Growing Retail Digital Payments

The Value of Interoperability

Alexander Copestake, Divya Kirti, and Maria Soledad Martinez Peria

NOTE/2025/004

FINTECH NOTE

Growing Retail Digital Payments

The Value of Interoperability

Prepared by Alexander Copestake, Divya Kirti, and Maria Soledad Martinez Peria

June 2025

Growing Retail Digital Payments: The Value of Interoperability

Note 2025/004

Prepared by Alexander Copestake, Divya Kirti, and Maria Soledad Martinez Peria*

Cataloging-in-Publication Data
IMF Library

Names: Copestake, Alexander, author. | Kirti, Divya, author. | Martinez Peria, Maria Soledad, author. | International Monetary Fund, publisher.
Title: Growing retail digital payments : the value of interoperability / Alexander Copestake, Divya Kirti, and Maria Soledad Martinez Peria.
Other titles: The value of interoperability. | FinTech notes (International Monetary Fund).
Description: Washington, DC : International Monetary Fund, 2025. | Jun. 2025. | NOTE/2025/004. | Includes bibliographical references.
Identifiers: ISBN:
9798229014250 (paper)
9798229015066 (ePub)
9798229015080 (WebPDF)
Subjects: LCSH: Digital currency. | Fintech. | Financial services industry—Technological innovations.
Classification: HG1710.C6 2025

RECOMMENDED CITATION: Copestake, Alexander, Divya Kirti, and Maria Soledad Martinez Peria. 2025. “Growing Retail Digital Payments: The Value of Interoperability.” IMF Fintech Note 2025/004, International Monetary Fund, Washington, DC.

Publication orders may be placed online or through the mail:
International Monetary Fund, Publication Services
P.O. Box 92780, Washington, DC 20090, U.S.A.
T. +(1) 202.623.7430
publications@IMF.org
IMFbookstore.org
elibrary.IMF.org

*The authors would like to thank Ritesh Shukla, Nikita Agrawal, Kapil Patil, and Harshya Matthews at the National Payments Corporation of India (NPCI) for sharing data and for many helpful conversations. The authors also thank Itai Agur, Tanuj Bhojwani, Daniel Björkegren, Luis Breuer, Markus Brunnermeier, Kamya Chandra, Nada Choueiri, Sonja Davidovic, Harald Finger, Deepro Guha, Srinivas Gynedi, Vikram Haksar, Paavi Kulshreshth, Nikhil Kumar, Rohit Kumar, Xavier Lavayssiere, Nicola Limodio, Tommaso Mancini-Griffoli, Filippo Mezzanotti, Sudip Mohapatra, Nandan Nilekani, Anca Paduraru, Divyanshu Pathak, Manasa Patnam, Dinar Prihardini, Guillermo Galicia Rabadan, Karthik Raghupathy, Pallavi Rao, Marco Reuter, Krishna Srinivasan, Nujin Suphaphiphat, Jay Surti, K Vijayakumar, Yao Zeng, and seminar participants at the IMF for helpful comments and discussions. Cage Englander and Ariadne Checo de los Santos provided excellent research assistance.

Contents

BOXES

FIGURES

TABLES

Glossary

Closed-loop payment system: A type of payment network in which all participants—the payer, the payee, and the system facilitating the transaction—operate within a single, unified network. See also Patel, Kasiyanto, and Reslow (2024) for a detailed discussion.

E-money: An electronic store of monetary value, expressed in an existing official monetary unit, representing a claim enforceable against the electronic money issuer, and accepted as means of payment by undertakings other than the electronic money issuer. See also Dobler and others (2021).

Immediate Payment Service (IMPS): India's real-time interbank electronic fund transfer service, run by National Payments Corporation of India (NPCI).

Interoperability: The technical, semantic, and business compatibility that allows end users to transact seamlessly with each other across systems (Boar and others 2021). The first element requires that systems implement common technical standards such that their hardware and software can interact. The second element requires that the exchanged information is interpreted and acted upon consistently across systems. The third element requires that the interacting systems agree on the rights and obligations of participants. In the case of an interoperable payment system, all constituent parts (for example, user-facing third-party application providers [TPAPs], payment service providers [PSPs], NPCI) must agree who can access the combined platform, when and how to clear and settle obligations, and how to address transaction failures.

National Payments Corporation of India (NPCI): A not-for-profit company regulated by the Reserve Bank of India that administers the Unified Payments Interface (UPI), Immediate Payment Service (IMPS), and other payments infrastructure.

Network effects: Externalities in which the utility that one user derives from consumption of a good increases with the number of other agents consuming the good (Katz and Shapiro 1985).

Payment Service Provider (PSP): A bank that is a member of the UPI system and integrated with NPCI's IMPS, such that it can facilitate transactions on behalf of end users either through its own app or through an app provided by a TPAP.

Third-party application provider (TPAP): A nonbank entity, typically a fintech or technology company, that partners with a PSP to offer UPI-based services to end users through an app. The TPAP provides the user-facing application, while the PSP processes the transaction through its connection to NPCI's IMPS infrastructure.

Two-sided markets: Markets in which a platform enables interactions between two distinct user groups (for example, consumers and merchants), where the value that each side derives depends on the size or participation of the other side, and these cross-group externalities are not internalized by the users themselves. For technical conditions, see, for instance, Rochet and Tirole (2006) and Armstrong and Wright (2008).

Introduction

Policymakers in many countries aim to increase the adoption and usage of retail digital payment systems. They see several potential benefits. A transition from cash to digital payments could stimulate commerce and growth by reducing transaction costs and information asymmetries (Dubey and Purnanandam 2023). Digital transactions could expand access to credit by creating an electronic record of payments, allowing for better screening and monitoring (Ouyang 2021; Berg, Fuster, and Puri 2022; Alok and others 2024), and digital payments platforms may permit new means of debt enforcement that unlock further lending opportunities (Rishabh and Schäublin 2021; Brunnermeier and Payne 2023). Finally, adoption of digital payment technologies could encourage formalization (Klapper, Miller, and Hess 2019) and lower crime by reducing the need to carry cash (Wright and others 2017).[1]

Which types of digital payment systems should countries consider introducing to support adoption and reduce the use of cash? Closed-loop systems, which require both the payer and payee to use the same payment provider, have been successful in onboarding users in many cases.[2,3] In part, this success results from network effects: as adoption grows, the platform becomes more valuable to existing and new users, creating a virtuous cycle whereby growth in the number of users encourages more users to join. One potential drawback of closed-loop systems, however, is that these network effects may also produce a small number of dominant providers, limiting user choice. Interoperable payment systems, such as India's Unified Payments Interface (UPI), are alternatives to closed-loop systems that could also foster the adoption of digital payments.[4] Such systems allow for seamless payments between users of different payment providers.[5,6] While network effects remain, in an interoperable system they operate primarily at the level of the overall platform, not at the level of individual payment providers, reducing the tendency for activity to concentrate on a small number of providers and preserving user choice.

This Fintech Note details how interoperability can improve users' experience with digital payments and so increase adoption, then presents granular evidence on its role in the take-off of India's UPI. Since its launch in 2016, UPI has grown quickly, while some proxies for cash usage have begun to decline (Figure 1). UPI now processes more than 18 billion transactions per month and dominates other electronic retail

[1] For an overview of different types of retail payment systems, see Patel, Kasiyanto, and Reslow (2024).

[2] Throughout this Note, we use the shorthand "provider" to refer to the entity providing the app through which the end user of a payments system interacts with the system. This provider may or may not play a direct role in the settlement of the transaction, as discussed in the "Context" section. Similarly, we use the term "app" to encompass any user-facing interface through which end users interact with a payments system, noting that these may not necessarily involve a smartphone (see, for instance, the *99# service in India).

[3] See, for instance, the rapid adoption of payment apps in China (International Monetary Fund 2017), or of mobile money in parts of Africa prior to the introduction of interoperability (Brunnermeier, Limodio, and Spadavecchia 2023; Cong, Easley, and Prasad 2024).

[4] Other interoperable retail fast payment systems include Pix in Brazil, TIPS in the euro area, CoDi in Mexico, and FedNow in the United States.

[5] In this sense, interoperability parallels the analogous concept of "compatibility" in mobile phone networks, where customers of one network can make calls to and receive calls from customers of another network. See, for instance, Björkegren (2022).

[6] In the case of India, for instance, the National Payments Corporation of India (NPCI, regulated by the Reserve Bank of India) provides payment rails through which participating app providers can facilitate transfers between the bank accounts of any two users of the platform.

payments in India.[7] India now makes faster payments than any other country (Appendix Figure 1.1; see also ACI Worldwide (2023)). At the same time, proxies for cash usage have fallen. Prior work has not considered the role of interoperability in driving this rapid growth, instead focusing on demographics (Crouzet and others 2024) and the demonetization shock (for example, Crouzet, Gupta, and Mezzanotti 2023; Dubey and Purnanandam 2023; Agarwal and others 2024).[8,9]

Interoperability can support faster adoption of digital payments through two key mechanisms. Without interoperability, payments must be made and received through the same app. With interoperability, each user can interact with every other user of the system, regardless of their respective app choices. This could improve users' experience of digital payments in two main ways. First, and most directly, users are freed to pick their favorite app—so can pick, for example, the one whose brand they trust the most or whose systems process transactions most reliably. Second, interoperability increases the incentives of existing providers to invest in improving quality to retain their users and encourages innovative new providers to launch apps. Overall, users benefit from higher quality and more varied app choices and are more likely to use the system.

We present evidence in support of both mechanisms using granular data covering all UPI transactions. First, interoperability does increase freedom for users. Many users initially chose to join the system through trusted and familiar brands. Subsequently, users took advantage of their ability to switch to more innovative and reliable apps. Second, the potential loss of users to other providers offering higher quality apps incentivized incumbents to upgrade their services. Moreover, innovative app providers were able to enter the market and attract users, despite the initial dominance of one incumbent.

Despite this evidence showing the benefits of interoperability, it remains challenging to isolate the role of interoperability in increasing usage of digital payments. The primary challenge is to pinpoint the impact of interoperability, relative to the introduction of closed-loop payment systems. India may have seen rapid growth of retail digital payments even without an interoperable system, given the absence of other convenient alternatives to cash.

We use two natural experiments to show that interoperability does increase take-up of retail digital payments overall. In both cases, we complement rich data on UPI with data covering all transactions facilitated by a major fintech firm. This provider initially only offered users the ability to make payments on a closed network—that is, their counterparty had to have the same wallet app. In the first natural experiment, we examine users' app choices in the months after demonetization pushed many to try digital payment methods for the first time. After sampling both, users increasingly chose the interoperable UPI system over the closed-loop alternative. Crucially, transactions that would not be possible without interoperability—those where the sender and recipient use different apps—were a substantial part of this

[7] UPI volume as of March 2025; see NPCI statistics here. See also Cornelli and others (2024).

[8] With the stated purpose of reducing illegal activities funded with cash, on November 8, 2016, the Government of India announced the demonetization of all ₹500 and ₹1,000 banknotes.

[9] Cornelli and others (2025) document a positive association between finance app adoption and fast payment systems, especially when fast payment systems are open to both banks and nonbanks. Ancalle and Gracia Garcia (2024) also provide aggregate evidence that digital payment usage increased in Peru after the central bank introduced an interoperability mandate.

growth. The fintech provider later joined UPI, expanding the set of transactions possible for both its users and UPI users. This allows us to consider a second natural experiment, comparing regions with varying presence of the closed-loop provider ex ante, which therefore saw different increases in de facto interoperability when the two systems integrated. Regions where interoperability increased by more indeed saw a significant increase in adoption of digital payments, both in absolute terms and relative to cash.

