps to support these findings. Also here, machine learning methods can help. Traditionally SCs are assessed in two ways: their fit to the pre-treatment outcome variable for the treated unit, and by comparing a synthetic version of other key variables, constructed using the same weights $\widehat{\omega}_j$. While the former remains obviously a key test, the latter is subject to the criticism that conceivably one could simply now show covariates with a good fit. But even when this problem does not occur, a more fundamental question is how to judge these tests: simply comparing weighted averages across a number of variables might be a good approximation, albeit one always depending on the reader's agreement.

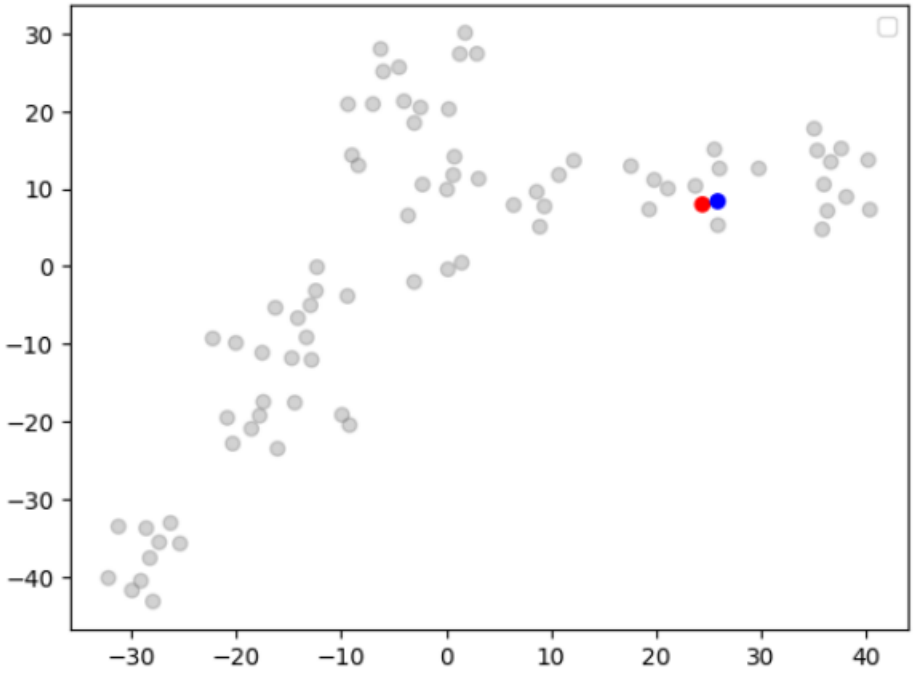
A more objective way to test control fit is to represent all relevant data in a lower dimension. This is achievable by algorithms called *manifold learning*, so called because they are calibrated to fit the high-dimensional data distribution using a lower-dimension distribution (formally, an underlying data manifold). Specifically, in the case of time series variables such as this application, the pre-treatment values for Costa Rica, the other countries and the "machine control" are used in a t-distributed stochastic neighbour embedding (t-SNE, van der Maaten and Hinton (2008)). In essence, t-SNE approximates a bivariate distribution with statistical sampling properties resembling the higher dimensional space of the original data. In our application, each point in time is used as a different dimension. Data points more similar as a whole to each other would tend to appear closer in this two-dimensional distribution than more different pairs of points.

Because the result has two dimensions, it can be interpreted as a coordinate system, which offers two convenient advantages. First, the results can be plotted and visually inspected, allowing a quick assessment of how close the control is to the unit of interest – the closer, the better as it means they would be more likely to come from similar areas in the data distribution. Second, and most important, the distance

between the unit of interest and all others (including the SC) can be ranked, serving as a form of p-testing and therefore the control power can be tested relative to the population of donors, which was also itself automatically chosen. In this case, the synthetic "machine control" is the closest to pre-2019 Costa Rica compared to the other countries, underscoring the quality of the estimated counterfactual (Graph 6).

The SC estimated with machine learning is the best approximation to actual Costa Rica

Graph 6



Sources: IMF; authors' calculations. Blue: actual Costa Rica; red: synthetic Costa Rica; grey: all other countries. The values in the axes have no intrinsic meaning. The distance between any two dots is proportional to their difference, if they were sampled from a two-dimensional distribution. In other words, closer dots are more likely to be similar than far away dots. Note that synthetic Costa Rica is the closest dot to Costa Rica, confirming numerically it is a good counterfactual. Embeddings in the two-dimensional space calculated with the t-SNE methodology of van der Maaten and Hinton (2008) with data before SINPE Móvil's wide adoption.

4. Conclusion

Costa Rica is an excellent case study for the transformational effect of fast payment systems. While SINPE Móvil took several years to take off, it has now achieved widespread adoption, with the majority of the adult population making transfers of small amounts instead of cash. As we have shown, it has also helped to lower non-interest expenses by Costa Rican banks, and thus to enhance bank efficiency.

