Pagamentos Instantâneos, Pix e *Unified Payments Interface* (UPI): Um Estudo de Caso[1]

Tatiana Silveira Camacho*
Guilherme Jonas Costa da Silva **

Resumo: O debate em torno da infraestrutura de pagamento é central para o crescimento de uma economia e, no Brasil, esta mudou drasticamente nos últimos dez anos. Os pagamentos instantâneos fazem parte desse ecossistema crescente, com disponibilidade de acesso a fundos quase de forma imediata. Por meio dos Modelos Autorregressivos de Defasagens Distribuídas (ARDL), o artigo tem como objetivo testar hipóteses acerca da experiência indiana a Unified *Payments Interface* (UPI), com o intuito de extrair lições importantes para o Pix brasileiro. Usando um conjunto de dados indiano (abril de 2016 a novembro de 2020), os resultados empíricos trazem para o centro do debate a importância da inovação financeira, da adoção do *mobile banking* e da *internet* para o desenvolvimento econômico do país. No curto prazo transações bancárias via *mobile banking,* e planos de assinatura de telefone móvel, tem uma influência direta sobre os fluxos de UPI. Enquanto que no longo prazo, substitutos para os pagamentos instantâneos, tais como cartões de crédito e débito, têm caráter complementar a estes instrumentos, pois aumentam o fluxo monetário na economia. O grau de sofisticação do sistema financeiro (M1/PIB) tem efeitos de curto e longo prazo nos pagamentos instantâneos.

Palavras-chave: Pix, *Unified Payments Interface* (UPI), Banco Central, Modelos ARDL.
Código JEL: G21, O38.
Área Temática: Inovação e mudanças técnica, organizacional e institucional (Área 5)

Instant Payments, Pix and Unified Payments Interface (UPI): A Case Study

Abstract: A core component of the economy are payment infrastructures, which have changed dramatically in the last ten years. Instant payments are part of this growing ecosystem, with access to funds almost immediately. Through Autoregressive Distributed Lag Models (ARDL), the article aims to test hypotheses about the Indian experience of the Unified Payments Interface (UPI), in order to extract important lessons for the Brazilian Pix. Empirical results using an Indian dataset (April 2016 to November 2020) brings to the center of the debate the importance of financial innovation, the adoption of mobile banking and the internet for economic development. In the short term, transactions via mobile banking, and mobile phone subscription, have a direct influence on UPI flows. While in the long run, substitutes for instant payments, such as credit and debit cards, are complementary to these instruments, as they increase cash flow in the economy. The degree of sophistication of the financial system (M1/GDP) has short-term and long-term effects on instant payments.

Keywords: **Pix, *Unified Payments Interface* (UPI), Central Banks, ARDL Models.**

[1] Os autores agradecem à CAPES pelo apoio financeiro.
* Doutoranda da Universidade Federal de Uberlândia (UFU). E-mail: tatianacamachoecon@gmail.com (https://orcid.org/0000-0001-7636-2225)
** Doutor em Economia pelo CEDEPLAR/UFMG e Professor Associado da Universidade Federal de Uberlândia (UFU). Email:guilhermejonas@yahoo.com.br (https://orcid.org/0000-0002-0947-0821).

1. Introduction

Payment systems are the pulse of capitalism, an essential component of the financial infrastructure, and necessary for any market economy that depends on the daily settlement of thousands of transactions resulting from the purchase/sale of goods, services, and assets. Globalization and the internet changed the way agents interact with their investments and resources, especially with the widespread use of mobile phones and apps. Provoking a shift in how payment systems interact with the economy, retailers and entrepreneurs, present their products in platforms directed to niche customers, using social media accounts, performing buying and selling in a global market.

Particularly, payment systems has seen a stream of innovations that lead to new emerging technologies, unseen and unimplemented new capabilities that propel service transformation, higher functionality, and new revenue strategies (Gomber et al, 2017). It is known that financial deepening goes hand in hand with economic development, in which fast payments can easily be put in this category.

In need for speed and corresponding drive towards instant payment, real-time gross settlement systems (RTGS), and automated clearinghouses within countries and across regions are bundling the clearing and settlement of transactions. The current environment makes it possible to offer customized financial solutions in payments, loans, and investment using customer data through application programming interface (API) platforms. This ecosystem has required more assertive strategic actions by large organizations, such as the Central Bank.

Considering new technologies, decentralized finance, digital assets the Brazilian Central Bank (BCB) has decided to take on the implementation of the Instant Payment System (SPI). Being the biggest economy in Latin America, and in comparison, to its counterparts in other areas of the world, Brazil needed to enhance payments technology. Pix was made public in November 2020, with a promise in reducing cash transactions, and providing the informal economy financial inclusion through internet infrastructure.

Paper motivation is directed to instant payment mechanisms and to test hypothesis towards their underlying explanatory variables. On a macro-level, financial sophistication, economic growth, payment substitutes, and a measure of the relative popularity of banking apps are used to better understand these dynamics. The Indian Unified Payments Interface (UPI) implemented in 2016 an instant payment system, was identified and used as a broader study case for the Brazilian instant payment, Pix. Using time-series methodology, specifically Autoregressive Distributed Lag Models (ARDL), with an Indian dataset (April 2016 to November 2020) important inferences are made. Empirical studies on payment systems are typically country-specific, which makes comparison between countries difficult. But, due to demographic, geographic, territory dimensions and both being BRICS countries, some important parallels can be made between Brazil and India.

This study directly contributes to the growing literature in payment innovations, a novel analysis, in which few studies on payment systems are presented from this perspective. A time series empirical application, that emphasizes short and long run effects towards practical policy lessons for both countries. Preliminary results show that financial deepening and economic growth have important effects on instant payment mechanisms (and vice-versa). Other payment options such as credit and debit cards, will have a complementary nature, and mobile banking volume will enhance fast transactions. Through telephone wireless subscription base, and mobile transactions there is a case for policies towards enhancements in nationwide telecommunication infrastructure.

This article is divided into four main parts, including this introduction. In the next section, the Brazilian Payment Systems will be defined and briefly debated, encompassing the Instant Payment System (SPI) and Pix. The Indian study case, Unified Payment Interface (UPI), is analysed in the following item making important inferences to substantiate our econometric approach. The third section is subdivided into four parts presenting: 1) empirical review on payment systems, 2) dataset, methodology, 3) long run and 4) short run estimations. Finishing the article with our main conclusions.

2. Instant Payments and Central Banks

According to the Bank of International Settlements (BIS), "*a payment system is a set of instruments, procedures, and rules for the transfer of funds between or among participants and the entity operating the arrangement*" (BIS, 2012, p.8). Brazilian law (Lei nº 10.214 de 27 de Março de 2001, Art. 2º)[2] defines the Payment System (SPB) as: *"entities, systems, and procedures related to the transfer of funds and other financial assets, or the processing, clearing, and settlement of payments in any form"*. The Brazilian Association of Financial and Capital Market Entities (ANBIMA) has a broader definition stating that the Brazilian Payment System (SPB) is a "*set of entities, systems, and mechanisms related to the processing and settlement of funds, transactions with foreign currency or with financial assets and securities* (ANBIMA, 2020, p.24).

Payment Systems are based on an agreed-upon operational infrastructure, encompassing participants and the operator of the arrangement (Bech; Hancock, 2020). They are usually divided into **large-value payment system (LVPS)** which handles high-priority payments; and **small value payment systems (SVPS)** that deals with a large volume of low-value payments like cheques, credit transfers, direct debits, and card payment transactions, at a relatively minor cost, reliably and securely (BRITO, 2002; PINTO, 2004; CARVALHO, 2011; BIS, 2012).

Retail payments are typically between end customers such as households and firms (person-to-person, person-to-business, business-to-business), consisting of many forms of payment instruments including card-based systems such as ATMs, debit, credit cards, and digital payment forms such as internet banking. These payment systems are typically run by both private and public sector providers (KAHN; ROBERDS, 2009; BECH ET AL, 2017; LUBIS ET AL, 2019, BECH; HANCOCK, 2020).

The *front end* is where these payments usually initiate, like a bank account, including the service channel used to process the payment (a mobile application) and the payment instrument (credit transfer). *Back-end* arrangements comprise clearing and settlement of payment instruments. Settlement can be done once at a time, and in real-time (*Real Time Gross Settlement Systems*), if the payer's Payment Service Provider (PSP) has sufficient funds. Provided the payer's PSP has insufficient funds, the payment is rejected or queued. The alternative is the *Deferred Net Settlement* (DNS), a clearing system that operates on a net basis, where netting and settlement take place after a specified period. There are also hybrid systems that combine characteristics of RTGS and DNS (BECH; HANCOCK, 2020).

In an environment where consumers are increasingly used to instant communication via e-mail, social media, payments have evolved to offer the same experience in commercial transactions. Fast payments[3] can be defined by two key features: speed and continuous service availability. Based on these features, and according to the BIS report: "*fast payment" is defined as a payment in which message transmission and availability of "final" funds to the payee occur in real-time or near-real-time as near as a 24-hour and seven-day (24/7) basis as possible"* (BIS; 2016, p.6). Final funds are received, such that the payee has unconditional and irrevocable access to them, providing strong certainty of payment to the payee (BIS, 2016)[4].

Traditional payment messages are not cleared or settled until the subsequent business day. Payment orders are collected in batches, which introduces delays on individual payments. On top of that, clearing and settlement are often limited to certain days or business hours. So, the payee typically does not receive funds until inter-PSP settlement occurs, which could be a day or more after payment initiation (BIS, 2016).

Fast payment systems implementation requires interaction and collective decision-making. Therefore, a common challenge in many countries is to overcome potential conflicting issues between different stakeholders (Bech et al, 2017). Benefits to consumers from new payment methods often depend

2 Provisional Measure nº 2.115-16, of February 23rd, 2001, which was converted into Law nº 10.214 of 2001.

3 The terms used for fast payments may vary, although the underlying meaning could still be the same. Other common terms are "instant", "immediate", "real-time" or "faster payments" (BIS, 2016).

4 An interesting point made by Giraldo-Mora et al (2020) is that a real time payment only needs to provide the perception of an instant payment, in the foreground, with no regard to the actual process in the background. Considering these technical and organizational conceptualizations of real time, the authors define instant payments a little differently: *as a traceable and predictable payment instrument in which funds are made available to end consumers just in time for the payment context* (GIRALDO-MORA et al, 2020, p.3).

on seamlessly coordinating across large networks needed for fast payment system success, which may require either a large degree of control by one firm or a great deal of cooperation among rivals[5].