Taken together, our findings suggest that supporting interoperability could be a promising policy for countries seeking to transition away from cash. By expanding users' freedom to choose their favorite app, and increasing competition among providers, interoperability can increase the attractiveness of digital payments relative to cash and pull more users into the system. As overall adoption grows and more providers join, policymakers should also remain vigilant to the emergence of market power and be prepared to act to maintain a fully open, interoperable, and competitive system.

Context: India's Unified Payments Interface

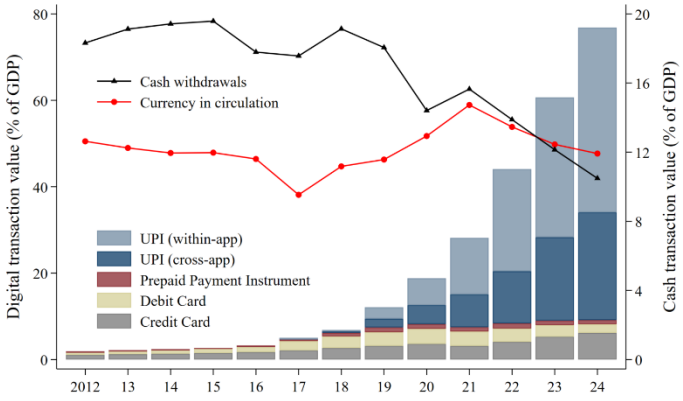
UPI is an instant payments platform built over the Immediate Payment Service (IMPS) infrastructure, India's preexisting real-time interbank electronic fund transfer service. Banks and third-party application providers (TPAPs) that choose to participate can use the interface to exchange payment messages.[10] Through UPI apps provided by banks and TPAPs, end users can execute free push (pay) and pull (receive) transactions with other users identified by a unique virtual ID. This design allows fintech firms to specialize in providing user-friendly payments apps, while the underlying funds remain in accounts at users' banks. Consider a simplified example transaction shown in Figure 2, panel 1. A user seeking to make a payment can open an app (provider shown in the purple square) and use that to make a transfer to a user of a different payments app (provider shown in the blue square). The National Payments Corporation of India (NPCI), which runs UPI, sits in the middle and ensures that the payer's and payee's banks debit and credit the amount accordingly.[11] Even in this simplified transaction, up to four different UPI participant organizations are involved: the payer's provider, the payee's provider, the payer's bank, and the payee's bank. Their ability to interact in this way is the defining characteristic of an interoperable system (see Box 1 for details).

[10] In the case of TPAPs, the interaction with the interface is indirect, conducted through a partnership with a payment service provider bank that is connected to the underlying payment rails.

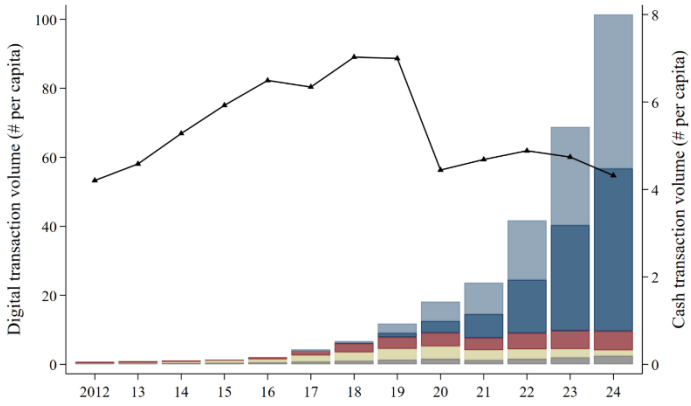
[11] Settlement for end users is immediate, while settlement among financial institutions is managed through deferred net settlement with ten daily cycles.

Figure 1. Retail Digital Payments in India

1. Value (Percent of GDP)



2. Volume (Transactions per Capita)



Sources: RBI; Haver Analytics; BIS; WDI; and IMF staff analysis.
Note: This graph shows the value and volume of UPI and other electronic retail payment methods in India. Prepaid payment instruments include smart cards and mobile wallets that are preloaded with value using cash, card, or other methods. UPI includes both peer-to-merchant and peer-to-peer transactions as many retail payments to small merchants are recorded as peer-to-peer. UPI = Unified Payments Interface.

This interoperable approach stands in contrast to closed-loop digital payment systems, where both the payer and the payee must use the same provider of payment services. In a typical closed-loop transaction, shown in Figure 2, panel 2, the payer first loads money into an electronic wallet hosted by their provider. To transact, the payee must also maintain a wallet with the same provider. They can then receive a transfer through the provider's network, at which point they can either keep the money in the network for other payments or initiate a withdrawal of the funds to their bank account—which may be subject to fees and delays. Note that the need for both counterparties to hold wallets with the same provider creates a network effect: the more users a provider has, the more attractive it is to new users, since it offers more possibilities for transactions. This is not the case with app providers under UPI, as we detail in the next section.[12]

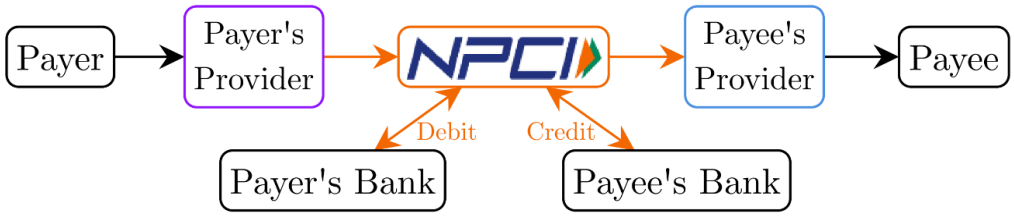
The UPI ecosystem has grown steadily, reaching more than 600 banks and more than 200 apps (Figure 3). Many users initially joined the network through apps provided by their banks, then subsequently migrated to apps provided by fintech firms—which often include additional features, such as automatic bill payments, rewards and credits, investment or insurance products. In competing for users, these app providers have also introduced various technological innovations to reduce payment friction, such as quick-response (QR) codes (which use a smartphone's camera to remove the need to type in a recipient's account details) and "soundboxes" (which announce the receipt of funds through a speaker, so that merchants do not need to manually check their phone for confirmation).[13]

[12] Note that electronic wallets and other e-money systems are not necessarily closed-loop and can be made interoperable; we explore such a case in the "Evidence on Overall Adoption" section. Likewise, not all closed-loop systems require preloading funds into electronic wallets.

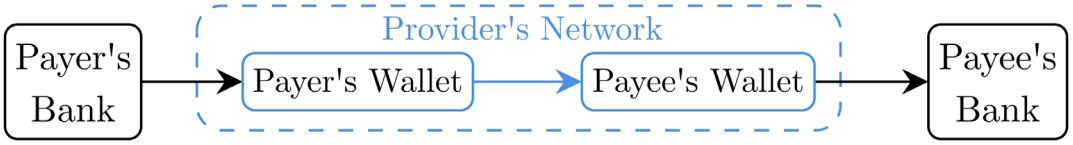
[13] See Chowdhry and Ahmed (2024) for a detailed discussion of how soundboxes reduce barriers to adoption.

Figure 2. Structure of UPI versus Closed-Loop Payment Systems

1. Interoperable Ecosystem of Banks and Payment Providers (for example, UPI)



2. Example of a Closed-Loop System



Note: These graphs show stylized representations of transactions under UPI and a typical closed-loop system. For a more detailed account of the steps involved in a UPI transaction, see Box 8 of Reserve Bank of India (2022).

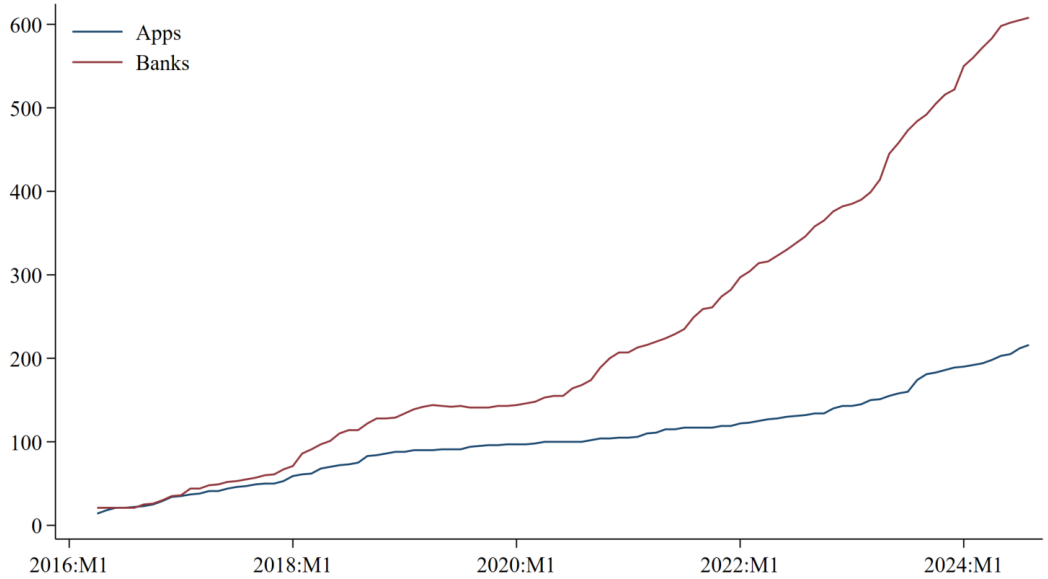
Box 1. Interoperability and UPI

Interoperability is the technical, semantic, and business compatibility that allows end users to transact seamlessly with each other across systems (Boar and others 2021). The first element requires that systems implement common technical standards such that their hardware and software can interact. The second element requires that the exchanged information is interpreted and acted upon consistently across systems. The third element requires that the interacting systems agree on the rights and obligations of participants. In the case of an interoperable payment system, all constituent parts (for example, user-facing third-party application providers [TPAPs], payment service providers [PSPs], National Payments Corporation of India [NPCI]) must agree who can access the combined platform, when and how to clear and settle obligations, and how to address transaction failures.[14]

The Unified Payments Interface (UPI) enabled new types of transactions between clients of different banks and fintech payment providers. Prior to UPI, end users could already make transfers between some of the participants that would later join UPI. For instance, users could (1) make bank-to-bank transfers through IMPS, (2) transfer money between some bank accounts and electronic wallets issued by closed-loop e-money providers, and (3) transfer money between electronic wallets hosted by the same closed-loop e-money provider. However, users could neither initiate transactions between bank accounts using apps offered by third parties nor transfer money between electronic wallets offered by different e-money providers. UPI increased interoperability on both these dimensions by allowing TPAPs—including both new fintech firms and existing e-wallet providers—to interact with NPCI's IMPS through a partner PSP. End users gained the ability to choose any participating TPAP without needing to coordinate with their counterparty. The extent of this interoperability in practice subsequently grew further as more banks and closed-loop e-money providers joined the system.

[14] For the roles and responsibilities of UPI participants, see https://www.npci.org.in/what-we-do/upi/roles-responsibilities.

Figure 3. Number of Participating Apps and Banks



Sources: NPCI; and IMF staff analysis.
Note: This graph shows the cumulative number of apps and banks participating in the Unified Payments Interface ecosystem over time.