These effects are visible in the data we have presented, but also in daily life. If a pedestrian on a main street in Costa Rica passes a street musician, she will no longer be able to use a lack of change as an excuse for not tipping. It is likely that the musician will accept a transfer through SINPE Móvil. Moreover, it is increasingly possible to use SINPE Móvil for daily needs everywhere in Costa Rica: for shopping, for going out to dinner, for paying utilities, rent, etc. Here, it is important to mention that there are other strategies and initiatives in place in Costa Rica regarding the

payment system. One of the latest is the electronic payment in public transport, which is expanding and reducing the use of cash in trains and buses in this country.

Finally, the role played by the Central Bank of Costa Rica and other banks committed to electronic fast payments was undeniably critical. The central bank provided leadership started the discussion and brought together key parties. It was the catalytic force that finally overthrew the reign of cash in Costa Rican society.

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Annex A. Characteristics of Costa Rica's FPS

Characteristics of Costa Rica's fast payment systems — Table 1

	TFT/PIN	SINPE Móvil
Type	Retail	Retail
Year of introduction	2000	2015
Rule book and standards	Central bank	Central bank
System operator	Central bank	Central bank
Clearing and settlement	Central bank	Central bank
Standard for the user interface	NA	Central bank
User interface	Private sector	Private sector
Development of other features	Private sector	Private sector
KYC/AML/CFT*	Private sector	Private sector
Settlement model	RTGS (real time settlement)	RTGS (deferred settlement)
Scope or payment types*	P2P, P2B, B2B, B2P, P2G, G2P, G2G	P2P, P2B, B2B, B2P, P2G, G2P, G2G
Average transfer amount (USD)	USD 5,725	USD 30
% of population (15 years and older) using it, as of June 2024	-	76%
Speed	<10 seg	<10 seg
Transactions per capita in 2022	4	71
Transactions per user in 2022	NA	110
Channels	Banking app, online banking or branch office	SMS banking, branch office, ATM banking app, online banking.
Daily transaction value limit (USD)	No limit.	No limit if made through authenticated channels. Mandatory limit up to USD 190 otherwise.[1]
Information for payment	Receiver's IBAN account number	Receiver's cell phone number
Currency	CRC, USD, EUR	CRC
Offline use	No	Yes
Charge to the customer (USD)	Set by banks[2]	No cost if up to USD 190 approx.[3]
Proxy lookup functionality	Yes	Yes
Request-to-pay functionality	-	In development
CAGR* of value of cash withdrawals from ATM* (last 5y)		-13%
Estimate of cost savings from reduced use of cash (last 5 years) as % GDP		-0.05%

[1] Private sector can increase the limit to make the service more competitive and depending to their risk appetite and the clients needs. [2] The fees of all participants are published in the web of the CB. [3] Private sector can set the fee above that amount. * KYC: know your client, AML: anti-money laundering, CFT: combating financing of terrorism, CAGR: compound annual growth rate, ATM: automated teller machine, P2P: person-to-person, P2B: person-to.business, P2G: person-to-government, and so forth.

The organisation of digital payments in India – lessons from the Unified Payments Interface (UPI)

Giulio Cornelli, Jon Frost, Leonardo Gambacorta, Sonalika Sinha and Robert M Townsend[1]

December 2024

Abstract

In India, the Unified Payments Interface (UPI) has become a leading payment system – processing more than 15 billion transactions per month as of November 2024. The strong growth of UPI can be attributed to the ease of development of applications, and an open, technology-agnostic architecture which enables transactions across multiple third-party application providers. User-friendly interfaces and zero transaction costs for end-users have also helped to increase adoption. Transactions are possible through mobile number-based or identity-based proxies and interoperable quick response (QR) codes. The system has been strengthened by active partnership with the private sector. UPI is governed by strict regulations on data storage and use. Adept regulatory conditions have been critical in laying the foundation for this success, and in addressing challenges that have arisen such as technical glitches, non-uniform interoperability and scalability for cross-border transactions. The UPI model has made rapid strides in India's financial inclusion, while preserving consumer protection and financial stability.

Keywords: Digital payments infrastructure, Unified Payment Interface (UPI), payment system, banks, big tech, fintech, India.

1. Introduction

India's payment market has changed dramatically in the past decade. Among the most consequential changes is the rapid adoption of the Unified Payments Interface (UPI) – a fast payment system that is often referred to by authorities as a 'digital public