The involvement of authorities is one of the seven key drivers identified by Hartman et al (2019) in implementing instant payments infrastructure[6]. Although external factors may influence supply-side actors (private payment providers) to offer instant payment services, customers demand to use such services (adoption decisions by the end-user), and strong network effects (number of initial users, coverage, and reach) are fundamental to promote a new payment technology[7]. How features and pricing of fast payments compare with those of alternative payment methods (such as cash, credit, debit cards, cheques, and traditional credit transfers) will indicate viability and different use cases, as customers start placing value on speed, convenience, and service availability in different situations.

Complementary technologies, including mobile payment services, vastly broaden the potential of instant payment technology, since it imports the benefits of traditional banking instruments to compete in low-value payments. Acceptance by merchants, internet, mobile device accessibility and consumer demographic characteristics (such as age, education, income, and payment habits) are also important factors in the diffusion of novel instruments.

Context-specific payment mechanisms enables more granular services, however, structuring and sharing of data promote their integration, which largely depends on sector-wide cooperation, as stated earlier. PSPs may need to incur not only in individual costs to update their internal systems but investments that will establish data consistent inter-PSP systems to provide fast payments (BIS, 2016; GIRALDO MORA ET AL, 2020)

Each potential provider will likely consider its private expected return based on its perception of costs, benefits, and investment in a cooperative effort. Individual PSPs in a particular market may also try to set their system as the standard, leading to a diversity of incompatible networks and, thus, to a lower outcome from an end-user perspective. Development of payment innovations that require investment in shared infrastructure, at the level of the individual firm, tends to be slow and socially suboptimal (BIS, 2016; HARTMAN ET AL; 2019).

Thus, featuring network externalities, with decision-making complexities and viewed as a public good, it may be a long time before a new payment technology is adopted in the absence of a strong external incentive. Central banks play an important role not only in ensuring cooperation between the different actors, establishing common standards, but sometimes taking on an operational role, fostering greater efficiency and system resilience (BECH ET AL, 2017).

Central Bank motivations are quite different from profit considerations driving the private sector (Blix et al, 2003; Bech, Hobijn, 2006). Using their influence, knowledge, and analytical capabilities with authorities and industry stakeholders, central banks contribute by adopting a long-term perspective, with positive externalities. A consistent strategy to promote an efficient outcome about these deployments, and in accordance with its mandate[8].

The Brazilian Central Bank (BCB) has actively taken a catalyst, oversight and operational role, with

---

5 BERGER, Allen et al. A framework for analyzing efficiency, risks, costs, and innovations in the payments system. Journal of Money, Credit and Banking, v. 28, n. 4, p. 696-732, 1996.

6 The seven key drivers are: 1) Involvement of authorities in instant payments; 2) Structure of the market for payment services; 3) End user access to telecommunications and payment infrastructures; 4) consumer's characteristics; 5) payment preferences and habits; 6) transfer speed; 7) fee levels (Hartman et al, 2019).

7 To achieve high coverage of potential users depends on numerous factors such as: 1) the decision of individual PSPs regarding the participation in one or more fast payment systems or schemes; 2) the access criteria imposed on PSPs by a fast payment system; 3) the percentage of the population that have payment accounts at PSPs and that choose to adopt the service; and 4) ease with which different system interoperate (BIS; 2016, p. 11).

8 In general terms, three approaches can be identified, pertaining instant payment implementations and the central bank's catalyst role: 1) Low degree of involvement: central banks that have not actively promoted fast payments in their catalyst role for change; 2) Moderate degree of involvement: while not pursuing a specific strategic policy to develop a fast payment system; central banks have a mandate to secure and facilitate the operation of these systems, with an open dialogue to market participants, providing resources and guidance when necessary; 3) High degree involvement: some central banks consider the implementation of fast payments as a strategic policy objective in the field of retail payments, to modernize a country's payment infrastructure: to bring it on par with that of other economies, contribute to payment innovations, improve the general speed of payments, facilitate financial inclusion and faster remittances (BIS, 2016, p.58).

a high degree of involvement in Pix's development, considered a strategic public policy objective. Broad coverage, interoperable systems, network effects, and potential long-term benefits that are difficult to measure presently, are very strong arguments to understand why the Brazilian Central Bank (BCB) engaged in such enterprise. Conveying user-centric modernization of Brazilian retail payments, other arguments favouring Pix's implementation will be discussed, alongside its technical attributes, in the following topic.

2.1 Pix

The Brazilian Payment System (SPB) is currently characterized by a solid and comprehensive legal ground, with mandatory use of central counterparties for the settlement of obligations, with certainty as well as irrevocability based on risk management mechanisms. The Brazilian Central Bank (BCB) has followed related activities within the scope of the National Financial System (SFN) and the Brazilian Payment System (SPB), in a coordinated and multidisciplinary manner[9]. Technological evolution is central to developing framework issues, such as inclusion and competition.

According to the BCB (BCB; 2020a, 2021) the Instant Payment System (SPI), is a centralized infrastructure for the settlement of fast payments between different institutions. A unique architecture for real-time gross settlement (RTGS) via messaging, in the national reserve transfer system (STR), clearing payments through specific purpose accounts that direct participants maintain with the BCB, called Instant Payment Accounts (CPI). Overdraft is not allowed in these accounts (BCB, 2020).

Instant payment ecosystem will be formed by an open arrangement instituted by the BCB (Pix), by payment service providers participating in the arrangement (financial and payment institutions), by a single platform that will settle transactions carried out between different parties (STR) and the *Directory of Transactional Account Identifiers* (DICT)[10], whose responsibility is to store keys used to identify accounts. Both the Instant Payment System (SPI) and the DICT will be developed, and managed by the BCB operating 24 hours a day, seven days a week, every day of the year.

Transactions will occur in the National Financial System Network (RSFN), which is the data communication infrastructure that aims to support traffic information within the scope of the National Financial System (SFN), for services authorized by the BCB, as provided in the circular 3,970, of November 28th, 2019[11]. To participate, the provider must be: 1) Transactional account provider; 2) Payment initiation service provider; 3) Indirect participant; 4) Direct participant; 5) Governmental entity; 6) Special liquidator[12]. Commercial banks, multiple banks with a commercial portfolio and savings banks must be direct participants: settle transactions and access the SPI and the DICT directly. Payment institutions without authorization to operate (and are Pix providers) are necessarily indirect participants in the SPI

9 Through its Agenda BC#, the BCB, comprises guidelines and dimensions to be pursued by its policies. The agenda is structured in four main dimensions*: Inclusion, Competitiveness, Transparency,* and *Education*. Each of these dimensions is developed through thematic groups (BCB, 2020a).

10 Pix keys are stored in the DICT, and in the process of initiating a Pix, identification of the user's transactional account must be done by consulting the DICT, when dealing with transactions between end users with different participants. But, if the transaction occurs between transactional accounts in the same participant, it is up to the participant, and consulting his internal database to identify the receiver.

11 Its main objective is to support data traffic directly related to critical services, it is able to support traffic of another nature, as long as there is no harm to its main objective (BCB, 2020).

12 Definitions: 1. Transactional account provider: a financial institution or payment institution that offers a transactional account (deposit account, savings deposit or a prepaid account) to the end user. 2. Payment initiation service provider: institution that will initiate payment at the request of a customer holding a transactional account but doesn't participate in the financial settlement. This form of participation is subject to specific regulations.3. Indirect participant: an institution that offers a transactional account to an end user, but that does not own a PI account at the BCB, nor does it have a direct connection with the SPI. Uses the services of a settler in the SPI for the purpose of settling instant payments.4. Direct participant: an institution authorized to operate by the Central Bank that offers a transactional account to an end user and who, for the purposes of settling instant payments, holds a PI account.5. Governmental entity: National Treasury, with the sole purpose of making payments and receiving payments related to its typical activities; 6. Special liquidator: a financial or payment institution authorized to operate by the Central Bank of Brazil whose purpose is to provide settlement services to other participants and that observes the requirements to act as a liquidating participant in the SPI. But it does not meet Pix's requirement for participation and does not send or receive a Pix to its end users (BCB, 2020).

(BCB, 2020).

Major financial and payment institutions authorized to operate by the Central Bank of Brazil (BCB), with more than 500 hundred thousand active customer accounts (deposit, savings accounts, and prepaid payment accounts) had mandatory participation, therefore network effects were guaranteed by the BCB (BCB Resolution No. 1, of August 12, 2020).

Pix went into restricted operation (test mode) on November 3rd, 2020, and in full operation on November 16th, 2020. Enabling only "push" transactions (with payment orders) and funds availability, it requires previous registration, linking the payer's accounts with his keys through the bank's API. Payers can initiate payments in at least three different ways (Article 12, BCB Resolution No. 1): a) using keys or nicknames to identify the transactional account, such as a cell phone number, individual registration number (CPF), legal entity registration number (CNPJ), an e-mail address or a random key created through the banking app; b) through QR Code (static or dynamic)[13,14]. Each recipient will freely choose the type of instant payment initiation he will accept. If none of the options available are acceptable, it is possible to inform the complete data account and proceed with the settlement manually (BCB, 2020).

Correctly identifying the receiver through the DICT, the payer sends an instruction that will eventually reach the payment service provider, and then the direct participant in the Instant Payment System (SPI). The instruction (message) will pass through the addressing database and the unique real-time gross settlement infrastructure. The SPI direct participant is warned that his client will receive a credit in his account, after information verification, settling the transaction.

Pix started with no minimum or maximum value limit for transfers, but due to safety issues in October 2021, the BCB limited evening transfers to R$1000,00 between eight pm to six am. However, participants will be able to set maximum value limits, per paying user, per transaction, by day, or by month, based on criteria and regulations to mitigate fraud, money laundering, and prevent terrorism.

Imposing social distancing, and accelerating discontinuity in cash payments in developed and developing markets, the COVID-19 pandemic, propelled internet-based settlements (BCB; 2020). With more than 60 million keys registered, in the first week of November 2020 and 700 institutions authorized by the Central Bank to offer Pix, it entered the payment market to spearhead the digital revolution in the National Financial System (SFN), propelling inter-bank instant payments.

Designed primarily at improving the experience of payers and payees, the goal was to build a solution that would be easy, and quick as making a cash payment, while also making use of the infrastructure (RTGS) already built with the reestablishment of the Brazilian Payment System in the 2000s. Numerous instant payment use cases around the world could be a parameter to the Brazilian Pix, like CODI in Mexico[15]. Being a BRIC member, the Indian Unified Payment Interface (UPI) was chosen as a study case. Possible implications of this system in the short and long run could eventually substantiate important policies for the Brazilian payment market. Context and technical characteristics of the Unified Payment Interface (UPI) will be briefly presented in the next section.

3. The Indian Payment Systems and Unified Payment Interface (UPI)

As in March 2016, total currency circulation in India was Rs.16,415 billion which constituted about 12.04% of the GDP. Compared to Brazil (3.93%), there was a clear dependence on cash[16]. It was a pivotal

13 The dynamic QR Code is generated exclusively for each transaction, it allows the insertion of information such as recipient identification, facilitating reconciliation and commercial automation. The static QR Code is used in multiple transactions as it allows the definition of a fixed price, or the entry of an amount defined by the payer. In this sense, it is ideal for small retailers, service providers and individuals (BANCO CENTRAL DO BRASIL, 2020).