The spread of UPI was facilitated by earlier public and private investments that reduced potential barriers to widespread adoption, including a wider "Digital Public Infrastructure" agenda (Alonso and others 2023; D'Silva and others 2019). The Pradhan Mantri Jan Dhan Yojana financial inclusion program opened hundreds of millions of new bank accounts (Agarwal and others 2017). The Aadhaar biometric ID program provided each individual with a unique, verifiable digital identity that could be used to speed up transaction authentication and Know Your Customer checks (Alonso and others 2023). Lastly, the cost of mobile data fell by roughly 96 percent during the mid-2010s, driven in part by the entry of Reliance Jio, a new 4G-only network operator (Alonso and others 2023). Together, these factors created a context in which many potential UPI users could easily access and use UPI apps. Subsequent pilot projects in 2020 and 2021 led to new offline payment functionalities that facilitate small value payments even in areas with limited internet or telecom connectivity.[15] Today, UPI adoption is widespread across regions (Appendix Figure 1.2), albeit with usage highest in richer, younger, more educated and urban areas (Appendix Figure 1.3).

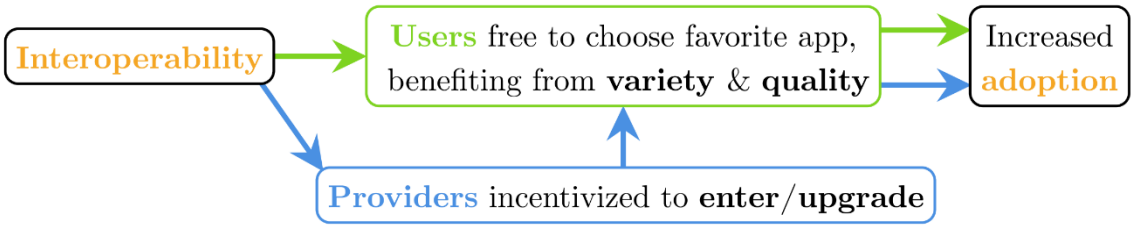
Conceptual Framework

In this section, we lay out a simple conceptual framework showing how interoperability could empower users and increase adoption of digital payments. Figure 4 shows that interoperability can improve users' experience of digital payments in two main ways. First, users benefit directly, as indicated by the green

[15] For details, see PwC India (2022) and the RBI's Framework for Facilitating Small Value Digital Payments in Offline Mode.

arrows in Figure 4. Second, users benefit indirectly—through the impact of interoperability on providers—as indicated by the blue arrows.[16]

Figure 4. Overview of the Conceptual Framework



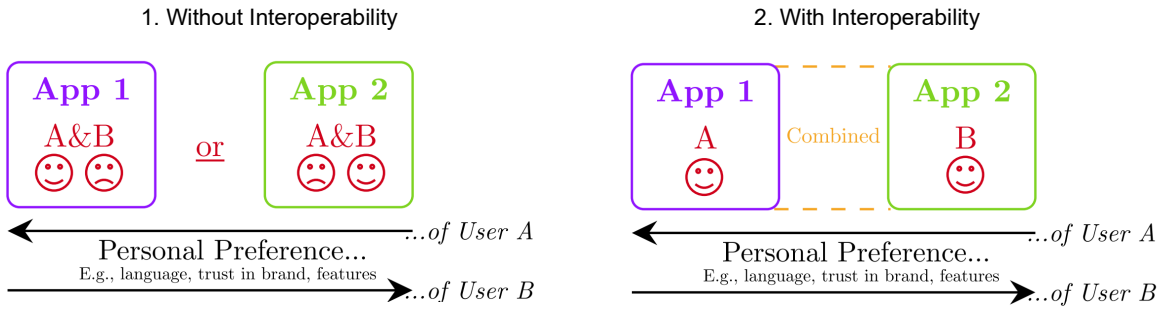
Direct Benefits of Interoperability for Users

Interoperability removes the need for both counterparties to a transaction to use the same app, increasing each user's freedom to choose their favorite. Without interoperability, network effects could prevent users from adopting their ideal app, since each user's first priority is to select an app used by their counterparty, so that the transaction is possible. With interoperability, users are free to select their favorite app, regardless of apps' existing user bases. Here "favorite" could have two meanings, which we consider in turn.

First, "favorite" could imply a close match to an individual or group's specific preferences, which are not commonly shared. For example, if the two apps offer distinct language options, then a user whose preferred language is only offered by one app will prefer that app. Similarly, users may differ in the institutions that they trust to facilitate their financial transactions, or different groups of users (for example, customers vs. merchants) may value different app features. To fix ideas, consider two potential users, A and B, who want to transact with one another, and could do so using either digital payments or cash. Suppose that two digital payments apps—App 1 and App 2—are available, as shown in Figure 5, and neither of them charge fees (as under UPI). User A prefers App 1, but User B prefers App 2. Without interoperability, both must coordinate on one app to transact (Figure 5, panel 1), which means one user will not be able to use their ideal app—making them more likely to choose cash instead.

[16] We also note that while in some two-sided markets a lack of interoperability can enable cross-subsidization between user groups that expands adoption (see, for example, Edelman and Wright 2015; Tan and Zhou 2021; Wang 2025), in our context, this is less applicable since (1) the value of one-sided P2P payments is much larger than that of two-sided P2M payments and (2) providers cannot charge transaction fees, reducing the potential for cross-subsidization.

Figure 5. Variety—Interoperability Allows Different Users to Choose Different Apps



Interoperability allows different users to choose different apps, unlocking the full benefits of a variety of apps being available. With all apps combined as part of one interoperable system, users no longer need to select the same app as those with whom they wish to transact. Each user is free to select the app that is the best match for their individual preferences—User A can select App 1 and User B can select App 2 (Figure 5, panel 2). Both users have their ideal digital payment experience, so both are more likely to use digital payments and less likely to use cash for transactions. Thus, the usage of digital payments will be higher than in the scenario without interoperability.

Second, "favorite" could refer to high-quality apps, where quality encompasses all features of the user experience on whose value all users agree. For instance, quality could refer to the frequency of errors on attempted transactions, where every user prefers apps with fewer technical glitches. Consider an alternative scenario, with three users and two apps—App 1 and App 3—that differ on quality (Figure 6). Assume that Users A and B have already chosen App 1 for some external reason, such as not knowing that App 3 exists. Without interoperability, User C, who is aware of the existence of App 3, faces a dilemma: App 3 is higher quality, but they would not be able to use it to transact with Users A and B. Thus, they also select App 1 (Figure 6, panel 1) and receive a worse user experience, making them more likely to instead choose cash for some transactions.

Interoperability allows each new user to choose the highest quality app available, regardless of others' choices. Interoperability links the two apps into one combined system, such that the set of counterparties to which each user has access is unaffected by their app choice. User C can thus choose App 3, while still being able to transact with Users A and B (Figure 6, panel 2)—again improving the user experience and so encouraging adoption of digital payments.

Figure 6. Quality—Interoperability Frees New Users to Choose the Best App

Indirect Benefits for Users through the Impact on App Providers

Interoperability could also benefit users indirectly by facilitating the entry of new app providers or by incentivizing incumbent providers to upgrade their apps. First, interoperability could lower the cost to new providers of launching a payments app, increasing the variety and quality of apps available to users. Returning to Figure 5, consider the case of a firm weighing whether to enter the market for digital payment apps. Without interoperability, it would need to attract both Users A and B to get off the ground, since network effects create a "winner-takes-all" market. Under interoperability, it could instead target just one user—locating to the left of App 1 and attracting User A, or locating to the right of App 2 and attracting User B. By removing app-level network effects, interoperability thus lowers the number of users new apps must attract to reach viability. A new app only needs to achieve traction with one portion of the overall customer base, allowing the provider to focus its initial customer acquisition efforts (for example, marketing or promotions) accordingly.[17] Interoperability can thus increase entry of new apps, potentially expanding the variety or quality of apps available to users, which makes their freedom to choose among them even more valuable and further improves the user experience, increasing adoption of digital payments.[18]

[17] A similar dynamic also applies with respect to quality. Returning to Figure 6, without interoperability, a new app must overcome the network effects that lead User C to choose App 1. With interoperability, a new app can attract User C as long as it offers a higher quality service than the incumbent.

[18] In addition, some implementations of interoperable systems, including UPI, also support entry by directly lowering the development costs associated with producing a payments app. Specifically, a closed-loop app developer must build both the "front end" (that is, the user interface) and the "back end" (that is, the rails on which the electronic transfers occur). With UPI and similar interoperable systems, most of the back-end infrastructure is provided directly by the central bank or other governmental or quasi-governmental organizations, leaving the app developer free to focus primarily on front-end development. Given these low costs, and the various opportunities for apps to sell add-on services to payments customers (as discussed in the "Context: India's Unified Payments Interface" section), we assume throughout that potential entrants exist that are willing to enter the app market.

Finally, interoperability could incentivize incumbent providers to upgrade their quality to avoid losing users. Consider Figure 6 again: without interoperability, if App 1 can attract Users A and B, it ends up attracting User C regardless of its quality level—that is, network effects give it market power. In contrast, under interoperability App 1 will lose users unless it makes improvements, since its quality is below that of App 3. Assuming that app providers profit in proportion to their number of users (for example, by cross-selling credit or insurance services), interoperability thus increases App 1's incentive to invest in upgrading its quality. Again, such an increase in quality further improves users' experience of digital payments, supporting the expansion of adoption.

Evidence on Benefits of Interoperability for Users

This section presents empirical evidence consistent with both mechanisms described in the conceptual framework. We first consider the direct benefits of interoperability for users and find evidence that users value both the variety and quality of apps accessible on an interoperable system. We then turn to the indirect benefits that arise through the impact on app providers and show that interoperability can both facilitate the entry of new providers and incentivize upgrading by incumbents. This analysis focuses on privately provided UPI apps, so in Box 2 we also consider the potential role of apps produced directly by the public sector.

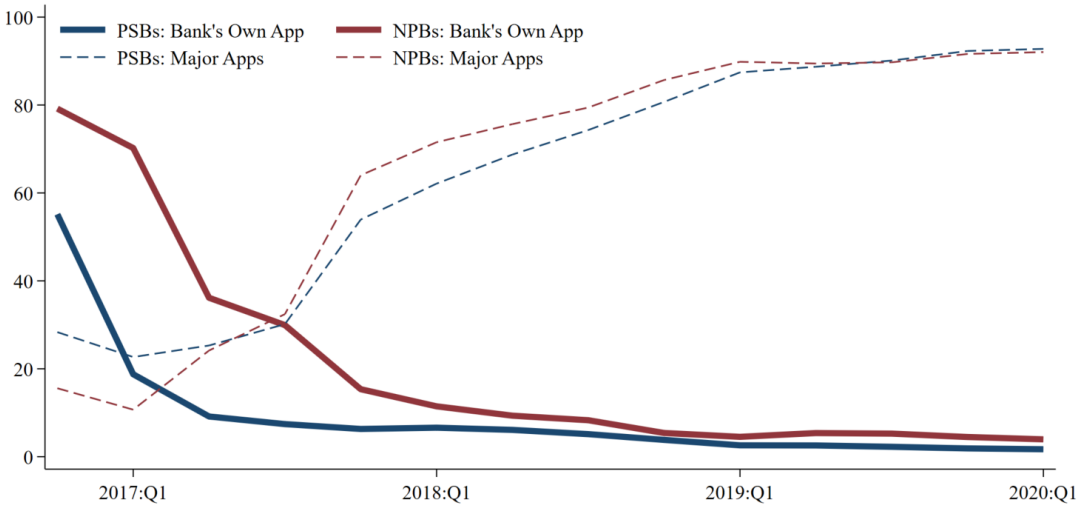
Direct Benefits for Users

Different users initially chose different UPI apps, consistent with heterogeneity in personal preferences that makes the variety of apps accessible in an interoperable system valuable to users. The thick lines in Figure 7 show the share of transactions, by value, that users conducted on the app produced by their bank, for two types of banks—the public sector banks (PSBs) and the new private banks (NPBs). During the crucial early period in which UPI launched and reached a critical mass of users, more than half of users accessed the system through their existing bank's app. Thus, when the system was unfamiliar, many first joined it through a trusted entity with whom they shared an existing financial relationship. This highlights the value of having a variety of apps available: users differed in the degree to which they trusted different apps—equivalent to the different personal preferences shown in Figure 5—and, hence, valued the freedom to select their favorite that interoperability provides. Indeed, these personal preferences are substantial: over the whole sample period, for a given app-bank pair, transaction values are ten times higher if both are from the same entity (Appendix Table 1.1).