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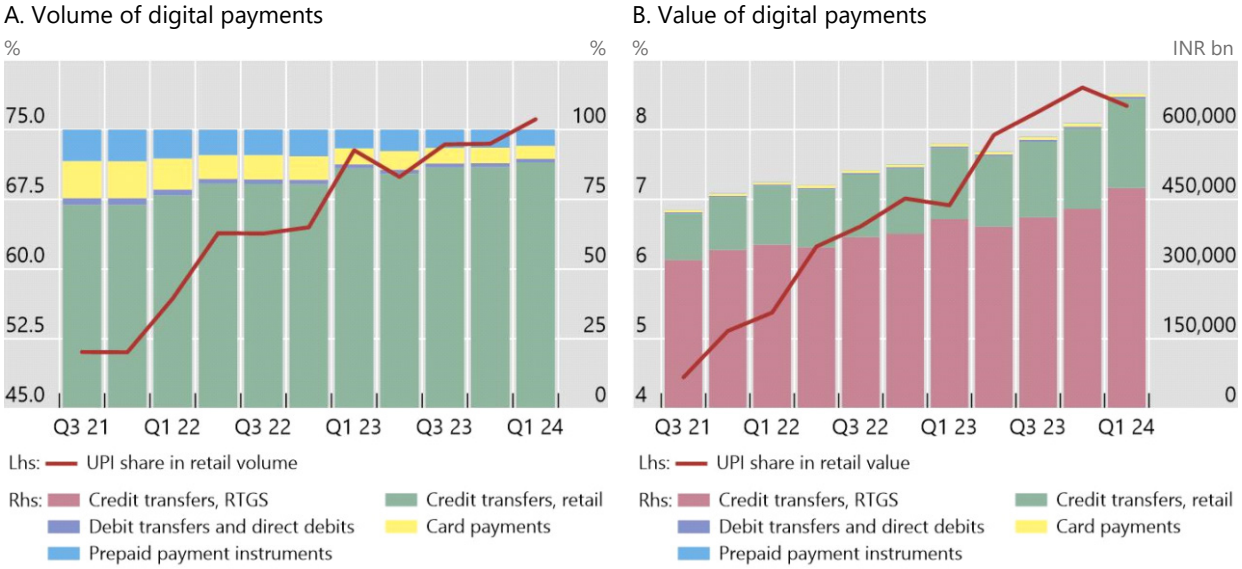
good'.[2] As part of broader efforts to modernise India's payment systems and promote digital transactions, the Reserve Bank of India (RBI) launched UPI in 2016. It is operated by the National Payments Corporation of India (NPCI), a non-profit entity. Since then, UPI has seen remarkable growth. This article seeks to understand the factors behind success of UPI, and its impact on industrial organisation of India's payments market.

To understand the scale and scope of UPI, it is important to put it into the context of India's overall digital payments infrastructure. As of February 2024, this market was worth INR 21,000,000 crores (USD 2.52 trillion).[3] Total digital payments in India encompass five main components: financial market infrastructures (FMIs); retail credit transfers; debit transfers; card payments and prepaid payment instruments. UPI falls under the retail credit transfers category.

Over the past few years, the volume of digital payments in India has surged significantly, expanding by 3.2 times since June 2021 (see Graph 1.A).[4] UPI has played a pivotal role in this growth. As of March 2024, UPI accounted for a staggering 81.8%

Digital payment systems in India have grown fast, with UPI increasingly dominant — Graph 1



Footnotes : Total digital payments are composed of five components : i) Financial Market Infrastructures (FMIs) ; ii) Credit Transfers - Retail ; iii) Debit Transfers and Direct Debits ; iv) Card Payments ; and v) Prepaid Payment Instruments. Note that UPI is captured under Retail (Credit transfers) category. In value terms, Financial Market Infrastructures (FMI) indicates credit transfers through RTGS and therefore the largest, whereas retail transactions tend to be small-ticket transactions and therefore much larger in volume.

Sources: RBI Payment System Indicators; authors' calculations.

[2] See, for example, this 2022 tweet from the Indian Ministry of Finance (link). The United Nations (UN) Secretary-General's roadmap for digital cooperation defines digital public goods as "*open-source software, open data, open artificial intelligence models, open standards and open content that adhere to privacy and other applicable international and domestic laws, standards and best practices and do no harm*" (see link).

[3] At an exchange rate of USD 1 = INR 83.4. A crore is equal to 10 million Indian Rupees.

[4] RBI began reporting of Payment System Indicators from June 2021 (link).

of the volume of total digital payments in India. As of November 2024, it was processing over 15 billion transactions per month. This demonstrates its widespread adoption for everyday transactions. But despite dominating volumes, UPI transactions contributed only 8.7% by value in March 2024 (Graph 1.B). This indicates a prevalence of small-ticket transactions through the platform. This not only underscores the increasing reliance in India's evolving financial landscape on digital payment solutions, particularly UPI; it also points to increased adoption by a wider user base.

India also observed a surge in digital payments in other real-time payment products after the Covid-19 pandemic. These included the National Electronic Fund Transfer (NEFT), the Immediate Payment System (IMPS) and the Real Time Gross Settlement (RTGS) for credit transfers and retail transactions. Each of these are secure, reliable and competitive systems. These payment systems often compete with one another in value or volume, and there is considerable product differentiation across products like UPI, IMPS and NEFT. Each of these is available 24x7, but they have various modes of use and associated transaction fees. Payment systems like NEFT and IMPS are facilitated through a consumer's internet banking; for payment initiation, the payer needs the receiver's bank account details. The NEFT allows for inter-bank fund transfers in batches in both offline and online modes, ie customers can use these facilities either electronically or by physically going to a bank. The IMPS is a real-time interbank electronic funds transfer service that allows customers to transfer funds instantly to any bank account using mobile phones or internet banking and offers a 24x7 instant fund transfer service. However, both NEFT and IMPS require users to have a bank account that can be accessed through internet banking or a mobile application of the bank in which they hold an account. Further, the transaction fees also differ by product. NEFT and IMPS levy a transaction fee for customers ranging from INR 1 to INR 25 (USD 0.012 to 0.3) depending on the volume of transaction.[5] In comparison with these products, UPI is a real-time payment service with zero transaction fees for end-users. UPI apps are enabled across multiple third-party application providers (such as big tech and fintech companies) or banks for facilitating fund transfers services using a single platform. UPI uses an open architecture, which enables quick and safe transactions. UPI is governed by strict data regulations.