14 BR Code is the QR Code standard that should be used by payment arrangements that are part of the Brazilian Payment System (SBP) that offer transaction initiation through this mechanism, as provided in circular nº 3,989/2020.

15 ALFONSO, Viviana C. et al. Retail payments in Latin America and the Caribbean: present and future. **BIS Quarterly Review**, 2020.

16 Through the Pradhan Mantri Jan Dhan Yojana financial inclusion program of the Government of India, allowed simple no-frills bank accounts, to individuals if they could supply their identity details. Up to July 2016 226 million accounts and 183 million cards were provided. By December 2019, almost 380 million bank accounts had been opened under PMJDY (THOMAS; CHATTERJEE, 2017; D'SILVA ET AL, 2019).

moment for the payments ecosystem in India (2016-2017), with the introduction of new systems and rapid changes in user behaviour, propelled by Demonetization[17]. A part of this transition in the payments system in India was the National Payment Corporation of India (NPCI) a non-profit owned by the Reserve Bank of India (RBI), and 56 commercial banks. In operation since 2016, it was created as an umbrella organization by the RBI, primarily intended to bring payment efficiencies to low-value transactions and drive the next generation of digital payments (D'SILVA ET AL, 2019).

Formally inaugurated by the RBI Governor in April 2016 and launched for public use in August 2016, UPI[18] was an Indian network for real-time payments, an around-the-clock platform that offers a set of Application Programming Interface (API) specifications to facilitate online payments. NPCI's clear objective was to create a uniform and affordable payment system, consolidating and integrating disparate systems with varying service levels, into a nationwide platform.

Built over the Immediate Payment Service (IMPS) infrastructure, UPI is used as a switching mechanism to enable digital instant payments and settlement between different financial institutions, a single mobile application that powers multiple bank accounts. It works as a common layer that orchestrates transactions and ensures settlement across participating bank accounts, using the existing systems to reliably process transactions across various channels.

With full interoperability across financial institutions, it prevents the dissemination of closed systems. A unified layer that offers peer-to-peer immediate payment, with a designed interface for account holders to transfer funds across different banks instantly. Through smartphones with a single identifier (payment identity) which can be either an Aadhaar[19] number, mobile number, a virtual payment address (VPA) or a UPI ID, not requiring any bank account information (NPCI, 2015; GOCHHWAL, 2017; NPCI, 2021; RBI,2021).

There are three following key players in the UPI ecosystem:

> *"(...) 1) The payment service providers (PSPs) who provide the interface for the payer and the payee (...) interoperability will ensure that, unlike wallets, the payer and payee can use two different PSPs. 2) Banks that provide the underlying accounts for the payer and payee. In some cases, the bank and the payment service provider will be the same. And 3) the NPCI which will act as the central switch to determine the virtual payments address (VPA) rendering credit and debit transactions through the IMPS platform, settling funds across banks (THOMAS; CHATTERJEE, 2017, p. 193).*

Downloading any UPI app, an encrypted SMS will be sent from the user's phone to check the authenticity of the number registered with the user's bank, binding the device with the mobile number. The user can now create a unique Virtual Payments Address (VPA), and register its bank accounts on the app. Account details received from the issuer bank (mobile number, VPA, username, bank name, account number, and IFSC code) are stored in the PSP. By entering the last 6 digits of the customer's debit card, the client's bank will be registered with the UPI application (GOCHHWAL, 2017; KAKADE; VESHNE, 2017).

The virtual ID can be shared with a third party to receive payments, and customers can use any PSP app he desires and start doing transactions safely. Clients can pay (push payment) and collect (pull payment). To "pull" or collect money, the beneficiary enters the virtual address of the payer. The payer gets

17 Where 86% of the currency notes were worthless overnight.

18 Abraham (2020) and D'Silva et al (2019), emphasize that UPI wasn't created in a vacuum and is often referred to as the "cashless layer" of India Stack. India Stack is the shared brand for a suite of applications and their accompanying platforms, that constitute the technological ecosystem around Aadhaar, India's centralised biometric identification system. The link created between the national digital identity system and the national payment system was aimed at creating network effects. They create a powerful "stack" of applications, innovative digital platforms, built as public goods.

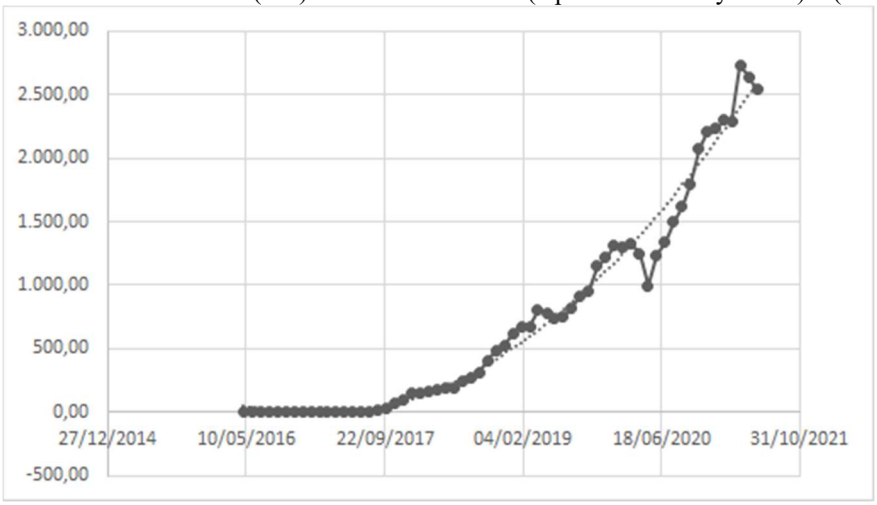
19 India is the only country which was able to register more than one billion (88.6% of its population) on an identification database called Aadhaar, a centralised biometric identification system which aided the country to digitize its payment services through UPI. The aadhaar system is purely focused on identity, as it collects minimal data or just enough to provide unique identity (name, date of birth, gender and residential address). Aadhaar was predominantly used for transferring government benefits through the Pradhan Mantri Jan Dhan Yojana (PMJDY) initiative (NPCI, 2015; THOMAS; CHATTERJEE, 2017, D'SILVA, 2019).

a notification on his mobile and decides to accept or decline. Accepting the payment, the payer enters his MPIN (which is encrypted using NPCI public key) to authorize the transaction. If a customer wishes to pay an amount, he undertakes the "push" option (sending money) entering the virtual address of the payee and authorizing the payment with M-PIN (NPCI, 2016; GOCHHWAL, 2017; THOMAS; CHATTERJEE, 2017).

Due to UPI's sui generis characteristics[20], and taking full advantage of payment flow mapping, it has witnessed rapid growth in the last four years. Graph 1 shows the volume of UPI transactions from April 2016 to May 2021, with a clear polynomial trend line, indicating overall growth. The abrupt decrease in transactions, in the first quarter of 2020, reflected the global pandemic. The initiative gained the spotlight as social distancing became a public health issue. Presently 297 banks are operating with UPI (as more banks and financial institutions operate with UPI bigger the network effects). In May 2021 the volume operated through the application was roughly 2,539.57 million transactions (NPCI, 2021).

Treating digital payments as a "public good"[21] and an important "infrastructure", the Indian experience challenges the business case for stand-alone private systems, establishing that central banks can be proactive and equal partners with private sector counterparts when it comes to fostering technological innovation in the financial sphere. The same argument could be made to Brazil's Pix. While it is still in its infancy, potential market failure could be a valid reason for why NPCI and the Brazilian Central Bank (BCB) played an important oversight and operational role in the implementation of these payment rails, sustaining the importance of governmental participation wherever private firms find insufficient market opportunity (ABRAHAM, 2020).

Graph 1. Volume in million (Mn) of UPI transactions (April/2016 – May//2021) – (Indian Database)



Source: National Payments Corporation of India (NPCI): https://www.npci.org.in/. Author's elaboration.

Even though UPI has a negligible value in comparison to other electronic payments, UPI has changed the landscape for small-scale retail payments in India. With an enormous growth of smartphone users and internet penetration in rural areas, there is increasing potential for acceptance among Indian customers. UPI leverages high teledensity in India to make mobile phones a primary device for consumers and merchants. A digital payment system, that cost-effectively facilitates payments without any POS (point of sale)

20 The key aspects of the Unified Payments Interface are: a) permits payments via mobile app, web; b) payments can be both sender and receiver initiated; c) payments are carried out in a secure manner, aligned with RBI guidelines; d) payments can be done using Aadhaar Number, Virtual Address, Account Number & Indian Financial System Code (IFSC), Mobile Number and MMID (Mobile Money Identifier); e) the payment uses 1-click, 2-factor authentication, biometric authentication and the use of the payer's smartphone for secure credential capture (NPCI, 2016).

21 *India's approach is built upon four pillars: (i) providing digital financial infrastructure as a public good; (ii) encouraging private innovation by providing open access to this infrastructure; (iii) creating a level playing field through the regulatory framework; and (iv) empowering individuals through a data-sharing framework that requires their consent. India offers important lessons that are equally relevant for both advanced economies and emerging market and developing economies (D'SILVA ET AL, 2019, p.1).*

machines, and no intermediaries like card networks, allowing instant settlement (GOCHHWAL, 2017).

Instant payments have developed more rapidly where payment provision is limited and mobile phone penetration is high, basically to overcome barriers to financial inclusion and access to the banking system. Real-time services boost scalability meaning that they can be applied to hundreds of millions of customers, increasing payment volumes, bringing efficiencies to retail and small-scale transactions, and providing cheap payment services to ordinary citizens (D'SILVA ET AL, 2019).

Looking at the bigger picture around Instant/Fast Payments, for countries that are in development, like Brazil and India, problems like digital literacy, internet infrastructure, access to bank accounts, a mobile number, and a smartphone are still questionable, especially considering economic inequality coupled with rural and poor infrastructure coverage. But, the progressive dematerialization of currency and the financial dimension of digital sovereignty have become a priority for many countries. To better understand this phenomenon, through an economic perspective UPI was chosen as a study case due to specific characteristics: instant mobile transfer, 24/7 money transfer, and four-year data availability on the payment system. Aware of the differences between the systems and that Pix was just implemented (November 2020), UPI can bring some light to what we can expect aggregately for the Brazilian instant payment system. An empirical review on payment systems will be done on the following topic, paving our way to the chosen methodology, database, and model specifications.