UPI users subsequently converged on apps that were plausibly higher quality, benefiting from the freedom to switch apps provided by interoperability. The later period shown in Figure 7 presents two signs that quality also matters for user adoption decisions. First, the share of users choosing their own bank's app fell substantially as the platform matured, consistent with users learning about higher quality alternatives. Users predominantly switched to what would become the top three apps, shown by the dashed lines. These apps are provided by fintech firms and offer more features than most banks' own apps (for example, these providers pioneered soundboxes). Second, the share of users choosing their

bank's own app was persistently higher for NPBs (shown by the red line in Figure 7) than for PSBs (shown by the blue line), consistent with existing evidence that NPBs are quicker to adopt and upgrade technology than PSBs and provide apps that users rate more highly.[19]

Figure 7. Share of Transactions Using the Payer's Bank's App by Value (Percent)



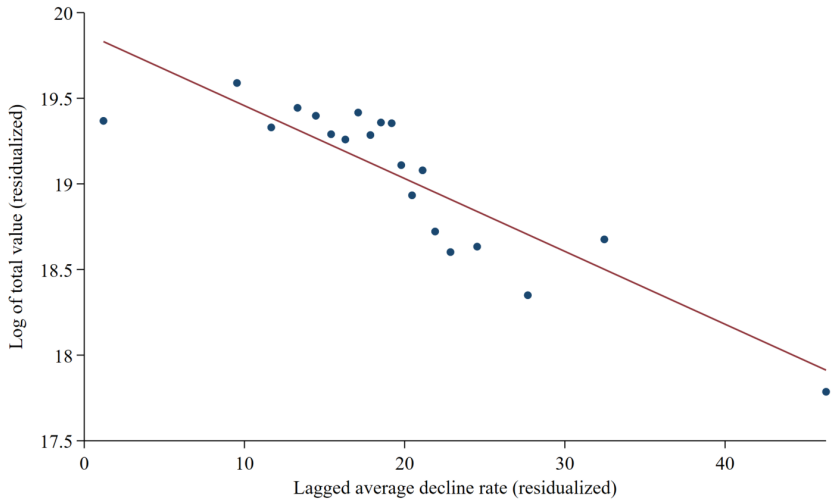
Sources: NPCI; and IMF staff analysis.
Note: The solid lines on this graph plot the share of transaction value that was processed by the payer's bank's own app, among each of PSBs and NPBs. The dashed lines show, for each group of banks, the share of transaction value that was instead processed by one of three major apps. NPBs = new private banks; PSBs = public sector banks.

Using an alternative proxy for quality based on transaction decline rates, we again find that users sought out high-quality apps. Apps' average transaction decline rates reflect the share of attempted transactions that result in an error, for instance, because of technical glitches, rather than completing successfully. Users prefer lower decline rates, all else equal.[20] On average, if an app has a one percentage point lower decline rate in a given quarter, then the total value of transactions it processes in the next quarter is 4 percent higher, even after accounting for the role of app-wise differences in average usage levels and national trends in UPI adoption (Figure 8 and Appendix Table 1.2). Again, this is consistent with users valuing higher quality apps and consequently exercising the freedom to switch apps that is unlocked by interoperability.

[19] See, for instance, Mishra, Prabhala, and Rajan (2022) and Chart II.16 from the RBI's 2023-24 Report on Currency and Finance.

[20] See also Ding and others (2025) for evidence that Pix users prefer banks whose transactions fail less often.

Figure 8. Average Transaction Decline Rates and App Transaction Values



Sources: NPCI; and IMF staff analysis.
Note: The chart shows a binned scatter plot of the log of total app-wise transaction values against lagged app-wise decline rates, where both variables are residualized on app and time fixed effects.

Indirect Benefits for Users through the Impact on App Providers

Interoperability prevented network effects from entrenching the position of a dominant incumbent. In August 2017, one year after the nationwide launch of UPI, 45 percent of payers on UPI used one app (hereafter, "App 1"), accounting for 29 percent of overall transaction value. In a market with strong network effects, such as closed-loop payments, this degree of concentration would be very difficult for a new entrant to overcome. However, as highlighted in the "Conceptual Framework" section, interoperability frees each user to switch to a differentiated or higher quality app, regardless of the decisions (or inertia) of other users. Indeed, Figure 3 shows that many new UPI apps entered the market after August 2017, of which two each subsequently achieved at least a 20 percent share of overall payer-side transaction value.

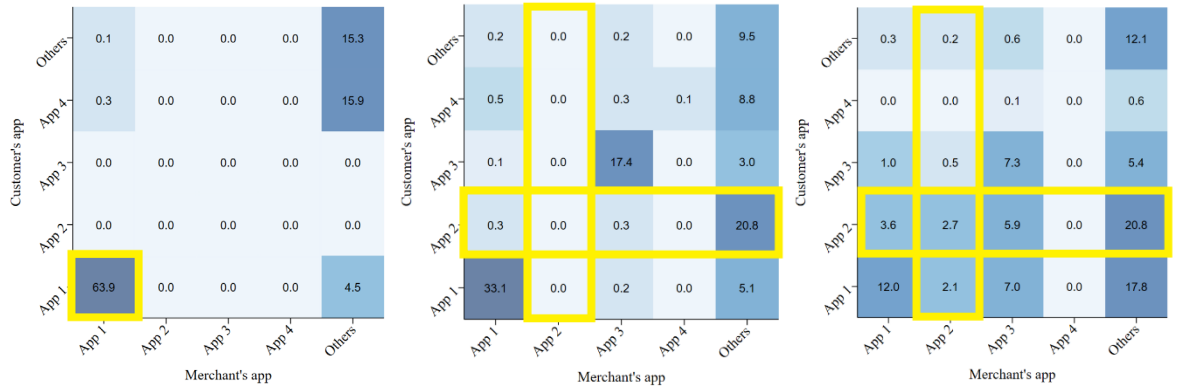
Interoperability played a direct role in facilitating entry by allowing new app providers to initially target specific subgroups. Figure 9 shows peer-to-merchant UPI transaction flows, broken out by the customer's app and the merchant's app. As noted earlier, this market was initially dominated by App 1 (Figure 9, panel 1). However, a major new provider (hereafter, "App 2") nonetheless entered in September 2017 and was able to build a substantial market share during 2018 (Figure 9, panel 2). Importantly, this occurred through servicing only one side of the market: merchants did not use App 2 (as shown by the empty App 2 column) even as a growing share of customers adopted it (as shown by the shaded cells in the App 2 row).[21] This ability to enter a network market by focusing on one subgroup of users—while those users' counterparties continue using their existing provider—does not exist in a non-interoperable system. Only from mid-2019 did App 2 begin establishing a presence on the merchant side, and by 2023, it had gained a substantial share of this market (as shown by the shaded App 2 column in Figure 9, panel

[21] In terms of Figure 5, panel 2, this is akin to App 2 building a position in the market by attracting only type B users, without needing to simultaneously attract type A users.

3). By facilitating entry in this way, interoperability allowed innovative new providers to enter, increasing the variety and quality of apps available to users, thus improving users' experience of digital payments.

Figure 9. Payer–Payee Peer-to-Merchant Flows (Percent of Aggregate Value)

1. August 2017 2. Full Year 2018 3. Full Year 2023

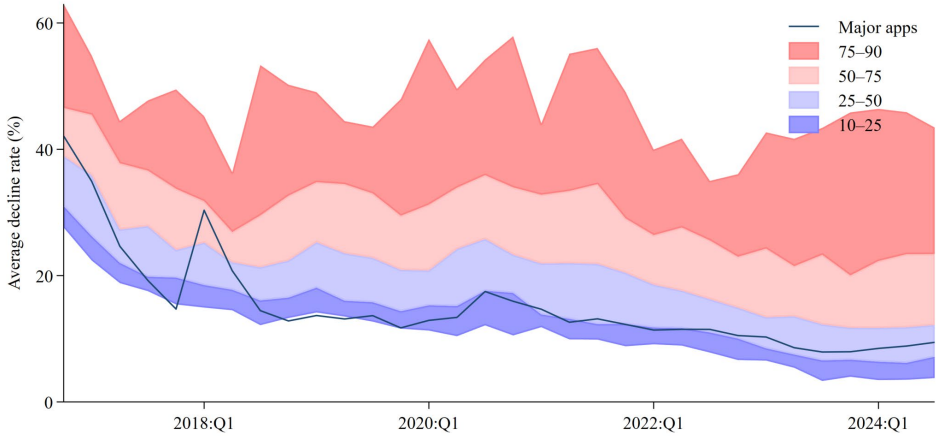


Sources: NPCI; and IMF staff analysis.

Note: These matrices show the share of the aggregate peer-to-merchant transaction value on the Unified Payments Interface that was facilitated by four major apps over time, split by each combination of payer and payee app.

Interoperability also incentivized existing providers to upgrade their quality. As highlighted in the previous section, users moved to higher quality apps, as measured by transaction decline rates (Figure 8). This incentivized providers to upgrade their services and reduce their decline rates, as we see from the downward trend of the distribution in Figure 10. Indeed, the largest three apps, which now facilitate more than 95 percent of payer-side transactions, exhibit an especially large improvement—shown by the plotted line in the figure—even as the total number of transactions they process has grown exponentially. Again, by incentivizing providers to upgrade their quality, interoperability made digital payments more attractive to users.

Figure 10. Distribution of Decline Rates by App



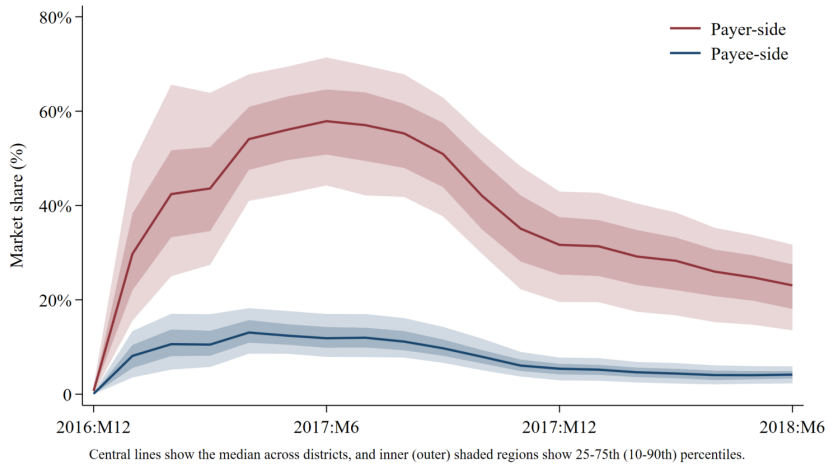
Sources: NPCI; and IMF staff analysis.