This article draws lessons from the success of UPI. We argue that this success majorly owes to ease of development of applications, easy use and zero-transaction fees for end-users. Further success factors have been strict data protection rules, active partnership with the private sector and adept regulation. In the following sections, we discuss the organisation of the Indian payment market since the launch of UPI. Section 2 discusses the changes in digital payment market in India, with a focus on payment volumes and values. Section 3 highlights the increasing investments in the payments market and increased adoption over time. Section 4 provides insights into the implications of payment systems for financial inclusion in India, and touches upon some challenges UPI faces. Section 5 concludes.

[5] RBI guidelines on transaction charges (link)

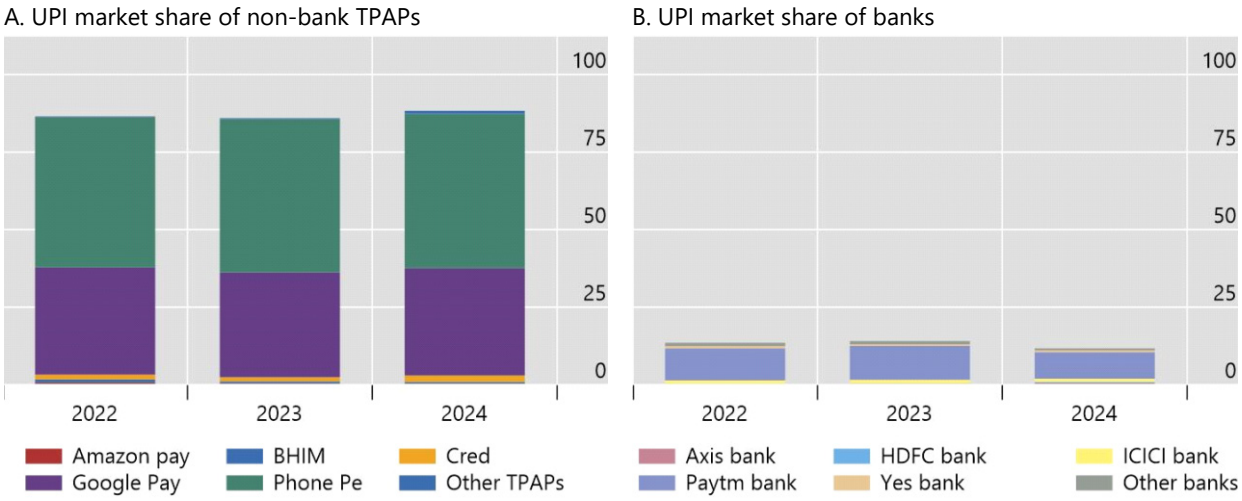
2. Changes in the digital payment market in India

Globally, UPI is among the most successful retail fast payment systems (FPS). Like other widely adopted FPS, it provides simplicity, safety and security to person-to-person (P2P) and person-to-merchant (P2M) transactions (see CPMI, 2021; Frost et al, 2024). In many countries, such as China and Kenya, digital payment adoption has been driven by dominant private systems ("walled gardens"). In India, different firms compete in the same system. Big tech and fintech companies like Google Pay and PhonePe[6] have achieved very large market shares in payment services (Graph 2.A). These firms have the advantage of having a wider user base, larger marketing and promotional budgets for advertising and dedicated customer support. Banks have a small market share in the initiation market (Graph 2.B), but they still actively provide payment services.[7]

Non-bank third-party application providers have large market shares in payment services

In per cent

Graph 2



Market shares based on value of transactions in the month of February each year.

Sources: NPCI; authors' calculations.

UPI has five key attributes – i) an open architecture infrastructure, ii) multi-party transactability, iii) ease of doing transactions, iv) strict data regulations, and v) a carefully calibrated regulatory environment.

An open infrastructure simply means that UPI allows third-party developers to build on top of its open platform and create their own app that can be integrated

[6] Google Pay is run by Google. PhonePe is an Indian payment firm headquartered in Bengaluru. Until December 2022 it was a subsidiary of e-commerce platform Flipkart. It continues to have a majority ownership stake by Flipkart's majority shareholder, US retailer Walmart.

[7] Both FPS and other forms of digital payments may have benefits for the real economy. See Jack and Suri (2014) and Uña et al (2023).

with UPI. Tech companies (big tech and fintech) and banks have free entry to use UPI and/or build their own apps with UPI as the third-party application. UPI allows users to make payments from one bank account to another. They can initiative these payments from their bank account through third-party application providers (TPAPs) such as Amazon Pay, Google Pay and PhonePe.[8] Big techs can be defined as large companies whose primary activity is digital services (BIS, 2019; Frost et al, 2019). Examples include Google, Apple or Amazon in the US, and Alibaba or Tencent in China. To build a UPI-enabled platform, third-party developers must obtain authorisation from NPCI and comply with technical specifications, security and privacy standards, testing and certification processes, and other relevant regulations set by NPCI.