4. Empirical review on payment systems

Empirical literature examining the role of electronic payment systems and their dynamics is quite sparse (Bech; Hobijin, 2006; Rooj; Sengupta, 2020). Only picking up speed in the last few years with the increasing importance of these innovations, changing the research focus from traditional money demand theories to modern empirical analyses (REDDY; KUMARASAMY, 2017).

Following a heterodox approach, Raj et al (2020) develops a menu of models through ARIMA, ARCH, ARDL estimations, to find that currency circulation in India has been moderated over the last decade, reflecting innovations in digital payment technology (debit and credit cards). Chaudhari et al (2019) reached the same conclusion: digital volume transactions through payment technology innovations, will have a statistically significant inverse relationship with India's currency demand in the long run.

Reddy and Kumarasamy (2017) also observe an inverse relationship with money demand and alternative payment modes, with time series approach. While credit cards decrease currency demand, debit cards increase money requirements. Customers do fewer cash transactions owning credit cards, debit cards increase marginal utility of money and currency demand.

Incorporating both the role of inside money and the role of outside money, Lubis et al (2019) explore the relationship between efficiency of payment system services and financial intermediation. Generalized method of moments (GMM) and vector correction model (VECM) were applied to a data set collected from Indonesia, only to conclude that financial intermediation is inversely affected by currency demand. Card-based payment systems were observed to have a statistically significant impact (through the long run with debit cards and short run with credit cards) on the reduction of currency demand.

Yilmazkuday (2011) investigated the credit channel of the monetary transmission mechanism through credit card usage, in a small economy (Turkey). Using a reduced-form vector autoregression (VAR) framework[22], both the credit view (credit cards) and the monetary view (short-term interest rates) seem to be important during high inflationary episodes for the real side of the economy. Specifically, credit card usage has been positively and significantly impacted mostly through shocks of output and lagged usage, suggesting the role of credit cards as a consumption smoothing tool.

In addition to monetary policy, economic growth is crucial while analysing electronic payments. The Reserve Bank of India report (RBI, 2020a) published a study supporting a statistically significant unidirectional Granger causal relationship from the growth of nominal GDP and private final consumption expenditure to the growth of digital retail transaction value. Using additionally an autoregressive distributed lag model (ARDL) framework, a long run relationship between digital retail transactions and private final consumption is also revealed.

22 Sample period (2002-2009).

Linking real-time gross settlement systems (RTGS) with economic growth in India, Rooj and Sengupta (2020), applying a multivariate Bayesian autoregressive vector model (BVAR) uncovered that high-value online transactions and economic growth are closely interlinked, indicating a presence of bidirectional causality between RTGS and economic growth in India. Lee and Yip (2008) argue that the RTGS system is a good performance indicator for the economy. Faster economic growth is usually associated with high turnover in the RTGS system.

Given the recent literature on the subject, most of the studies presented are based on an aggregate behaviour, macro-based framework. Which theoretically substantiates the chosen database, methodology, and empirical analysis done in the next section. Capturing the relevance of digitalization in India, through Unified Payments Interface (UPI), considering long and short run implications (ARDL model), important inferences can be taken considering financial sophistication, payment substitutes, and relative popularity of banking apps. These estimations and India's experience support lessons for other developing BRICS countries like Brazil, and their public policy towards telecommunications and payment infrastructure. In the following item, the estimated database will be described in details.

4.1 Database

Variables that are expected to directly influence instant payments are mobile phone usage and internet subscription. A greater impulse for fast payment applications will come from economic growth and increasing currency in circulation: GDP and employment can boost the transacted volume (with a positive sign), increasing proportionally the quantity of money publicly held (M1) (M1/GDP)[23]. It is relevant to notice that, statistical correlation between M1/GDP India and M1/GDP for Brazil is relatively high (0.56) between 2010 (Q2) and 2021 (Q3), making it a good proxy for the Brazilian economy[24].

The Indian Central Bank (RBI) uses currency over GDP (CIC/GDP) as a measure of currency in circulation. However, M1/GDP is used by Gala, Araújo, and Bresser-Pereira (2010) as a measure of the degree of financialization of an economy, based directly on Edwards (1995)[25]. Data from Indian Real Time Growth Settlement Systems (RTGS) is also expected to be an important measure to explain growth tendencies in instant payments. Credit and debit cards are included as the closest substitute for fast payment systems, whereas a negative and opposite sign can be expected between them.

To enhance econometric analysis, and capture relevant effects on payment volumes, and telecommunication infrastructure, total volume of transactions via mobile banking was divided by telephone wireless subscription base in millions, counting urban and rural telephone subscribers[26] (MB/WLESS).

Monthly data was collected (April 2016 to November 2020), with 56 observations. Volume[27] of transactions via UPI was taken from the National Payments Corporation of India (NPCI). RTGS data, volume of transactions via mobile banking (MB), total number of credit card transactions at POS terminals (NT1), and debit card transactions at POS terminals (NT2), was taken from the Reserve Bank of India

23 To calculate a proxy for monthly GDP, the strategy was to find the ratio of annual imports (the sum of monthly imports) to India's annual GDP. With the annual percentage, the share of imports to GDP is calculated:

$$MonthlyGDP = \frac{MonthlyImports}{PercentageofImportsbyGDP(referenceyear)}$$

24 Quarterly data on M1 and Real Gross Domestic Product (GDP) for Brazil and India was taken from the Federal Reserve Bank of Saint Louis (FRED). Correlations were estimated with Eviews 10.

25 An underlying assumption is that there may be endogeneity in relation to M1/GDP (explanatory variable) to the volume of transactions carried out by UPI (dependent variable). To better understand the nature of these variables, a Granger causality test was performed. Considering six lags, and p-value inferior to 0.05. It clearly appoints to a bidirectional movement: UPI Granger causes M1/GDP, and M1/GDP Granger causes UPI. This estimate, provides some substance to the notion that UPI does in fact impact the degree of financialization of the Indian economy.

26 Since mobile banking is considered to be an I(2) variable, mobile banking in first differences was divided by wireless subscription base in millions: $\left(\frac{DMB}{WLESS}\right)$, in order to be estimated in the ARDL framework.

27 Since our main goal is to analyse not only infrastructural aspects of instant payments, but considerations regarding technological innovations and currency demand, they can be better explained when payment indicators are taken in volume rather than in value terms (Chaudari et al, 2020).

(RBI). India's M1 was retrieved from the Federal Reserve Bank of Saint Louis (FRED) and telephone wireless subscription base in millions (WLESS), from taken from monthly reports of the Telecom Regulatory Authority of India (TRAI).

Descriptive statistics are presented in Table 1. Payment system data are expressed in Lakh[28] volume in millions of transactions. Out of all three payment systems, mobile banking has the biggest volume of customer transactions, followed by UPI and finally RTGS (although important in value, RTGS has small volumes of customer transactions). The (M1/GDP) ratio shows stability around 2.55 throughout the sample period, peaking in the first months of 2020, which is expected, since COVID-19 increased significantly physical currency demand M1 (the most liquid portions of money supply), due to the COVID-19 related economic uncertainty.

Total number of debit card transactions at the point of sale (POS) terminals (NT2) is much bigger in the Indian economy than the total number of credit card transactions at the point of sale (POS) terminals (NT1). Debit cards in addition to functioning as an alternative medium of payment (compared to cash and instant payments), they are also used as a medium for immediate liquidity, employed to withdraw money from bank accounts. Mobile banking volumes to telephone wireless subscription (MB/WLESS) ratio shows relative stability through the whole sample period. A sharp decrease at the beginning of 2020 (second quarter) and then the spike accounts for an increase in mobile applications usage through social distancing impositions.

Table 1. Descriptive statistics of the analysed variables (Indian Database) (April 2016 to November 2020).

Unit	Variable	Mean	Median	St. Dev	Minimum	Maximum
Lakh (Mn in vol)	UPI	563,827	279,192	610,261	0,000373	2.210,23
Mn (Transactions)	NT1	134.121.119,04	132.319.906,00	35.652.698,19	72.827.537,00	204.968.027,00
Mn (Transactions)	NT2	318.054.207,91	337.317.940,00	95431068,94	118203204	458.447.093,00
Lakh (Mn in vol)	MB	6.683,45	3.744,38	6.495,49	486,67	22.713,54
Lakh (Mn in vol)	RTGS	106,3612	107,8927	18,5089	53,3488	136,5361
Ratio	M1/GDP	2,549603	2,339114	0,720418	1,449796	5,571920
Ratio	MB/WLESS	0,326498	0,151530	0,681786	-1,49	3,586411

Note: Data computed through software EViews 10. Not seasonally adjusted. *Mn: million; *Mn in vol: million in volume. Data source: National Payments Corporation of India (NPCI), Telecom Authority of India (TRAI), Reserve Bank of India (RBI), and Federal Reserve Bank of Saint Louis (FRED), (2021).

Data was seasonally adjusted using EViews 10, Census-13 tool, using x-11 and TRAMO/SEATS[29]. Two different methods were used to seasonally adjust, due to better fit in data idiosyncrasies[30,31]. Proceeding to the empirical analysis, we will briefly explain Autoregressive Distributed Lag Models (ARDL), detailing equation specifications to perform the necessary unit root tests and diagnostic tests, for estimation and empirical inference.

4.2 Methodology, model specifications, and results

[28] Lakh is an Indian unit of measure that is equal to 100.000 Rupees. For example, in India, 150.000 Indian Rupees becomes 1.50 lakh. So, if I have 236.93 Lakh in transactions (October 2019) there are 236.93 * 100,000 = 23.693 million in transactions.
29 X-11 based seasonal adjustment with automatic ARIMA selection, and SEATS based seasonal adjustment with automatic outlier detection and TRAMO based automatic ARIMA.
30 By seasonally adjusting UPI and Mobile Banking, some variables become negative. This happens when time series are very close to zero, and by seasonally adjusting them, you take away the seasonal effect of that period. So, if the variable is already at a very low level, it becomes negative.
[31] Correlations between the variables range from 0.13 to 0.87 for the estimated models. The Jarque-Bera normality test indicated a non-normal distribution of errors, which is expected to correct adding a bigger number of observations in the future.

The Autoregressive Distributed Lag Model (ARDL) proposed by Pesaran and Shin (1998) and Pesaran et al (2001) is an Ordinary Least Squares (OLS) time series model, a co-integration analysis known to be unbiased and efficient. Its main intuition is to test for relationships between variables in level, considering not only the dependent and independent variables that are related contemporaneously, but across historical (lagged) values. Consequently, long run and short run components are estimated simultaneously, removing problems associated with omitted variables and autocorrelation.

Presenting advantages over other time-series analyses, such as Vector Autoregression (VAR) and Error Corrected Vector Autoregression (VEC) models, it is a single equation approach, suitable for smaller sample sizes, and non-stationary co-integration tests since they can be used regardless of whether variables are I(1), I(0), or mutually integrated. Models are selected with the most appropriate lag for each variable through criterion choices, such as Akaike (AIC), Schwarz (SC), or Hannan-Quinn (HQ).