Note: The chart plots the average decline rate of the three largest UPI apps over time, alongside the distribution of average decline rates across all apps. Specifically, the dark red band shows the range of average decline rates encompassed by the 75th to 90th percentiles of the cross-app distribution of decline rates, the light red band plots the same for the 50th to 75th percentiles, and the blue bands similarly plot the ranges for the 25th to 50th and 10th to 25th percentiles.

Box 2. Evidence on Public Provision of Digital Payments Apps

Comparing across apps available on the unified payments interface (UPI) can also shed light on the potential role for public sector app providers. The National Payments Corporation of India launched the Bharat Interface for Money (BHIM) app in late 2016, when total UPI usage was small and there were fewer other providers (as shown in Figure 3). Indeed, BHIM initially accounted for more than half of payer-side total transaction value (Box Figure 2.1), prior to the take-off of apps produced by major fintech firms (as shown in Figure 7). This highlights the potential catalytic role of direct public provision of payment apps. The public sector can help overcome coordination failures—for example, low user adoption because of a lack of high-quality apps, alongside a lack of high-quality apps as a result of low user adoption—and so kick-start an ecosystem.

Box Figure 2.1. BHIM District-Wise Shares of UPI Transaction Value over Time (%)



Note: The solid lines show the share of UPI transaction value that was processed through BHIM in the median district. The blue (red) line calculates the share based on payer-side (payee-side) transactions. The inner (outer) shaded regions show the 25th–75th (10th–90th) percentiles.

Evidence on Overall Adoption

In this section, we turn to the question of whether interoperability can indeed increase adoption of digital payments and hence encourage a transition away from cash. Our conceptual framework suggests that interoperability could make adopting digital payments more attractive through both its direct benefits for users and its indirect benefits through the impact on providers. Our empirical evidence in the "Evidence on Benefits of Interoperability for Users" section finds evidence in support of both these channels. But does greater interoperability then increase overall adoption of digital payments? To answer this question, it is important to identify a relevant benchmark level of adoption—a "business as usual" outcome that would occur with only closed-loop systems—against which to measure the extent of adoption under interoperability. This section presents evidence from two natural experiments that permit such comparisons, one comparing adoption of UPI to adoption of an alternative, non-interoperable payments

platform, and the other comparing UPI adoption in districts that experienced a larger versus smaller increase in de facto interoperability after an expansion of the UPI ecosystem.[22]

In the first natural experiment, we compare adoption of UPI and a non-interoperable alternative after India's demonetization shock in November 2016.[23] The resulting decline in cash availability, illustrated by the green line in Figure 11, created a sudden increase in demand for non-cash forms of payment and hence a sharp uptick in usage of mobile payment technologies (see, for example, Patnam and Yao 2020; Crouzet, Gupta, and Mezzanotti 2023). Many users tried out different options, including both UPI and incumbent closed-loop alternatives, as shown in Figure 11 by the sharp uptick in the blue and red lines in late 2016.

Over time, users showed a marked preference for UPI over the non-interoperable alternative. By March 2017, the cash shortage had eased, and growth in usage of the non-interoperable, closed-loop incumbent payment platform plateaued. In contrast, adoption of UPI continued to grow through 2017, reflecting that—after trying it out during the demonetization period—new users continued to join and existing users increased their reliance on the system. The difference in trends is large: while adoption of the non-interoperable alternative was flat, UPI grew roughly three-fold from March to October 2017.

Moreover, UPI's interoperability was central to its growth. Cross-app payments rose even more than within-app payments (Appendix Figure 1.4), suggesting that the extra feature of UPI relative to the closed-loop incumbent—that is, interoperability—was indeed valued by users. This comparison of post-demonetization trends suggests that interoperability can indeed increase adoption of digital payments.

In the second natural experiment, we exploit an external policy change that resulted in interoperability increasing by different degrees in different districts. This allows us to compare digital payments adoption in places where interoperability increased by more, to adoption in places where it increased by less. Specifically, after a directive by the Reserve Bank of India mandating interoperability, a major incumbent closed-loop provider joined UPI, connecting all its existing users to UPI. With this integration, the interoperability of digital payments increased, since two separate payments platforms were effectively combined into a single network. Importantly, the size of this increase in interoperability varied across districts. Where the closed-loop incumbent had no users ex ante, no new users were onboarded onto UPI at the moment of integration, so there was effectively no increase in de facto interoperability. In contrast, in districts with many users of the incumbent platform ex ante, there was a large increase in the number of users who could now send payments through UPI, so de facto interoperability increased substantially. More generally, the larger the role of the incumbent ex ante, which implied a more fragmented digital payments market, the greater the increase in the number of possible connections after integration.[24]

[22] In both cases, we supplement our UPI data (provided by NPCI) with data from a major Indian fintech firm, whose platform was initially a closed-loop substitute for UPI but later integrated with UPI and thus became a complement to it.

[23] For details on the demonetization shock and its effects, see Chodorow-Reich and others (2020) and Lahiri (2020).

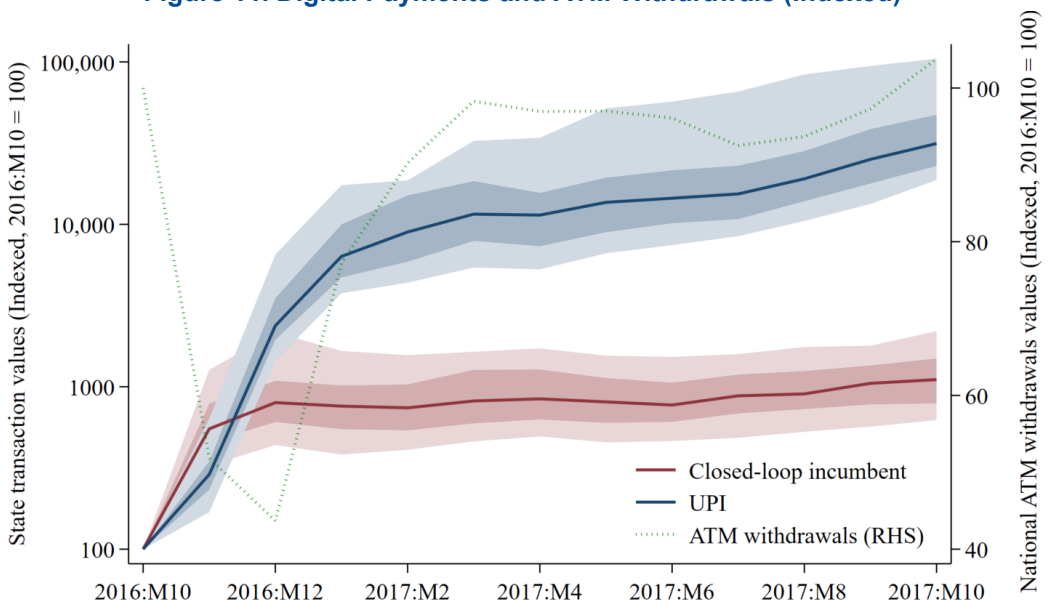
[24] For further detail on the methodology we use to quantify the impact of this "integration shock", see Copestake and others (2025).

We find that adoption of digital payments grows substantially faster in districts experiencing a larger increase in de facto interoperability. The blue values in Figure 12 plot the difference in total peer-to-merchant (P2M) transaction values, across both payment networks, between an average district with an above-median presence of the incumbent ex ante—and hence a larger increase in de facto interoperability ex post—and an average district with a below-median presence of the incumbent ex ante. Over the first year after the integration, total P2M transaction value per person increased by an average of 8 Rupees per month more in the former district than in the latter district. This difference is both persistent and substantial, equal to more than 80% of average P2M digital payments per person in above-median districts in the month prior to integration.[25] Moreover, this increase reflects a rise in all three components of total transactions: transactions where both counterparties used the incumbent app, transactions where only one used the incumbent app, and transactions where neither used it (Appendix Figure 1.5). Intuitively, integration benefited both the incumbent app joining UPI and apps already on UPI, by increasing overall usage of the platform and enabling new cross-app transactions.

Importantly, total digital payments also rise relative to a proxy for cash usage. Estimating cash usage is difficult because cash transactions can occur anonymously and may not be recorded in any ledger, especially in the informal sector. However, we can approximate cash usage with the value of automated teller machine (ATM) withdrawals in each district. When we measure the impact of integration on transaction values relative to cash withdrawals, we find a very similar picture, as shown by the maroon values in Figure 12. Total digital payments relative to cash withdrawals rise substantially and persistently more after integration in districts that face greater increases in de facto interoperability. This evidence suggests that interoperability can indeed support adoption of digital payments and encourage a transition away from cash.

[25] This difference amounts to 118% of average monthly P2M digital payments per person in below-median districts in the year after interoperability. See Copestake and others (2025) for estimates of the implications of this integration event for aggregate national adoption.

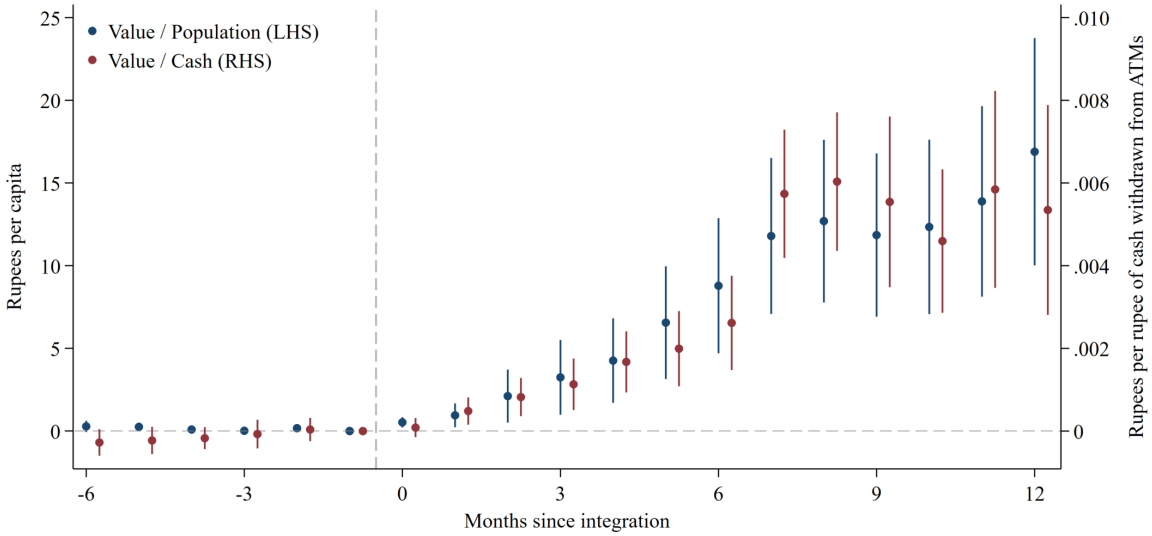
Figure 11. Digital Payments and ATM Withdrawals (Indexed)



Sources: NPCI, a major Indian fintech firm; and IMF staff analysis.

Note: The dashed green line shows national ATM withdrawals, by value, indexed to 100 in the month before demonetization (October 2016). The red line shows the total value of transactions on a major closed-loop incumbent digital payments platform in the median state, again indexed to 100 in October 2016. The blue line shows the same for transactions on UPI. The inner (outer) blue and red shaded regions show the 25th–75th (10th–90th) percentiles across states.