UPI also enables multi-application transactions. This means that users registered on any UPI platform can make safe and quick transactions to any other account registered with UPI. These could be accounts linked to third-party payment service providers (PSPs) or bank accounts. Users are not restricted to using a particular bank's mobile app or payment platform but can use the UPI app or any UPI-enabled app to make transactions. This makes UPI a convenient single platform for transactions, eliminating the need for users to maintain multiple accounts or download multiple apps to make payments. Payment over UPI does not depend on full bank account numbers or other information of the recipients. Instead, they can use a mobile phone number or scan a quick response (QR) code by phone to initiate a transaction.[9]

The use of UPI data is strictly regulated. For this reason, big techs have not been allowed to extract rents from users' transaction data.[10] Users can access their own transaction data from their bank and there are separate data sharing initiatives,[11] but payment initiators (TPAPs) cannot collect individual transaction data.

Finally, regulators in India have carefully calibrated the rules governing the system, supporting competition while being mindful of financial stability. While it is worth underscoring that the associated credit risk remains on the balance sheet of banks and other regulated lenders, the sheer volume of transactions by dominant players could raise competition and financial stability concerns. In 2021, the NPCI announced a restriction on the total volume of transactions processed by any one TPAP in the UPI system, capping it at 30%.[12] TPAPs that surpass the three-month transaction volume limit have been advised to decrease their market share to avoid market disruption and encourage future use.[13]

[8] See the NPCI website for list of UPI third party apps (link).

[9] A quick response (QR code) is a two-dimensional barcode that can be scanned by a smartphone or other device to initiate a payment.

[10] In many private payment systems (walled gardens), firms can extract rents from users in the form of high fees or exclusive control over (valuable) personal data. In UPI, prices and the use of data are regulated, preventing these types of abuse by payment service providers.

[11] For instance, regarding the India's Data Empowerment Protection Architecture (DEPA) and open banking initiatives, see Tiwari et al (2022).

[12] See NPCI Press Release (2020) (link)

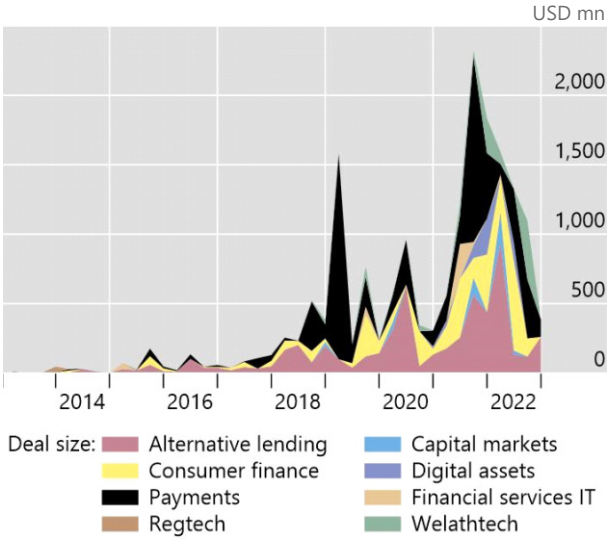
[13] While the rule was originally scheduled to take effect on 1 January 2021, the NPCI later extended the deadline to 31 December 2024, NPCI Press Release (2022) (link).

3. Increasing investments

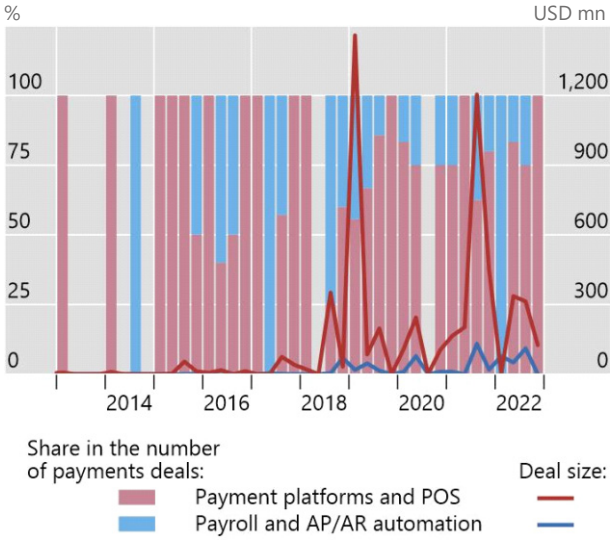
In addition to the structural attributes, robust private investment has been an important driver of the growth in India's digital payment system, supporting greater opportunity for market entry and innovation. Investment in Indian fintech firms spiked in early 2019 and again in 2021 when payment firms took up nearly half the volume, marking a shift in investors' interest (graph 3, left-hand panel). The majority of investments was in companies whose core business was providing payment services and point-of-sales (PoS) devices (right-hand panel). The spike in the value of investment deals in 2019 related to the growing adoption of UPI and large deals by Paytm and PhonePe. In 2021, the surge in investment followed from an increased preference for using digital payment systems after the Covid-19 pandemic.