The ARDL model is estimated in the form of error correction vectors (ARDL-ECM), as illustrated in equation (1), below:

$$\Delta y_t = \alpha_0 + \alpha_{1t}\Gamma + \delta_1 y_{t-i} + \delta_2 x_{t-i} + \sum_{i=0}^{n} \varphi_{1i}\Delta y_{t-i} + \sum_{i=0}^{n} \varphi_{2i}\Delta x_{t-i} + \varepsilon_t \quad (1)$$

Wherein Δ is first difference operator; α_o the constant; $\alpha_{1t}\Gamma$ the trend; $\delta_i, i = 1,2$ are the long run parameters; $\varphi_i, i = 1,2$ are the short run parameters; and ε_t is the error term that must be a white noise, a residual term which is supposed to be: serially independent, homoscedastic and normally distributed (*i.i.d*).

After OLS estimations, F-statistics, bounds testing approach developed by Pesaran and Shin (2001), are used to verify joint significance of long-term parameters in ARDL modelling. Two sets of asymptotic critical values (limits) for I(0) bounds and I(1) bounds are estimated[32].With the null that there is no co-integration: $H_0 = \varphi_1 = \varphi_2 = \varphi_3 = 0$, and the alternative that $H_1 \neq \varphi_1 \neq \varphi_2 \neq \varphi_3 \neq 0$, if the null hypothesis is rejected, there will be strong statistical evidence that variables have a long-term relationship between them. Confirming the existence of co-integrating vectors among variables of interest, long and short-term coefficients of the models are estimated, as well as the speed of adjustment to the long-term equilibrium. Equilibrium adjustment speed (ECM coefficient) must be negative and statistically significant and smaller than one in module.

Auxiliary econometric procedures will be necessary, in addition to ARDL estimations for robust inference:

- Traditional unit root tests to diagnose stationarity, such as the Dickey-Fuller (DF), the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. It is not necessary that variables be stationary, but that at least one of them must be non-stationary.
- Evaluation of serial correlation using the Lagrange Multiplier (LM) test.
- Heteroscedasticity analysis through the Breusch-Godfrey (BPG) test and White test.
- Functional form, and model specification with the Ramsey-Reset Test.
- Parameter stability analysis through the Cumulative Sum of Residuals (CUSUM) and Cumulative Sum of Residuals squared (CUSUMSQ) tests, according to Brown et al (1975). Structural breaks in the variables can be observed if the cumulative sum line traverses the area between the 5% critical parameters.

Estimated models and choice of explanatory variables are carried out under the framework of the empirical literature, according to section 3. A macro-framework with reduced form equations was devised to better comprehend, the nature of instant payments, with direct applicability to the Indian UPI. Financial

32 These sets provide a band covering of all possible classifications of the regressors into: I(0), I(1) or mutually co-integrated. If the computed Wald or F-statistic falls below the lower critical value bounds, a conclusive inference can be drawn, that there is no co-integrating relationship. If the empirical analysis shows that the estimated F is higher than the upper bound, it is possible to infer a co-integrating relationship between dependent variable and regressors. If the value of the Wald or F-statistic falls inside these bounds, inference is inconclusive and knowledge of the order of integration of the underlying variables is required before inferences can be made.

innovation in payment systems plays a supportive role. A straight analogy is that payment systems are the "plumbing" of the economy. If plumbing in a house is well planned and installed, consequently there will be a continuous flow of water. Instant Payments enhances economic activity (water flow), reaching the most pervasive item today, which are smartphones. Hence, transaction volume of instant payments directly depends on internet infrastructure, access to smartphones (wireless telephone subscription), and mobile banking apps.

In this sense:

- The volume of transactions via mobile banking by telephone wireless subscription base in millions (DMB/WLESS) ratio, would be positively correlated to Unified Payments Interface (UPI). Increasing mobile banking usage (DMB), could motivate the adoption and use of instant payment transactions.
- Total number of credit card transactions at point-of-sale terminals (POS) (NT1), and total number of debit card transactions at point-of-sale (POS) terminals (NT2), provide a convenient form of making payments for goods and services and could be interpreted as direct substitutes for instant payment systems.
- The M1/GDP ratio (level of financial sophistication) could directly impact the flow of funds, while, Real-Time Gross Settlement System (RTGS), the most operated payment system, could be an approximate variable of total payments made in the economy, and a proxy for economic growth. Its customer transaction volume is inferior to UPI, but it is still expected to have a positive marginal effect on the instant payment mechanisms.

Seven models are specified below (Table 1), each model is a variation of the previous one, with alternating payment modes, and UPI as the dependent variable. Three important groups were separated: variable of interest, control variables, and those that need to be controlled considering the literature and research question. In the first four equations the ratios (DMB/WLESS) and (M1/GDP) were kept as explanatory control variables, whereas in the last three equations D(MB) and (M1/GDP) were the chosen variables. Table 1 presents the estimated ARDL models, each equation was estimated using EViews 10, and HAC covariance matrix (Newey-West) with degrees of freedom adjustment, and the Akaike Information Criterion (AIC) with up to six (6) lags.

Table 1. Estimated ARDL models. Dataset from Indian payment systems (April 2016 – November 2020).

Method	Model	Dependent Variable	Dependent Variables	Model Selected
ARDL	1	UPI	D(MB)/WLESS, RTGS, M1/GDP	(6,1,6,0)
ARDL	2	UPI	D(MB)/WLESS, NT1, M1/GDP	(4,0,6,2)
ARDL	3	UPI	D(MB)/WLESS, NT2, M1/GDP	(2,6,1,1)
ARDL	4	UPI	D(MB)/WLESS, D(MB), M1/GDP	(2,6,3,0)
ARDL	5	UPI	NT1, D(MB), M1/GDP	(4,6,0,2)
ARDL	6	UPI	NT2, D(MB), M1/GDP	(2,1,6,1)
ARDL	7	UPI	RTGS, D(MB), M1/GDP	(6,6,1,0)

Note. ARDL models with a maximum of six (6) lags. Model choice based on Akaike Information Criteria. Author's elaboration. Data output from EViews 10.

A notable aspect of using payment indicators is that they exhibit large shifts, reflecting the introduction of new instruments, policy interventions, and external shocks to the system. Considering the plunge in payments felt during COVID-19, a dummy variable was applied to the year 2020, when there was a significant change in time-series dynamics.

Accounting for seasonality, and applying unit root tests, all variables are I(1)[33]. Diagnostic tests

33 The one that showed idiosyncrasy was mobile banking (MB), that after first difference produced ambiguity between being

were also performed, to attest model stability, absence of autocorrelation, heteroscedasticity, and overall econometric consistency. Brown, Dubin, and Evans (1975), Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ) recursive residual tests, confirmed that all seven models are dynamically stable, neither exceeding the 5% level.

The Lagrange Multiplier (LM) test (Table 2), did not reject the null hypothesis of no serial correlation in the errors. Residuals are also homoscedastic, failing to reject the null of no heteroscedasticity, through the Breusch-Pagan-Godfrey (BPG) and White test. The Ramsey regression equation specification error test (RESET) shows that the functional form of the conditional mean in all seven models are correctly specified.

Diagnostic tests and stability tests done, the next step is to apply the ARDL bounds testing methodology (Pesaran et al, 2001), to confirm long run co-integrating relationships between variables. Narayan and Smyth (2005), point out that with small sample sizes the relevant critical values potentially deviate from the critical values reported in Pesaran et al (2001). In an earlier paper, Narayan (2004) calculates F-statistic critical values to their specific sample size[34]. Tabulating critical values for sample sizes ranging from 30 to 80 observations, critical values become 35,5% higher than those reported in Pesaran et al (2001) and 17,1% higher than those reported in Pesaran and Pesaran (1997).

Table 2. Diagnostic test ARDL models: dependent variable UPI (April 2016 – November 2020). Dataset from Indian payment systems

		Diagnostic Tests			
		Autocorrelation	Heteroskedasticity		Functional Form
Model	ARDL	Serial Correlation LM Test [Prob]	Heteroskedasticity BPG Test [Prob]	Heteroskedasticity White Test [Prob]	Ramsey-Reset Test [Prob]
1	(6,1,6,0)**	F(6,26) = 0,64 [0,69]	F(17,32) = 0,53 [0,91]	F(17,32) = 0,27 [0,99]	F(1,31) = 0,33 [0,56]
2	(4,0,6,2)**	F(6,27) = 0,66 [0,68]	F(16,33) = 0,53 [0,90]	F(16,33) = 0,79 [0,68]	F(1,32) = 0,03 [0,85]
3	(2,6,1,1)**	F(6,28) = 0,42 [1,03]	F(14,34) = 0,30 [0,99]	F(14,34) = 0,29 [0,99]	F(1,33) = 0,00 [0,97]
4	(2,6,3,0)**	F(6,27) = 1,56 [0,19]	F(15,33) = 0,71 [0,75]	F(15,33) = 0,63 [0,82]	F(1,32) = 0,18 [0,67]
5	(4,6,0,2)**	F(6,27) = 0,65 [0,68]	F(16,33) = 0,53 [0,91]	F(16,33) = 0,79 [0,68]	F(1,32) = 0,03 [0,85]
6	(2,1,6,1)**	F(6,28) = 1,06 [0,40]	F(14,34) = 0,30 [0,98]	F(14,34) = 0,29 [0,99]	F(1,33) = 0,00 [0,98]
7	(6,6,1,0)**	F(6,26) = 0,65 [0,68]	F(17,32) = 0,53 [0,91]	F(17,32) = 0,27 [0,99]	F(1,31) = 0,35 [0,55]

Note. ARDL model with a maximum of six (6) lags. Model choice based on Akaike Information Criteria. H0 for Autocorrelation LM Test = no autocorrelation. H0 for Heteroskedasticity BG Test = no heteroskedasticity. *case 1: no constant and no trend, **case 2: restricted constant and no trend, ***case 3: unrestricted constant and no trend, ****case 4: unrestricted constant and no trend; *****case 5: unrestricted constant and unrestricted trend. Source: Author's elaboration (EViews 10).

Table 3 below shows ARDL co-integration test considering Narayan's and Pesaran's critical values. As can be seen, the F-statistics of all seven models, fall in the I(1) superior bound at least at the 5% significance level. Confirming that the variables in our models are indeed co-integrated, it is important to advance in coefficient interpretation.

4.3 Long Run Estimations

All seven long run co-integrating equations are depicted in Table 4. These variables compose the long run coefficients, which are calculated by dividing the negative of the coefficient of the dependent

non-stationary and stationary (two out of two models). Mobile banking was transformed into first difference D(MB) in order to be better fitted through the chosen methods.