Figure 12. Impact of Integration on Peer-to-Merchant Transaction Values per Month



Sources: NPCI, a major Indian fintech firm; and IMF staff analysis.

Notes: The graph plots the estimated difference in the outcome variable between districts with a below vs. above-median market share of the incumbent in the month before integration—that is, between districts facing a smaller vs. larger increase in de facto interoperability. The outcome variable in blue is total district-level peer-to-merchant digital payments, across both digital payment platforms, measured in rupees per capita. The outcome variable in maroon is the same except normalized by ATM withdrawals—that is, measured in rupees of digital payments per rupee of cash withdrawn. The vertical bands show 95 percent confidence intervals and standard errors are clustered at the district level. Further details of the estimation procedure are provided in Copestake and others (2025).

Maintaining Choice over the Long Term

Over the longer term, the benefits of interoperability described above could be eroded if some providers become dominant. The preceding discussion highlighted the benefits of interoperability in increasing user choice and incentivizing new and incumbent providers to enter or upgrade the quality of their services. These arguments relied on the existence of a genuinely open, interoperable system in which users could freely switch between apps. In this final section, we consider possible threats to that assumption.[26]

First, users' ability to switch apps may be reduced if providers are able to create new network effects. Consider QR codes, for example. Some UPI providers initially offered proprietary, closed-loop QR codes to merchants that could only be read by the provider's own app—steering potential customers to also adopt that app. While the convenience of QR codes attracted more users onto UPI, the lack of QR code interoperability also constrained users' ability to choose the app that most closely matched their personal preferences, as detailed in the "Conceptual Framework" section. Non-interoperable QR codes were therefore prohibited by the RBI to reinforce UPI's design as a fully open and interoperable payments system (Reserve Bank of India, 2020). Even with interoperable QR codes, nonstandardized branding around them can create an impression that they are only readable by a given app, again potentially creating network effects if customers are unaware that the QR code is nonetheless interoperable.[27]

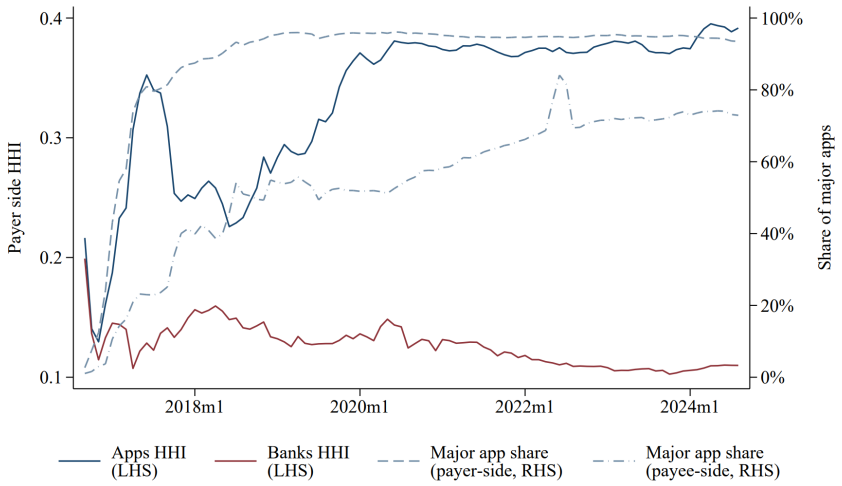
Second, even without network effects in payments, the underlying economics of app provision could generate market power for the top providers. Given the zero-fee structure of UPI, many app providers generate revenue to support their provision of UPI payments by offering complementary services, such as lending and insurance products. If these secondary markets are prone to market power—for example, through economies of scale or scope—this could in turn lead to dominance in the UPI market. Customers may not switch to an app that offers better UPI-related services if doing so would mean sacrificing other benefits that their current provider bundles with UPI payments.

The market for UPI apps has become highly concentrated. Figure 13 highlights that, on various aggregate metrics, concentration in the market for UPI apps has risen since the early years of the platform. Moreover, more granular measures provide further evidence that large app providers may still be able to create or harness residual network effects, despite the interoperable rails underlying the system. In half of UPI transactions, the payer and payee both use the same app, as shown by the yellow-outlined cells in Figure 14, and this share has been roughly stable over the last few years. As the transaction volumes of the two largest apps have grown, the two apps' user bases have also become more regionally specialized (Figure 15). Such patterns are consistent with providers finding ways to steer users to adopt the same app as those with whom they frequently transact—constraining the beneficial "freedom to choose" highlighted in the "Conceptual Framework" section.

[26] In addition, market power that increases concentration could reduce the resilience of the system, by increasing users' reliance on a small number of apps.

[27] Indeed, Phatak and others (2020) recommend standardizing QR code branding to ensure a consistent experience for customers.

Figure 13. Concentration among UPI Ecosystem Participants

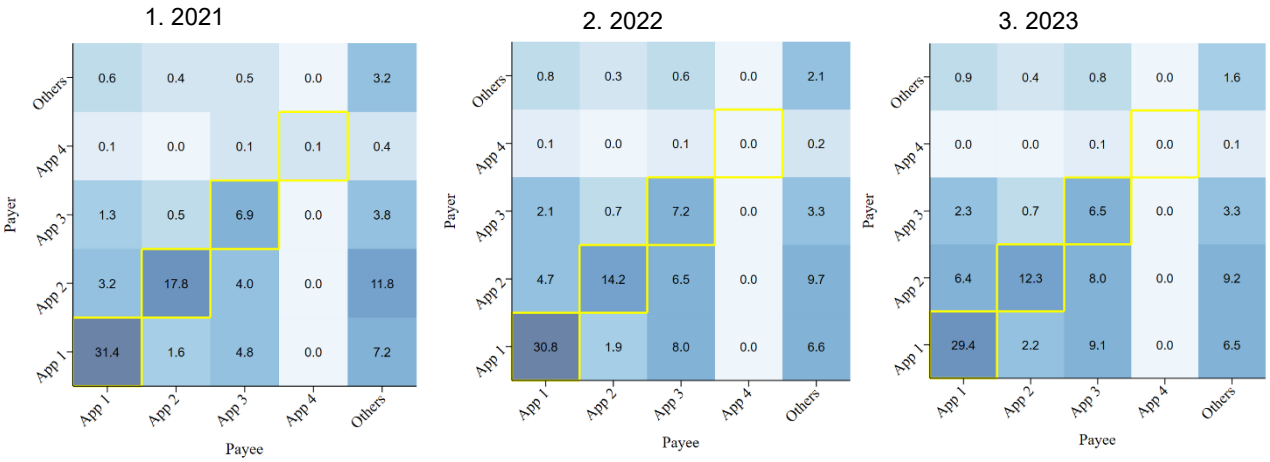


Sources: NPCI; and IMF staff analysis.

Note: This graph plots four different measures of concentration among UPI ecosystem participants. The red solid line shows the HHI of payers' banks over time, and the blue solid line shows the same for payers' apps. The dashed and dot-dashed lines show the share of all transactions facilitated by the top three apps on, respectively, the payer and payee side. HHI = Herfindahl–Hirschman Index. LHS = left-hand side scale. RHS = right-hand side scale.

Regulators of interoperable payment systems should monitor app dominance, and be prepared to act to maintain a level playing field among apps. Granular data on usage patterns, combined with qualitative user research, can help identify specific underlying mechanisms generating market power for dominant apps. Regulators can then tailor policy responses directly to the mechanisms.

Figure 14. Payer–Payee Flows: P2P + P2M (Percent of Aggregate Volume)

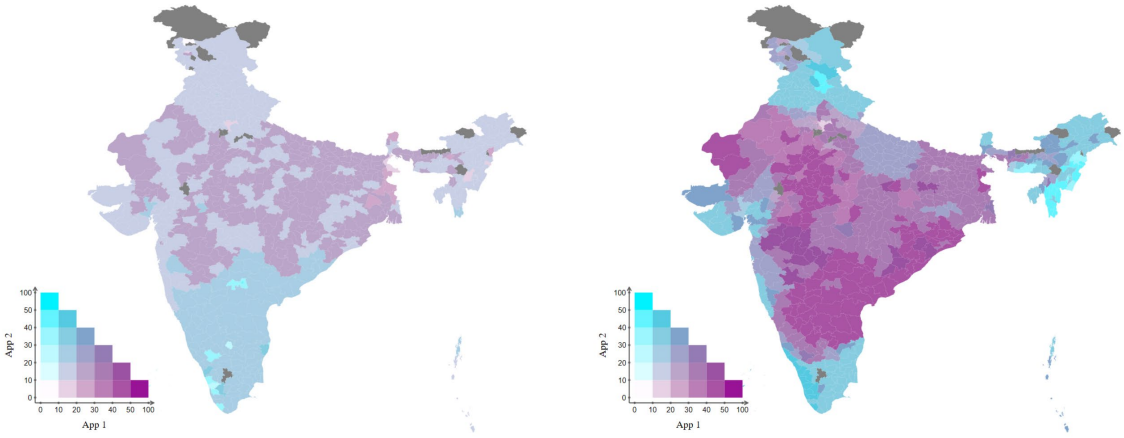


Sources: NPCI; and IMF staff analysis.

Note: These matrices show the share of the aggregate peer-to-peer and peer-to-merchant transaction volume on UPI that was facilitated by four major apps over time, split by each combination of payer and payee app. P2P = peer-to-peer; P2M = peer-to-merchant.

Figure 15. Shares of App 1 and App 2: P2P + P2M (Percent of Aggregate Volume)

1. 2018 2. 2023 .



Sources: NPCI; and IMF staff analysis.

Note: These maps show the share of aggregate UPI transaction volume (across both the payer and payee sides) facilitated by App 1 and App 2. Purple shading indicates a higher share for App 1, and blue shading indicates a higher share for App 2. P2P = peer-to-peer; P2M = peer-to-merchant. The boundaries, colors, denominations, and any other information shown on the maps do not imply, on the part of the International Monetary Fund, any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.

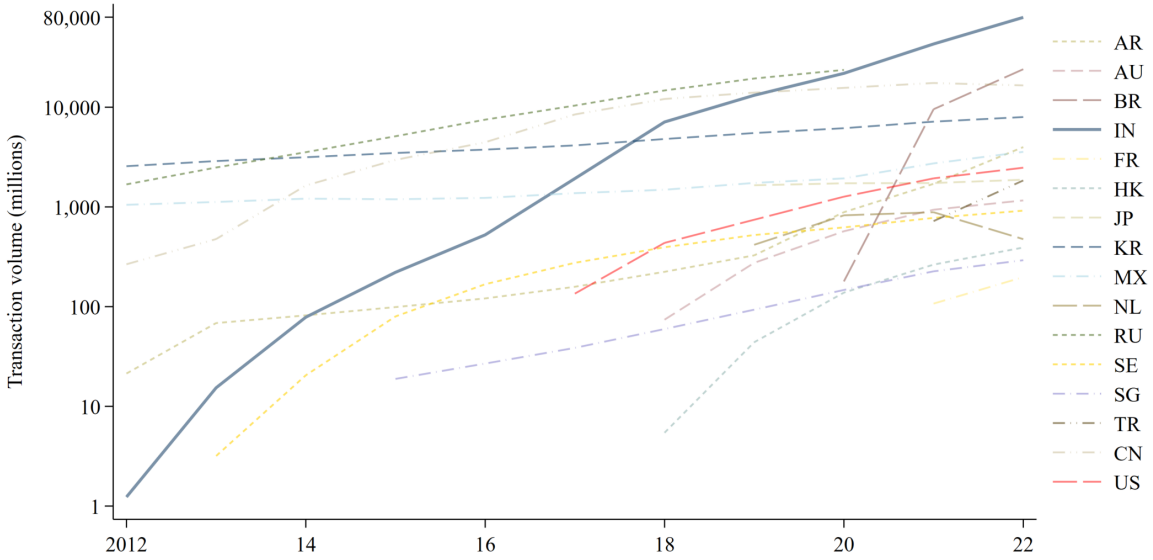
Conclusions and Policy Implications

UPI has transformed the digital payments landscape in India. Evidence from the platform suggests that interoperability can improve users' experience of digital payments and expand overall adoption. Interoperability directly increases users' freedom to choose their favorite app, enabling them to take full advantage of the variety and quality of apps available. Interoperability can also facilitate entry by new providers and incentivize existing providers to upgrade their apps, offering indirect benefits to users. As a result, interoperability can make adopting digital payments more attractive for users and hence increase overall adoption relative to a world with only closed-loop alternatives.