Equity investment in payment firms has surged — Graph 3

A. Investment deals at payment companies reached half of the fintech deal volume at times



B. Within payment company deals most of the target firms operate as payment platforms

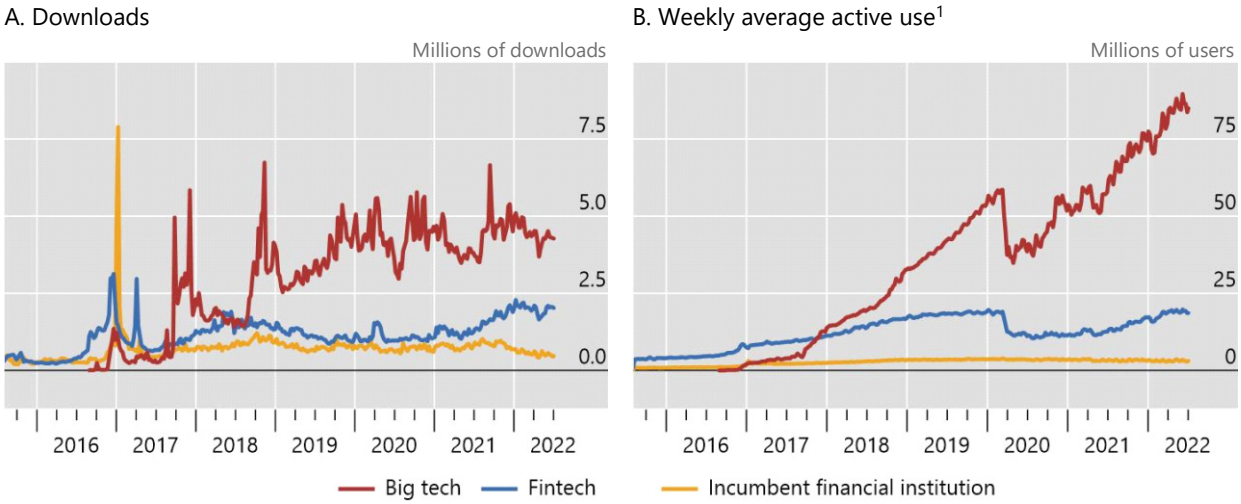


Sources: PitchBook Data Inc; authors' calculations.

In terms of UPI use, big tech payment apps have become increasingly popular and widely used in the UPI system. This trend seems likely to continue in the future. This can also be seen in Graph 4, which shows the number of downloads and weekly average active use of big tech payment apps in the UPI system. The left-hand panel represents the number of downloads in millions, and the right-hand panel represents the weekly average active use in millions of users, taken from the provider Sensor Tower.

In UPI, big tech payment apps have seen particularly rapid adoption

Graph 4



Based on the top 25 finance apps as classified by Sensor Tower. For more details see Cornelli, G, J Frost, C Velasquez, J Warren and C Yang (2024): "Fast payment systems as a catalyst of digital finance app adoption", BIS Working Papers, forthcoming.

[1] Weekly average of daily active users.

Sources: Sensor Tower; authors' calculations.

The number of downloads and weekly active usage shown in Graph 4 indicates rapid adoption of big tech payment apps in the UPI system. Use of big tech apps accelerated particularly with the Covid-19 pandemic – growing from about 60 million to almost 90 million daily active users. By contrast, fintech payment apps saw a decline during the pandemic, and only recovered to their pre-Covid levels of use after two years. Overall, the data suggest that especially big tech payment apps are popular and widely used for payment initiation – even as banks have continued to play an important role in back-end settlements.

At the sectoral level, UPI-based transactions are mainly focused on retail payments, characterised by a large volume of small-ticket transactions in real time. Wholesale payments, ie transactions between businesses, make up a small share of overall payment volume but a larger share of their value. At the merchant level, these transactions are highest for categories like groceries and supermarkets, and restaurants. Merchant category-wise classification of UPI is provided in Table A1 in the Annex.

In 2020, in an effort to simplify offline payments and enhance user experience, all payment system operators were required to switch to at least one interoperable QR codes –UPI or Bharat QR. This, in turn, reduced the cost and complexity of digital transactions for end-users including small and medium-sized enterprises (SMEs). It has also set the stage for further innovation, including in tokenisation of credit cards,[14] and cross-border payments. In June 2022, RBI approved linking of credit cards

[14] Tokenisation of credit cards refers to a security protocol that creates a randomly generated identifier rather than an individual's card number and personal details. This should not be confused with tokenisation as the digital representation of assets on a programmable platform. For the latter, see Aldasoro et al (2023) and Carstens and Nilekani (2024).

to UPI, starting with RuPay credit cards, which is a domestic card payment network operated by the NPCI (RBI SDR, 2022). In September 2023, the scope of UPI expanded to include credit lines as a funding account, wherein individuals can give consent to making payments via the UPI using pre-sanctioned credit lines from a scheduled commercial bank.[15] As of that date, services such as savings account, overdraft accounts, prepaid wallets, credit cards and pre-sanctioned credit lines can be linked to UPI.