34 The critical value bounds are calculated using stochastic simulations for T=31 (observations) and 40.000 replications for the F-statistic (NARAYAN, 2004).

variable by the independent variable coefficient. The constant (C), M1/GDP ratio, credit card transactions (NT1) and debit card transactions (NT2) are the most significant variables. Whereas, equations 01 and 07 won´t be analysed due to lack of statistical relevance.

Observing remaining models in Table 4, some regularities can be ascertained. Equations 02 and 05 are very similar in output. Volume of credit card transactions at POS terminals (NT1) is significant at least at the 10% value, which means that credit card transactions affect positively the volume of UPI transactions. A 1 million credit card increase in transactions will rise UPI transactions in $2.81\times10^{-6}$and 2.76×10^{-6} lakh in instant payment transactions. At an even higher level of significance is the (M1/GDP) ratio that also positively impacts the volume of UPI transactions (a 1% increase in the M1/GDP ratio will increase UPI transactions in 8,12% and 8,13%).

Table 3. ARDL Cointegration Test: Bounds Testing Approach, for the seven specified models. Critical values (Narayan, 2004; Pesaran et al, 2001) (April 2016 – November 2020). Dataset from Indian payment systems.

			Critical Values								
			Narayan (2004)				Pesaran et al (2001)				Long run cointegration
Model	ARDL Model	Bounds Test - F	I(0) Bound		I(1) Bound		I(0) Bound		I(1) Bound		
			5%	1%	5%	1%	5%	1%	5%	1%	
1	(6,1,6,0)	11,2	3,04	4,18	4,00	5,32	2,79	3,65	3,67	4,66	Yes
2	(4,0,6,2)	4,26	3,04	4,18	4,00	5,32	2,79	3,65	3,67	4,66	Yes (at the 5% level)
3	(2,6,1,1)	9,65	3,04	4,18	4,00	5,32	2,79	3,65	3,67	4,66	Yes
4	(2,6,3,0)	12,73	3,04	4,18	4,00	5,32	2,79	3,65	3,67	4,66	Yes
5	(4,6,0,2)	4,25	3,04	4,18	4,00	5,32	2,79	3,65	3,67	4,66	Yes (at the 5% level)
6	(2,1,6,1)	9,66	3,04	4,18	4	5,32	2,79	3,65	3,67	4,66	Yes
7	(6,6,1,0)	11,35	3,04	4,18	4,00	5,32	2,79	3,65	3,67	4,66	Yes

Note. Data computed through software EViews 10. Pesaran et al (2001) bounds testing approach, H_0: no long run relationship. Critical values are those from (Narayan, 2004) and Pesaran et al (2001), considering case II: restricted intercept and no trend (for 50 observations).

The total number of debit card transactions at POS terminals (NT2) is statistically relevant in models 03 and 06, an increase of 1 million debit card transactions will cause a concurrent increase of 2.08×10^{-6} and a 1.96×10^{-6} lakh unified instant payments (UPI) transactions. Both credit and debit card transactions show a positive correlation in the long run, to instant payments, at the 10% significance level. Ratio (M1/GDP) also positively inlfuences the volume of UPI transactions: a 1% increase in the M1/GDP ratio will increase UPI transactions by 5,26% and 5,21%.

Model 04 is somehow different from the other models as it is the only one that depicts statistical significance at the 10% level to the total volume of mobile banking transactions. With a 1% increase in mobile banking transactions, there will be a 0,24% increase in instant payment transactions through UPI. This is relatively straightforward, if there is an increase in UPI application use more people will turn to mobile banking activities, in the long run.

Possible substitution characteristics between UPI and credit and debit cards were emphasized previously. But from a macro view, and according to the time frame studied, they are not so much substitutes as they are means that increase instant payments usability and acceptability in the long run (complementary). This also occurs with mobile banking in equation 04, bigger usage of banking apps in India, induces more UPI transactions, and a deeper profusion of digitalization.

Instant payments and mobile banking applications have the same intuition as credit and debit cards: to intensify money transactions, and currency circulation domestically. To redirect transfers to the real side of the economy and to induce income-generating activities, the Brazilian central bank implemented instant

payments, reducing transaction fees to nearly zero. If per capita income and standard living are rising, purchasing power grows which incentivizes transactions, deepening development and sophistication of the national payment system.

Table 4. ARDL Long Run Coefficients (levels equation) for the seven specified models (dependent Variable UPI), (April 2016 – November 2020). Dataset from Indian payment systems.

Model	1	2	3	4	5	6	7
ARDL Model	(6,1,6,0)	(4,0,6,2)	(2,6,1,1)	(2,6,3,0)	(4,6,0,2)	(2,1,6,1)	(6,6,1,0)
D(MB)/WLESS	3702.69 [0.14]	833.05 [0.15]	2663.50 [0.251]	(-25983.5) [0.100]			
D(MB)				**24.932 [0.073]***	0.716 [0.152]	2.285091 [0.246]	3.141 [0.129]
NT1		**2.81E-06 [0.086]***			**2.76E-06 [0.090]***		
NT2			**2.08E-06 [0,065]***			**1.96E-06 [0.080]***	
RTGS	30.70 [0.14]						29.485 [0.134]
M1/GDP	(-154.19) [0.66]	**812.213 [0,00]***	**526.9347 [0.020]***	(-51.409) [0.819]	**813.159 [0.005]***	**521.158 [0.021]***	(-145.4409) [0.668]
C	**(-2749.39) [0.074]***	**(-2182.30) [0.00]***	**(-1495.98) [0.011]***	126.776 [0.800]	**(-2177.34) [0.001]***	**(-1453.154) [0.014]***	**(-2651.929) [0.066]***

Note: Software used for estimation EViews 10. ARDL models considered are case II: Restricted Constant and No Trend. *Statistically relevant variables at the 5% and 10% levels

If payments are an easy and accessible instrument, transactions will naturally rise. More specifically, through the Granger causality test performed [footnote[26]] the measure of financial development of an economy (M1/GDP) Granger Causes instant payment, and UPI transactions Granger causes financial development of an economy, in a bidirectional movement. Digital connectivity becomes an instrument to help overcome inequality and insertion of the unbanked (Lubis et al, 2019).

4.4 Short Run Estimations

Short-term adjustments via the error correction mechanism (ECM) were also estimated (Table 05). The historical past value of the dependent variable, considering the previous five months, **model 01 (6,1,6,0),** will have a negative coefficient, quite contrary to what is expected from economic inference. Previous growth in payments would induce more growth and use in periods to come. This goes to show that an increase in instant payments, would not consequently increase transactions in the following periods. During system implementation, growth rate of UPI is much higher. As an innovative payment mechanism, it attracts a bigger proportion of users. With diffusion, it continues to grow, but at a lower rate, acceptance can in fact decrease, if it is not convenient to a particular type of customer.

RTGS as a proxy for all payments made in the Indian economy is statistically relevant at the 5th lag, with a positive effect on instant payments (volume-wise). While (MB)/WLESS ratio has an immediate impact of 0.92% on UPI transactions. The error correction mechanism (ECM) (-0.036) is negative and statistically significant at the 1% level, showing that 3% of deviations from the long-term trajectory will be corrected in the following month.

Previous values of UPI transactions, considering model **02 (4,0,6,2)** are significant (p-value < 0.05), producing a positive coefficient of 0.33 lakh transactions (in volume). Total number of credit card transactions (NT1) are relevant at the 5th lag: an increase of 1 million credit card transactions five months previously will increase UPI transactions by 1.30×10^{-6} lakh. Ratio of money publicly held to the growth of domestic product (M1/GDP), increments UPI transactions by 0.60% after one lag. In the following

month, 7% deviations from the long run trajectory will be adjusted, according to the error correction mechanism.

Lagged value of UPI transactions will affect its present value in -0.325 and MB/WLESS will negatively impact UPI transactions up to 5/6 lags, in **Model 03 (2,6,1,1).** Also demonstrating variability is the M1/GDP ratio, which will produce a negative outcome on UPI transactions: a 1% increase in M1/GDP will decrease UPI transactions by -0.5%. The error correction mechanism is negative and statistically significant correcting in 6% the long-term trajectory.

Model 04 (2,6,3,0) is similar to model 03. UPI lagged dependent variable is statistically significant (p-value < 0.05), and negatively correlated to its present value. The ratio of volume of mobile banking transactions versus wireless subscription base (MB/WLESS) will negatively influence UPI transactions, at the 5^{th} /6^{th} lag, a 1% increase in MB/WLESS ratio will decrease UPI transactions in -0,25%. Volume of transactions through mobile banking also shows a negative and statistically significant coefficient in the short run. The error correction mechanism is also relevant at the 1% level, showing that 9% of deviations from the long-term trajectory will be corrected in the next period.

Table 5. ARDL Short Run Dynamics: Error Correction and Significant Variables, for the seven specified models (dependent Variable UPI), (April 2016 – November 2020). Dataset from Indian payment systems.

Model	1	2	3	4	5	6	7
ARDL Model	(6,1,6,0)	(4,0,6,2)	(2,6,1,1)	(2,6,3,0)	(4,6,0,2)	(2,1,6,1)	(6,6,1,0)
D(UPI (-1))			**(-0.325) [0.036]***	**(-0.319) [0.036]***		**(-0.326) [0.035]***	
D(UPI (-2))		**0.313 [0.002]***			**(0.314) [0.002]***		
D(UPI (-5))	**(-0.342) [0.000]***						**(-0.347) [0.000]***
D(MB)/WLESS	**92.55 [0.000]***						
(D(MB)/WLESS (-5))			**(-18.398) [0.022]***	**(-25.568) [0.004]***			
D(D(MB))							**0.080 [0.000]***
D(D(MB) (-2))				**(-1,923) [0.046]***			
D(D(MB) (-5)))						**(-0.016) [0.020]***	
D(NT1 (-5))		**1.30E-06 [0.000]***			**1.29E-06 [0.000]***		
D(RTGS (-5))	**3.878 [0.000]***						**3.901 [0.000]***
D(M1/GDP)			**(-51.607) [0.005]***			**(-51.612) [0.005]***	
D(M1/GDP (-1))		**60.963 [0.031]***			**60.782 [0.032]***		
DUMMY	**52.47 [0.000]***	**65.25 [0.000]***	**22.672 [0.077]***	**82.541 [0.000]***	**65.537 [0.000]***	**23.735 [0.065]***	**54.042 [0.000]***
CointEq (-1)	**(-0.036) [0.000]***	**(-0.074) [0.000]***	**(-0.060) [0.000]***	**(-0.098) [0.000]***	**(-0.074) [0.000]***	**(-0.061) [0.000]***	**(-0.037) [0.000]***
R-squared (R2)	0,903	0,889	0,835	0,853	0,889	0,834	0,903
Durbin - Watson Statistic	2,184	2,01	2,146	2,175	2,013	2,15	2,198

Note: Software used for estimation EViews 10. ARDL models considered are case II: Restricted Constant and No Trend. * Statistically relevant variables at the 5% and 10% levels.