Providing infrastructure for interoperable systems, or otherwise supporting interoperability through regulation, could be a promising avenue for countries seeking to transition from cash to digital payments. For such policies to be effective, policymakers should first ensure that complementary enabling investments are in place—as with the reduction in mobile data costs and the expansion of bank accounts and digital identity in India. In the early stages of an interoperable system, when user take-up is low, adoption can be accelerated by providing a public app and by encouraging existing payments platforms to connect their networks to the system. Integrating financial institutions that users already trust—for example, users' existing banks or payments providers—can thus help bridge users from legacy systems to the new interoperable platform. As the interoperable platform matures and more providers join, policymakers should watch for the emergence of dominant private providers and be prepared to take action to maintain a fully open, interoperable and competitive system. Payment authorities should use a range of metrics to identify potential threats to this goal and tailor any responses to the specific underlying anti-competitive mechanism. At all stages of development, the system operator should consult with current and potential private sector participants to ensure that its design choices support the health of the interoperable ecosystem.

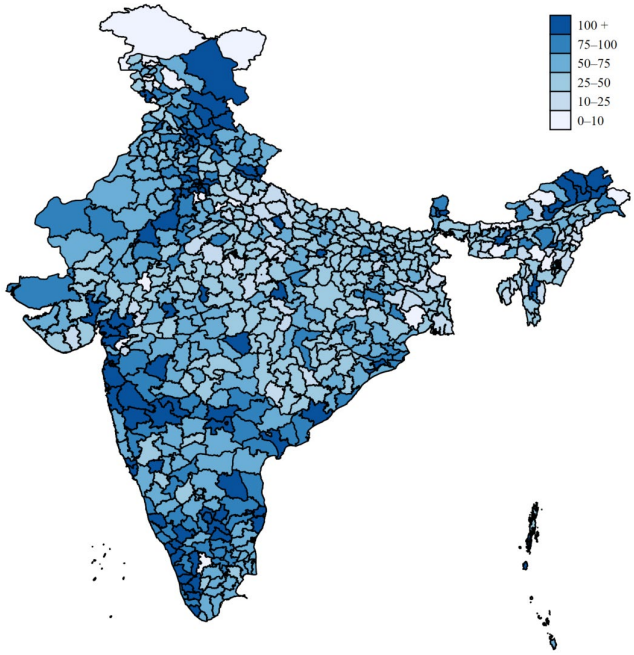
Appendix. Additional Figures and Results

Appendix Figure 1.1. Volume of Fast Payment Transactions (Millions)



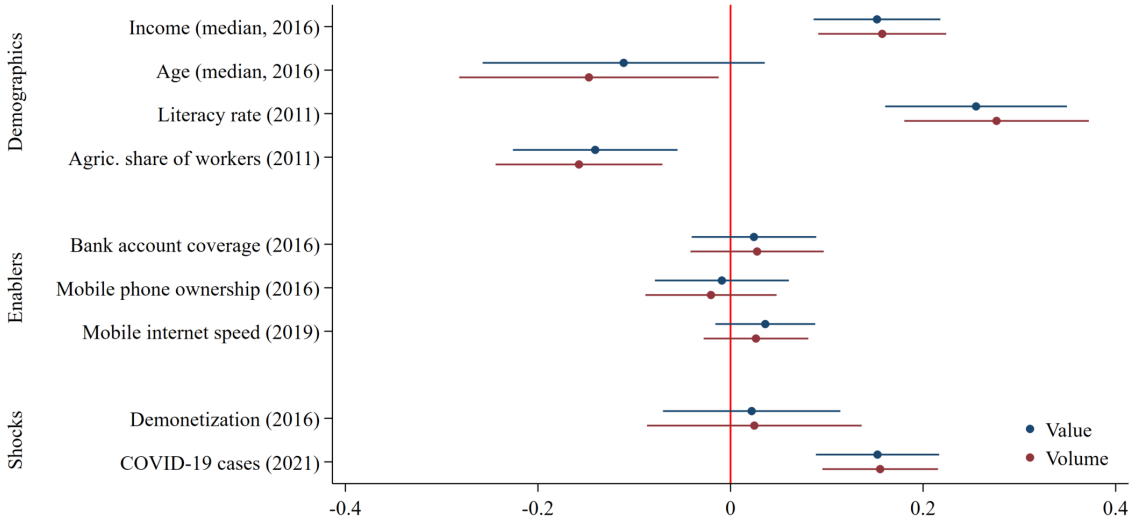
Sources: BIS; Statista; TCH; and IMF staff analysis.
Note: Fast payments: real-time or near real-time transfers of funds between accounts of end users as close to a 24/7 basis as possible (Frost and others 2024). US data comprise Zelle from 2017 and RTP from 2020.

Appendix Figure 1.2. UPI Transaction Volume in 2023 (# per Capita)



Sources: NPCI; and IMF staff analysis.
Note: This map shows the UPI transaction volume of Indian districts in 2023. The boundaries, colors, denominations, and any other information shown on the maps do not imply, on the part of the International Monetary Fund, any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.

Appendix Figure 1.3. Association with Log UPI Value or Volume in 2023 (Rupees per Capita, # per Capita)



Sources: Census; CMIE; NPCI; Ookla; Crouzet, Gupta, and Mezzanotti (2023); and IMF staff analysis.
Notes: This graph plots the coefficients from a regression of district-wise log UPI value or volume in 2023 on the standardized values of all the variables listed on the left-hand side, as well as state fixed effects. Each coefficient times 100 therefore shows the approximate percent increase in district-wise UPI value or volume that is associated with a district having had a one standard deviation higher value of the left-hand-side variable. Lines show 95 percent confidence intervals, where standard errors are clustered by state. The demonetization variable is from Crouzet, Gupta, and Mezzanotti (2023).

Appendix Table 1.1. Regression of Log Total Transaction Value on Dummy for App-Bank Matches

	(1)	(2)	(3)	(4)
1{Bank's own app}	6.985***	9.087***	8.641***	9.061***
	(0.535)	(0.344)	(0.433)	(0.423)
Fixed effects:				
– App		✓	✓	
– Bank			✓	
– App-time				✓
– Bank-time				✓
Observations	130,061	130,055	130,055	129,741

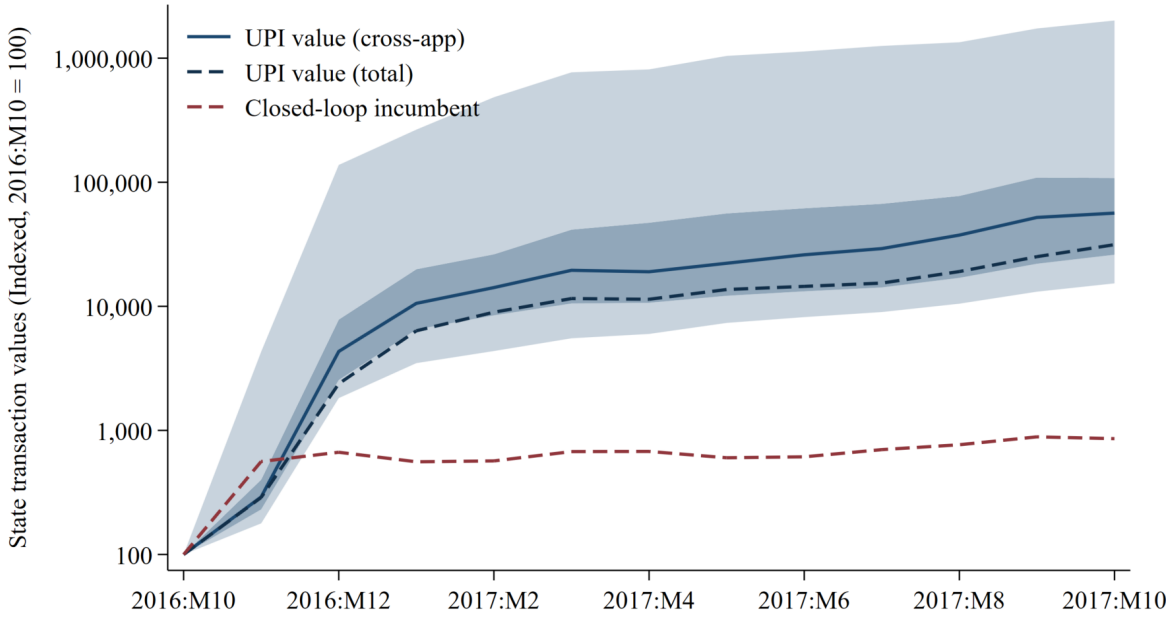
Sources: NPCI; and IMF staff analysis.
Note: This table plots coefficients from regressions of log total UPI transaction value on a dummy for app-bank matches. For a given app-bank pair, each coefficient times 100 shows the approximate percentage increase in transaction values that is associated with the app being produced by the bank, rather than being produced by another bank or a nonbank entity. App and app-time (bank and bank-time) fixed effects control for average levels or trends in usage of each app (bank). Standard errors are shown in parentheses, clustered at the app and bank levels.
* $p < .1$, ** $p < .05$, *** $p < .01$.

Appendix Table 1.2. Regression of Log Total Transaction Value on Lagged Decline Rate

	(1)	(2)	(3)	(4)
L.Decline rate	-0.121***	-0.0825***	-0.124***	-0.0430***
	(0.0122)	(0.0124)	(0.0139)	(0.0118)
Fixed effects:				
– App		✓		✓
– Time			✓	✓
Observations	2,382	2,364	2,382	2,364

Sources: NPCI; and IMF staff analysis.
Note: This table plots coefficients from regressions of log total transaction value on apps' lagged average decline rates. Each coefficient times 100 shows the approximate percentage change in app-wise transaction value in a given quarter that is associated with the app having had a one percentage point higher decline rate in the previous quarter. App fixed effects control for average usage levels by app, and time fixed effects control for aggregate trends in total transaction value. Standard errors are shown in parentheses, clustered at the app level.
* $p < .1$, ** $p < .05$, *** $p < .01$.