In the last few years, the UPI has extended its capabilities across borders. In July 2021, BHIM UPI partnered with the Royal Monetary Authority (RMA) of Bhutan to implement QR-based payments in Bhutan, adding a new milestone of cross-border financial integration. In August 2022, the UPI and RuPay card schemes signed a memorandum of understanding (MoU)[16] confirming a partnership with the payment solutions provider PayXpert to internationalise the acceptance of its payment solutions in the UK, starting with UPI-based QR-code payments. In the same year, UPI AUTOPAY also debuted in the mutual fund segment (and all recurring payments) to digitise its payment landscape by paying loan equal monthly instalments (EMIs) through UPI.

The growing scale of operations has improved outreach and transactions costs in domestic as well as cross-border initiatives. On 21 February 2023, a cross-border linkage between India and Singapore went live. The linkage operates through the countries' respective fast payment systems, namely UPI and Singapore's PayNow, with the aim of enabling cross-border fund transfers using their respective UPI-id, mobile number, or Virtual Payment Address (VPA). The collaboration between UPI and PayNow SG has brought significant advancements to cross-border remittances between India and Singapore. Leveraging PayNow SG's peer-to-peer funds transfer service, users can now seamlessly transfer funds using mobile numbers or virtual payment addresses (VPAs) in real-time, without the need for bank account details.

UPI has also introduced a novel approach to offline payments, through UPI Lite X which enables transactions in environments with limited network connectivity. Both payer and payee can engage in transactions offline, using the existing UPI Lite wallet with an INR 500 (~USD 6) upper limit for each transaction. Leveraging NFC communication, UPI Lite X ensures secure transactions without internet access, catering to scenarios such as flights, parking lots, or remote locations. Users initiate transactions through a simple process within the UPI app, without the need for a UPI PIN. This product focuses on user security, offering real-time balance refunds in cases of app uninstallation, device changes or loss/theft. This feature-rich solution enhances accessibility and success rates for offline transactions, providing a convenient option for users, particularly in rural areas.

15 RBI notification (2023), link.

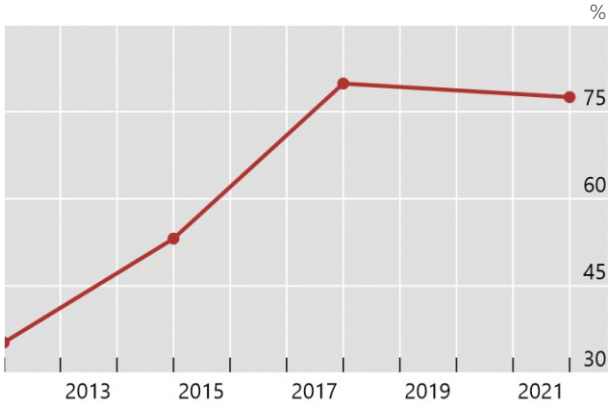
16 NPCI press release (2022), link.

4. Dividends for financial inclusion

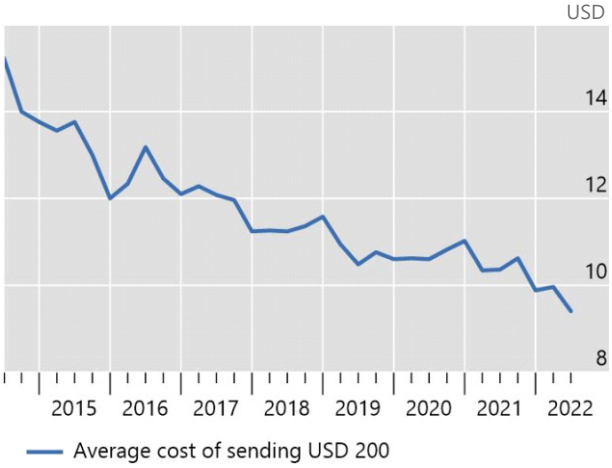
Progress in digital payments systems is one of India's major tools to enhance financial inclusion. Robust implementation and adoption of digital payment infrastructure has been used to promote greater access to financial services, potentially enhancing consumer welfare (Croxson et al, 2022). Evidenced by the rapid adoption by end users, the digital payments system has become more diverse over time. In India, the payments infrastructure has combined with the opening a large number of bank account through the digital identity system *Aadhaar*, which has considerably improved access to finance.[17] The share of adults with a bank account steadily increased until 2017 when it reached a peak at more than 75% (Graph 5, left-hand panel). Further, the cost of remittances has fallen consistently since 2015 (Graph 5, right-hand panel) on account of increased market competitiveness and easy technology adoption.

Account access has risen while payment costs have declined — Graph 5

A. Percentage of adults with a bank account has risen, then plateaued[1]



B. Remittance costs have fallen but are still substantial



[1] The percentage of respondents who report having an account (by themselves or together with someone else) at a bank or another type of financial institution (see the definition for "financial institution account") or report personally using a mobile money service in the past year (see the definition for "mobile money account"). The figure for 2008 comes from D D'Silva, Z Filková, F Packer and S Tiwari (2019), "The design of digital financial infrastructure: lessons from India", *BIS Papers*, no 106, December.

Sources: World Bank; BIS.