Fast payments will rise by 0.31 lakh transactions if there was a previous boost in payments flow two periods previously, **model 05 (4,6,0,2)**. Credit card transactions have a lagged positive and statistically significant impact on UPI transactions. Money publicly held to GDP (M1/GDP) also impact UPI transactions, presently and after one lag: a 1% increase in M1/GDP will increase transactions by 0,60%, at

a significant p-value (< 0.05) (like model 02). Deviations from the long run trajectory will be corrected in 7%.

In **model 06 (2,1,6,1)** the lagged dependent variable, UPI (-1) is negatively correlated and statistically significant, p-value (< 0.05) The total volume of mobile banking (DMB) transactions in lakhs also negatively impacts UPI transactions in the short run: an increase in 1 lakh transactions in mobile banking will impact UPI in -0.01 million transactions. M1/GDP ratio will have a statistically significant negative impact on UPI transactions, a very similar result to model 03.

Models 03, 04 and 06 include total number of debit card transactions at POS terminals (NT2), MB/WLESS ratio, M1/GDP ratio, and mobile banking transactions (DMB). Debit card transactions are not statistically significant; however, M1/GDP, MB/WLESS and (DMB) have relevant p-values producing a negative outcome on instant payment transactions. These last variables are relatively constant through the estimated time frame. Nonetheless as already pointed out, UPI has been increasing at smaller rates, positive increases in these variables could produce a reduction on instant payments: an increase in M1/GDP (a proxy for the depth and sophistication of the financial system) would decrease UPI transactions.

Lagged past UPI values affect positively and negatively all estimations. Particularly in **model 07 (6,6,1,0)** an increase of 1 lakh transactions five lags beforehand, will drop UPI transactions in -0.34 lakhs. Mobile banking has an immediate positive influence on UPI in 0.08 lakh. RTGS has a significant p-value (< 0.05), five lags previously increasing instant payments in 3.9 lakh transactions (volume-wise). And 9% of the long run deviations will be corrected in the next month according to the error correction term.

Dummy variables have relevant p-values ($p < 0.05$) demonstrating how important it is to account for the COVID-19 impact on payment systems. The R-squared (R^2) of all short run models are relatively high, ranging between 0.83 and 0.90. Following Granger and Newbold's (1974) rule of thumb for detecting spurious regressions, Durbin-Watson statistics are presented, maintaining values close to two, confirming econometric procedures.

Unified Instant Payments (UPI) and MB/WLESS growth rate has remained constant in the short run, yet UPI's trend is decreasing, when compared to the MB/WLESS ratio and mobile banking (DMB). The MB/WLESS ratio can partly explain UPI, but since it reflects volume of mobile banking transactions to mobile telephone subscriptions, it does not constitute a direct relationship, only a proxy for relative popularity of banking apps (not all mobile users adopt mobile banking in the short run).

Instant payments will capture a portion of clientele in this payment market, just like credit cards and debit cards, becoming a complementary payment instrument, in the growing list of possibilities. Both credit and debit card volumes show a positive correlation in the long run, to instant payments at least at a 10% significance level. Feedbacks show that these instruments will enhance instant payments usage. Fast payments will probably gradually occupy a bigger portion of the retail payments market, however, it won´t eliminate other payment options.

For the Brazilian use case (Pix), our study confirms a high adoption rate in the first months of implementation, credit and debit card usage is expected to incentivize instant payments, through payer/payee flow mechanisms. Banking apps will induce more Pix transactions, although to confirm if Pix/UPI are effectively reaching the informal economy and the unbanked, a thorough analysis must be taken on, investigating which sectors of society reached higher acceptance rates, and if the necessary infrastructure is already put in place.

A Pricewaterhouse Coopers Study in partnership with Instituto Locomotiva ("*O abismo digital no Brasil*", 2022) showed that there is a lot of work to be done in order to eliminate gaps related to the inequality in internet connection in the country, which have their roots, mainly, in problems associated to infrastructure, access to hardware devices and deficiencies in our educational system[35]. There are marked differences in internet access between extremes of income classes (100% in class A, compared to 64% in

[35] The PwC/Instituto Locomotiva study was structured based on two quantitative surveys carried out between July and August 2021. One of them, was carried out online, and brings together a national sample of 1,754 internet users, men and women, aged 18 and over. The margin of error is 2.3 percentage points. The other national survey, 2,300 people aged 18 or over were interviewed. Here, the margin of error is 1.9 percentage points. The results were weighted by region according to gender distribution, age group and schooling of Internet users aged 18 or over (PNAD – IBGE) (PwC, Instituto Locomotiva; 2022, p. 31)

DE). Lack of infrastructure is directly related to the income of a given region: the lower the income, the worse the signal: problems with amplitude, quality and signal distribution, in addition to cost and equipment[36]. Due to the continental dimension of both India and Brazil, public policy initiatives such as telecommunications infrastructure and internet diffusion must be viewed seriously.

4. Conclusions

The world has observed substantial transformations in financial and payment systems with the rise of new private platforms. An environment that has evolved to offer customized solutions and services, have propelled assertive strategic actions by policy makers such as central banks. In the midst of these digital transformations are retail instant/ fast payments, which provide speed and continuous service availability, so that the payee has unconditional and irrevocable access to funds.

With decision-making complexities, and network externalities, fast/instant payments are frequently viewed as a public good to payment institutions. Central banks have become relevant actors in policy deployment establishing common standards, procedures and even taking on an operational role increasing efficiency and system resilience. Pix and UPI are examples of such user-centric policies, conveying not only financial inclusion but demand-oriented instruments improving the experience of payers and payees, while also making use of back-end infrastructures that were already put in place in Brazil (restructuring of the Brazilian Payment System between 1999/2002) and Demonetisation in India.

Progressive digitalization of currency, the financial dimension of digital sovereignty, and the COVID-19 global pandemic put these forces into motion. To empirically comprehend the instant payment phenomenon, UPI was chosen as a study case for the Brazilian Pix. The Indian Unified Payments Interface (UPI) is a low-cost layer service created over the backbone of the Immediate Payment Service (IMPS), using virtual payments address (VPA), a UPI ID that shields account details while making payments or requesting them.

Using a tokenization principle (like Pix) it becomes a unique identifier that the bank uses to transfer money and make payments using IMPS as a payment rail. Aware that studies in payments systems are country-specific, the Indian Unified Payments Interface (UPI) was analysed through ARDL econometric approach. Our UPI empirical models (April 2016/ November 2020) confirm very high adoption rates in the first months of implementation, in which credit and debit card usage is expected to propel instant payments.

Fast payments have developed more rapidly where there are two important factors aligned: limited options of payment alternatives, and high penetration of mobile phones. This may well been created artificially in the Indian case through a forced digitalization through the Demonetization period, in 2016 and 2017, however for the Brazilian economy, that comparatively has a lower dependence in currency in circulation, the argument is valid.

Using short run and long run estimations, the main contribution and novelty of this paper, in comparison to the reviewed literature (Reddy and Kumarasamy, 2017; Chaudhari et al, 2019; Raj et al , 2020; Lubis et al, 2019; Yilmazkuday, 2011; Rooj and Sengupta, 2020) is identifying underlying instant payments characteristics, through financial sophistication (M1/GDP), economic growth (RTGS), payment substitutes (NT1/ NT2), and a measure of relative popularity of banking apps (MB/WLESS).

Credit (NT1) and debit card (NT2) volume of transactions are more of a complementary means that increase instant payment adoption, than substitutes. Mobile banking transactions and telephone wireless subscription base (MB/WLESS) has a direct short-run influence, as banking apps and more internet availability will prompt more Pix/UPI flows. As a proxy for depth and sophistication of the financial system M1/GDP (Gala, Araújo e Bresser-Pereira, 2010; Edwards, 1995), has a clear short and long run effects on instant payments, with a bidirectional causality between them.

Interlinked with economic growth, and considered a proxy for all payments made in the Indian economy (Rooj and Sengupta, 2020; Lee and Yip (2008) Real Time Gross settlement Systems (RTGS) has a positive short-run impact on instant payments volume-wise with a default lag of five periods in models

[36] São Paulo, for example in lower income districts, show increasing connectivity inequality between low and high income citizens. Problems that are seen in other state capitals in Brazil.

01 and 07. Nonetheless, in some models M1/GDP, MB/WLESS and (DMB) are producing negative shocks on instant payment transactions. As already pointed out, UPI has been increasing at smaller rates, where positive changes in these variables could produce a reduction on faster payments (negative impact of UPI lagged values).

In light of a macro view of payment systems, credit, debit card, and mobile transaction volumes are viewed as means to increase UPI/Pix usability and acceptability through payer/payee flow mechanisms, playing supportive roles in the long run. An increase in mobile banking transactions and telephone wireless subscription base directly impacts instant payment volumes in the short run. Financial sophistication and economic growth also play an important role in promoting a greater impulse for instant payment applications. Enhancing economic activity and redirecting transfers to the real side of the economy, central banks assist the informal sector, reducing transaction fees through instant payments. If per capita income and standard living are rising, economic logic leads us to the understanding that purchasing power grows which incentivizes transactions, deepening development and sophistication of the national payment system.

Another important factor are infrastructure gaps to guarantee good internet connectivity to citizens. Public policies towards universalizing quality signal, is not only necessary to develop financial sophistication but to promote economic growth: *internet inequality not only reflects the country's socioeconomic disparity but also helps reinforce it* (PwC, Instituto Locomotiva; 2022, p.27). Absence of internet connectivity in remote places and in low-income districts might have a relevant impact on financial inclusion (digital illiteracy, access to smartphones, and mobile banking accounts), an important avenue for future studies.

References

ABRAHAM, Sunil. "Unified Payment Interface: Towards greater cyber sovereignty," **ORF Issue Brief.** No. 380, July 2020, Observer Research Foundation. Disponível em: https://blog.sodipress.com/wp-content/uploads/2020/08/Unified-Payment-Interface.pdf. Acesso em: 12.jun.2021.

ALFONSO, Viviana C. et al. Retail payments in Latin America and the Caribbean: present and future. **BIS Quarterly Review**, 2020. Disponível em: https://www.bis.org/publ/qtrpdf/r_qt2012f.htm. Acesso em: 06.set.2021.

ASSOCIAÇÃO BRASILEIRA DAS ENTIDADES DOS MERCADOS FINANCEIRO E DE CAPITAIS (ANBIMA). **Sistema Financeiro Nacional e Participantes do Mercado**. Material de estudos da Certificação CPA-10. Disponível em: anbima.com.br. Acesso em: 02.jan.2021

BANCO CENTRAL DO BRASIL. Diretoria colegiada do Banco Central do Brasil. **Resolução nº1 de 12 de agosto de 2020.** Institui o arranjo de pagamentos do Pix e aprova o seu regulamento. Brasília: Diretoria colegiada do Banco Central do Brasil, 2020.

BANCO CENTRAL DO BRASIL (BCB, 2020). Estabilidade Financeira. **Pix**. Disponível em: https://www.bcb.gov.br/estabilidadefinanceira/pagamentosinstantaneos. Accesso em: 02.out.2020.

BANCO CENTRAL DO BRASIL (BCB, 2020a). **Relatório de Economia Bancária do Banco Central 2019.** Jun/2020. Disponível em: https://www.bcb.gov.br/publicacoes/relatorioeconomiabancaria. Acesso em: 04.jan.2021.

BANK OF INTERNATIONAL SETTLEMENTS (BIS). **Principle for financial Market infrastructures**. Committee on Payments and Market Infrastructures. Basel, Switzerland.Nov/2012. Disponível em: www.bis.org. Acesso em: 12.dez.2020.

BANK OF INTERNATIONAL SETTLEMENTS (BIS). **Fast payments: Enhancing the speed and availability of retail payments.** Committee on Payments and Market Infrastructures. Basel, Switzerland,

November 2016. Disponível em: www.bis.org. Acesso em: 18.11.2020.

BRASIL. Lei nº 10.214 de 27 de março de 2001. **Dispõe sobre a atuação das câmaras e dos prestadores de serviços de compensação e de liquidação, no âmbito do sistema de pagamentos brasileiro e dá outras providências.** Brasília, DF. Disponível em: https://legislacao.presidencia.gov.br/ . Acesso em: 11.dez.2020.

BECH, Morten L.; HANCOCK, Jenny. Innovations in payments. **BIS Quarterly Review.** Mar/2020. Disponível em: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3561180. Acesso em: 06.set.2021.

BECH, Morten L.; HOBIJN, Bart. Technology diffusion within central banking: the case of real-time gross settlement. **FRB of New York Staff Report,** n. 260, 2006. Disponível em: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=932596. Acesso em: 06.set.2021.

BECH, Morten et al. The quest for speed in payments. **BIS Quarterly Review March** 2017. Disponível em: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2931564. Acesso em: 06.set.2021.

BERGER, Allen et al. A framework for analyzing efficiency, risks, costs, and innovations in the payments system. **Journal of Money, Credit, and Banking,** v. 28, n. 4, p. 696-732, 1996.

BLIX, Mårten; DALTUNG, Sonja; HEIKENSTEN, Lars. On central bank efficiency. **Sveriges Riksbank Economic Review**, p. 81-93, 2003.

BRITO, Alan. A reestruturação do sistema de pagamentos brasileiro e seus impactos nas instituições financeiras. **Revista Contabilidade & Finanças,** v. 13, n. 28, p. 66-85, 2002. Disponível em: https://www.scielo.br/pdf/rcf/v13n28/v13n28a05.pdf. Acesso em: 23.dez.2020.

BROWN, R. Et al. J. Techniques for testing the constancy of regression relationships over time. **Journal of the Royal Statistical Society: Series B (Methodological)**, v. 37, n. 2, p. 149-163, 1975.

CARVALHO, Emílio. **A rentabilidade das transferências eletrônicas disponíveis–TEDs: estudo de caso do BRB.** Brasília-DF, 2011, 37 p. Monografia. Universidade de Brasília (UnB).

CHAUDHARI, Dipak et al. Payment systems innovation and currency demand in India: Some applied perspectives. **Reserve Bank of India Occasional Papers,** v. 40, n. 2, p. 33-63, 2019.

D'SILVA, Derryl et al. The design of digital financial infrastructure: lessons from India. Monetary and Economic Department. **BIS Paper**, n. 106, 2019. Disponível em: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3505373. Acesso em: 15.jun.2021.

EDWARDS, Sebastian. Why are Saving Rates so Different Across Countries? An International Comparative Analysis. **NBER Working Paper,** No. W5097, 1995.

GALA, Paulo et al. **Efeitos da taxa de câmbio na poupança interna: análise teórica e evidências empíricas para o caso brasileiro**. Textos para disscussão, 252. Maio/2010. FGV-EESP.

GIRALDO MORA, Juan Camilo et al. The Evolution of Global Instant Payment Infrastructure. **Available at SSRN**, 2020. Disponível em: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3591972. Acesso em: 02.maio.2021.

GOCHHWAL, Rahul. Unified Payment Interface—an Advancement in Payment Systems. **American Journal of Industrial and Business Management**, v. 7, n. 10, p. 1174-1191, 2017.

GOMBER, Peter et al. On the fintech revolution: Interpreting the forces of innovation, disruption, and transformation in financial services. **Journal of management information systems**, v. 35, n. 1, p. 220-265, 2018.

GRANGER, C; NEWBOLD, P. Spurious regressions in econometrics. **Journal of Econometrics**. North-Holland Publishing Company v.2, 111-120 p, 1974.

HARTMANN, Monika et al. Are instant payments becoming the new normal? A comparative study. **ECB Occasional Paper**, n. 229, 2019.

KAKADE, Radhika Basavaraj; VESHNE, Nupur A. Unified Payment Interface (UPI)–A Way Towards Cashless Economy. **International Research Journal of Engineering and Technology**, v. 4, n. 11, p. 762-766, 2017.

KAHN, Charles M.; ROBERDS, William. Why pay? An introduction to payments economics. **Journal of Financial Intermediation**, v. 18, n. 1, p. 1-23, 2009.

LEE, Esmond; YIP, Sara. Liquidity and Risk Management in the RTGS System—the Hong Kong Experience. **Hong Kong Monetary Authority Quarterly Bulletin**, p. 1-4, 2008.

LUBIS, Alexander. Gauging the Impact of Payment System Innovations on Financial Intermediation: Novel Empirical Evidence from Indonesia. **Journal of Emerging Market Finance**, v. 18, n. 3, p. 290-338, 2019.

NARAYAN, K, Paresh. Reformulating critical values for the bounds F-statistics approach to cointegration: an application to the tourism demand model for Fiji. Australia: Monash University, 2004.

NARAYAN, K, Paresh; SMYTH, Russel. Electricity consumption, employment, and real income in Australia evidence from multivariate Granger causality tests. Energy policy, v. 33, n. 9, p. 1109-1116, 2005.

NATIONAL PAYMENTS CORPORATION OF INDIA (NPCI). **Unified Payment Interface. API and Technology specifications.** Version 1.0 (Draft). Feb.2015. Disponível em:https://www.mygov.in/digidhan/pages/pdf/sbi/NPCI%20Unified%20Payment%20Interface.pdf Acesso em: 14.jun.2021.

NATIONAL PAYMENTS CORPORATION OF INDIA (NPCI). **Unified Payments Interface. Procedural Guidelines.** Jul.2016. Disponível em: http://www.slbcmadhyapradesh.in/docs/UPI_Procedural_Guidelines24_12_2016.pdf. Acesso em: 14. Jun. 2021

NATIONAL PAYMENTS CORPORATION OF INDIA (NPCI). **UPI Faqs.** Disponível em: https://www.npci.org.in/what-we-do/upi/faq. Acesso em: 10.jun.2021.

PESARAN, M. Hashem.; SHIN, Yongcheol. An autoregressive distributed-lag modeling approach to cointegration analysis. **Econometric Society Monographs,** v. 31, p. 371-413, 1998.

PESARAN, M. Hashem; PESARAN, Bahram. (1997), Working with Microfit 4.0: Interactive Econometric Analysis. Oxford, Oxford University Press.

PESARAN, M. Hashem.; SHIN, Yongcheol.; SMITH, J. Richard. Bounds testing approaches to the analysis of level relationships. **Journal of applied econometrics,** v. 16, n. 3, p. 289-326, 2001.

PINTO, Julio Cesar Costa. **A administração da conta reservas bancárias no âmbito do novo sistema**

de pagamentos brasileiro. Rio de Janeiro,2004, 59 p. Dissertação de Mestrado. Escola de Pós-Graduação em Economia (EPGE) - Fundação Getúlio Vargas (FGV).

Pricewaterhouse & Coopers (PwC). O abismo digital no Brasil. **Como a desigualdade de acesso à internet a infraestrutura inadequada e a educação deficitária limitam nossas opções para o futuro.** Pricewaterhouse and Coopers (PwC), Instituto Locomotiva (2022). Disponível em: https://www.pwc.com.br/pt/estudos/preocupacoes-ceos/mais-temas/2022/O_Abismo_Digital.pdf. Acesso em: 01. Apr. 2022

RAJ, Janak et al. Modelling and Forecasting Currency Demand in India: A Heterodox Approach. R**eserve Bank of India Occasional Papers.** Vol. 41, No,1; 2020.

REDDY, Shiva.; KUMARASAMY, Durairaj. Impact of Credit Cards and Debit Cards on Currency Demand and Seigniorage: Evidence from India. **Academy of Accounting and Financial Studies Journal**, v. 21, n. 3, p. 1K, 2017.

RESERVE BANK OF INDIA (RBI). **Assessment of the Progress of Digitasation from Cash to Eletronic** (Feb, 2020). Disponível em: https://rbi.org.in/scripts/PublicationsView.aspx?Id=19417. Acesso em: 09.mar.2021.

RESERVE BANK OF INDIA (RBI). **Payment and Settlement Systems and Information Technology.** Annual Report, (Aug 2020). (RBI, 2020a)
Disponível em https://m.rbi.org.in/Scripts/AnnualReportPublications.aspx?Id=1293#BOX91. Acesso em: 02.jun.2021

RESERVE BANK OF INDIA (RBI). **Payment and Settlement Systems and Information Technology.** Annual Report, 2021 (May 2021). (RBI, 2021a).
Disponível em: https://www.rbi.org.in/Scripts/AnnualReportPublications.aspx?year=2021. Acesso em:03.jun.2021.

ROOJ, Debasis; SENGUPTA, Reshmi. The Real-Time Impact on Real Economy—A Multivariate BVAR Analysis of Digital Payment Systems and Economic Growth in India. **ADBI Working Paper Series**, No. 1128, April. 2020. Disponível em: https://www.econstor.eu/handle/10419/238485. Acesso em: 30.abril.2021.

THOMAS, Roshna; CHATTERJEE, Abhijeet. Unified Payment Interface (UPI): A Catalyst Tool Supporting Digitalization–Utility, Prospects & Issues. **International Journal of Innovative Research And Advanced Studies (Ijiras) Volume**, v. 4, p. 192-195, 2017

YILMAZKUDAY, Hakan. Monetary policy and credit cards: Evidence from a small open economy. **Economic Modelling**, v. 28, n. 1-2, p. 201-210, 2011.