The improvement in financial infrastructure has led to increased participation of poorer and rural segments of the population in the financial system. In addition, the reduction in remittance costs has improved outcomes, particularly for households in rural areas. The reduction of these costs has allowed for higher settlement of remittances, contributing to the financial well-being of these members of society.

[17] Aadhaar allows for electronic know-your-customer (e-KYC), which can drastically lower the cost of opening a bank account. It is estimated that banks that use e-KYC can lower their cost of compliance from $15 to $0.07. See D'Silva et al (2019).

Despite its success, the UPI is not without challenges. These have included technical glitches and outages leading to incomplete or failed transactions.[18] Efforts to address these include continuous reconciliation processes, infrastructure improvements, and enhanced network connectivity. Additionally, UPI faces limitations due to uneven interoperability with other payment infrastructures, each of which have their own set of protocols, APIs and security standards. Steps are being taken to standardise across payment system products in a phased manner to upscale India's digital expansion. Further, as UPI expands its international partnerships, scalability is a major challenge, which significant efforts in software and network development. Security, regulatory compliance and scalability for international partnerships remain key priorities, with ongoing efforts to enhance public infrastructure, improve grievance redressal mechanisms, and increase consumer awareness.

5. Conclusion

India's digital payment ecosystem and experience of UPI holds important insights for the industrial organisation of payment markets across jurisdictions. Over time, the payments market has been developed with support from a range of public infrastructures and regulatory initiatives. While some large players are dominant providers of payment services, the UPI has allowed for a vibrant market with strong investments. There are at least five main factors driving the rapid adoption of UPI as a leading digital public infrastructure.

(i) Ease of development: First, UPI offers an open architecture which enables third-party developers to construct their own applications integrated with UPI. This facilitates tech companies and banks freely using UPI or develop their own apps using the UPI.

(ii) Ease of use: Second, UPI facilitates transactions across multiple applications. This allows users across various platforms to execute secure and swift transactions to any UPI-registered account, whether it is linked to applications of third-party payment service providers or banks. Users are not confined to a specific bank's app but can use any UPI-enabled app for transactions, streamlining the process and eliminating the need for multiple accounts or apps.

(iii) Data protection: Third, UPI is governed by strict data regulations, instilling a sense of trust in the system. Technology companies, both big tech and fintechs, cannot collect individual data on transactions made through these platforms.

(iv) Partnering with private sector: Fourth, UPI has witnessed robust private investments even as zero transaction costs are levied on end-users. These trends have been an important part of overall digital infrastructure initiatives, alongside digital identity (Aadhaar) which has facilitated the rapid opening of bank accounts that can connect with the payment system.

(v) Adept regulation: The fifth crucial element is regulation. The authorities in India aim to promote innovation, enhance consumer and producer welfare and

[18] The Economist (2023).

promote financial stability. To achieve these goals, regulators like the RBI and NPCI have introduced various policies and guidelines to facilitate innovation, ensure security and reduce the risks associated with digital payments. As a result, new innovations and products, such as tokenisation, offline payments and cross-border financial integration are being introduced in a phased manner while being mindful of financial stability.

UPI's success in transforming digital transactions in India comes with challenges like technical glitches, outages, and interoperability issues. Continuous efforts are being made to address these through infrastructure improvements, standardisation initiatives and enhanced grievance redressal mechanisms. As UPI expands its international partnerships, scalability, security and regulatory compliance remain critical priorities. Ongoing measures aim to enhance public infrastructure, ensure seamless transactions, and increase consumer awareness.

Overall, UPI has significantly improved India's digital public infrastructure by providing an efficient and credible payment system promoting financial inclusion while preserving consumer protection and financial stability. This has facilitated safe, real-time and cost-free digital transactions for users.

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Annex

UPI merchant category classification – February 2024		Table A1
Type	**MCC**	**Description**
High transacting categories	5411	Groceries and supermarkets
	5812	Eating places and restaurants
	4814	Telecommunication services, including local and long-distance calls, credit card calls, calls through use of magnetic stripe reading telephones and faxes
	5814	Fast food restaurants
	5816	Digital Goods – Games
	5541	Service stations (with or without ancillary services)
	5311	Department stores
	5912	Drug stores and pharmacies
	5462	Bakeries
	7299	Miscellaneous personal services not elsewhere classified
Medium transacting categories	6540	Debit card to wallet credit (Wallet top up)*
	4900	Utilities - electric, gas, water and sanitary
	5451	Dairies
	5813	Drinking places (alcoholic beverages) - bars, taverns, night-clubs, cocktail lounges and discothèques
	7322	Debt collection agencies
	5399	Miscellaneous general merchandise
	6012	Financial institutions - merchandise and services
	8999	Professional services not elsewhere classified
	5999	Miscellaneous and specialty retail outlets
	5422	Freezer and locker meat provisioners
All other categories	6211	Securities - brokers and dealers
	5499	Miscellaneous food shops convenience and specialty retail outlets
	9399	Government services - not elsewhere classified
	5732	Electronics shops
	4899	Cable and other pay television services
	4214	Motor freight carriers and trucking - local and long distance, moving and storage companies and local delivery
	7399	Business services not elsewhere classified
	4784	Tolls and bridge fees
	5172	Petroleum and petroleum products
		Others

Source: NPCI


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