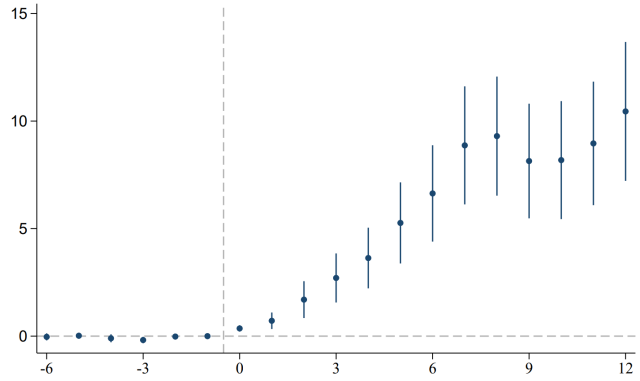
Appendix Figure 1.4. UPI Payments across Apps (Indexed)



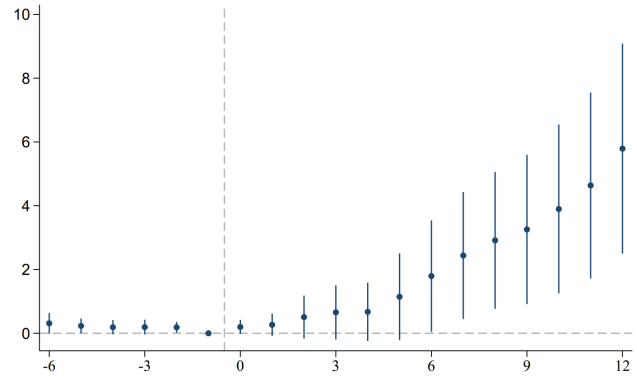
Sources: NPCI, a major Indian fintech firm; and IMF staff analysis.
Note: The blue and red dashed lines repeat those on Figure 11—that is, they show the total value of transactions on UPI and a major closed-loop incumbent digital payments platform in the median state, indexed to 100 in the month before demonetization (October 2016). The solid blue line plots the same for cross-app UPI payments only. The inner (outer) blue shaded regions show the 25th–75th (10th–90th) percentiles across states.

Appendix Figure 1.5. Impact on P2M Transaction Values per Month (Rupees per Capita)

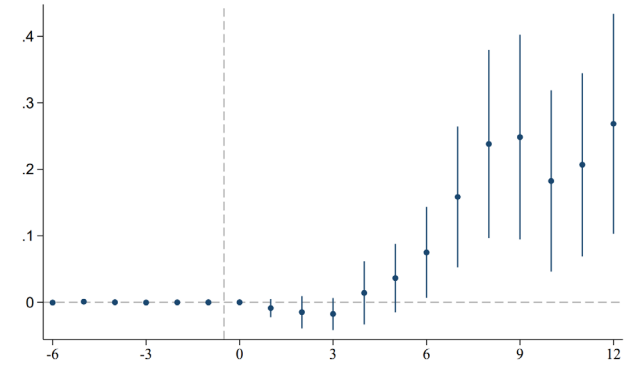
1. Transactions using only the Incumbent App



2. Transactions between the Incumbent App and Other UPI Apps



3. Transactions between Other UPI Apps



Sources: NPCI, a major Indian fintech firm; and IMF staff analysis.

Notes: The graphs plot the estimated difference in the outcome variable between districts with a below vs. above-median market share of the incumbent in the month before integration—that is, between districts facing a smaller vs. larger increase in de facto interoperability. The outcome variables are district-level peer-to-merchant digital payments, measured in rupees per capita, for (Panel 1) transactions between counterparties on the incumbent app, (Panel 2) transactions between the incumbent app and other UPI apps, and (Panel 3) transactions between counterparties on other UPI apps. The vertical bands show 95 percent confidence intervals, and standard errors are clustered at the district level. Further details of the estimation procedure are provided in Copestake and others (2025). P2M = peer-to-merchant.

References

ACI Worldwide. 2023. “Prime Time for Real-Time Report 2023.” https://www.aciworldwide.com/real-time-payments-report.

Agarwal, Sumit, Shashwat Alok, Pulak Ghosh, Soumya Kanti Ghosh, Tomasz Piskorski, and Amit Seru. 2017. “Banking the Unbanked: What do 280 Million New Bank Accounts Reveal about Financial Access?” SSRN Scholarly Paper 2906523, Social Science Research Network, Rochester, NY.

Agarwal, Sumit, Pulak Ghosh, Jing Li, and Tianyue Ruan. 2024. “Digital Payments and Consumption: Evidence from the 2016 Demonetization in India.” *The Review of Financial Studies*, Volume 37, Issue 8, Pages 2550–2585.

Alok, Shashwat, Pulak Ghosh, Nirupama Kulkarni, and Manju Puri. 2024. “Open Banking and Digital Payments: Implications for Credit Access” National Bureau of Economic Research, Working Paper Series, 33259.

Alonso, Cristian, Tanuj Bhojwani, Emine Hanedar, Dinar Prihardini, Gerardo Una, and Kateryna Zhabska. 2023. “Stacking Up the Benefits: Lessons from India’s Digital Journey.” IMF Working Paper No. 23/78, International Monetary Fund, Washington, DC.

Ancalle, Celene, and Maria Gracia Garcia. 2024. “Impact of Interoperability Regulation on the Use of Digital Payments in Peru.” Graduate Institute of International and Development Studies Working Paper, No. HEIDWP02-2024, Graduate Institute of International and Development Studies, Geneva.

Armstrong, Mark, and Wright, Julian. 2008. “Two-Sided Markets.” In *New Palgrave Dictionary of Economics*, 2nd edition, edited by Steven N. Durlauf and Lawrence E. Blume. London: Palgrave Macmillan.

Berg, Toblas, Andreas Fuster, and Manju Puri. 2022. “FinTech Lending.” *Annual Review of Financial Economics* 14: 187–207.

Björkegren, Daniel. 2022. “Competition in Network Industries: Evidence from the Rwandan Mobile Phone Network.” *The RAND Journal of Economics* 53: 200–25.

Boar, Codruta, Stijn Claessens, Anneke Kosse, Ross Leckow, and Tara Rice. 2021. “Interoperability between Payment Systems across Borders.” *BIS Bulletins*.

Brunnermeier, Markus K., Nicola Limodio, and Lorenzo Spadavecchia. 2023. “Mobile Money, Interoperability, and Financial Inclusion.” SSRN Scholarly Paper 4574641, Social Science Research Network, Rochester, NY.

Brunnermeier, Markus K., and Jonathan Payne. 2023. “Strategic Money and Credit Ledgers.” NBER Working Papers, number: 31561, National Bureau of Economic Research, Cambridge, MA.

Chodorow-Reich, Gabriel, Gita Gopinath, Prachi Mishra, and Abhinav Narayanan. 2020. “Cash and the Economy: Evidence from India’s Demonetization.” *The Quarterly Journal of Economics* 135: 57–103.

Chowdhry, Bhagwan, and Anas Ahmed. 2024. *FinTech for Billions: Simple, Human, Ubiquitous*. India: Penguin Random House India.

Cong, Lin William, David Easley, and Eswar Prasad. 2024. “Demystifying Electronic Payment Systems and Digital Currencies.” In *Oxford Research Encyclopedia of Economics and Finance*. Oxford University Press.

Copestake, Alexander, Divya Kirti, Maria Soledad Martinez Peria, and Yao Zeng (2025): “Integrating Fragmented Networks: The Value of Interoperability in Money and Payments.” IMF Working Paper, International Monetary Fund, Washington, DC.

Cornelli, Giulio, Jon Frost, Leonardo Gambacorta, Sonalika Sinha, and Robert M. Townsend. 2024. "The Organisation of Digital Payments in India – Lessons from the Unified Payments Interface (UPI)." Technical Report, SUERF.

Cornelli, G., Frost, J., Warren, J., Yang, C., & Velásquez, C. 2024. "Retail Fast Payment Systems as a catalyst for Digital Finance". Technical Report, Bank for International Settlements.

Crouzet, Nicolas, Pulak Ghosh, Apoorv Gupta, and Filippo Mezzanotti. 2024. "Demographics and Technology Diffusion: Evidence from Mobile Payments." SSRN Scholarly Paper 4778382, Social Science Research Network, Rochester, NY.

Crouzet, Nicolas, Apoorv Gupta, and Filippo Mezzanotti. 2023. "Shocks and Technology Adoption: Evidence from Electronic Payment Systems." *Journal of Political Economy* 131: 3003–65.

D'Silva, Derryl, Zuzana Filkova, Frank Packer, and Siddharth Tiwari. 2019. "The Design of Digital Financial Infrastructure: Lessons from India." *BIS Papers*, No 106.

Ding, Ding, Rodrigo Gonzalez, Yiming Ma, and Yao Zeng. 2025. "The Effect of Instant Payments on the Banking System: Liquidity Transformation and Risk-Taking." https://ssrn.com/abstract=5250569.

Dobler, Marc C., Jose M. Garrido, Dirk Jan Grolleman, Tanai Khiaonarong, and Jan Nolte. 2021. "E-Money: Prudential Supervision, Oversight, and User Protection." No. DP/2021/027, Departmental Papers. International Monetary Fund, Washington, DC.

Dubey, Tamanna Singh, and Amiyatosh Purnanandam 2023. "Can Cashless Payments Spur Economic Growth?" SSRN Scholarly Paper 4373602, Social Science Research Network, Rochester, NY.

Edelman, Benjamin, and Julian Wright. 2015. "Price Coherence and Excessive Intermediation." *The Quarterly Journal of Economics* 130: 1283–328, President and Fellows of Harvard College.

Frost, Jon, P. Koo Wilkens, Anneke Kosse, Vatsala Shreeti, and Carolina Velasquez. 2024. "Fast Payments: Design and Adoption." *BIS Quarterly Review,* March 2024: 31-37.

International Monetary Fund. 2017. "People's Republic of China: Financial System Stability Assessment." Technical Report, Country Report No. 2017/358, International Monetary Fund, Washington, DC.

Katz, Michael L., and Carl Shapiro. 1985. "Network Externalities, Competition, and Compatibility." *The American Economic Review* 75 (3): 424–40.

Klapper, Leora, Margaret Miller, and Jake Hess. 2019. "Leveraging Digital Financial Solutions to Promote Formal Business Participation." Technical Report, World Bank, Washington, DC.

Lahiri, Amartya. 2020. "The Great Indian Demonetization." *Journal of Economic Perspectives* 34: 55–74.

Mishra, Prachi, Nagpurnanand Prabhala, and Raghuram G. Rajan. 2022. "The Relationship Dilemma: Why Do Banks Differ in the Pace at Which They Adopt New Technology?" *The Review of Financial Studies* 35: 3418–66.

Ouyang, Shumiao. 2021. "Cashless Payment and Financial Inclusion." SSRN Scholarly Paper 3948925, Social Science Research Network, Rochester, NY.

Patel, Manisha, Safari Kasiyanto, and Andre Reslow. 2024. "Positioning Central Bank Digital Currency in the Payments Landscape." IMF Fintech Notes 2024/006, International Monetary Fund, Washington, DC.

Patnam, Manasa, and Weijia Yao. 2020. "The Real Effects of Mobile Money: Evidence from a Large-Scale Fintech Expansion." IMF Working Papers No. 2020/138, International Monetary Fund, Washington, DC.

Phatak, D. B., Arvind Kumar, Sunil Mehta, A.S. Ramasastri, Dilip Asbe, and Vishwas Patel. 2020. "Report of the Committee on the Analysis of QR Code." Technical Report, Reserve Bank of India.

PwC India. 2022. “The Emerging Potential of Offline Payments in India.” Technical Report, PricewaterhouseCoopers Private Limited, Delhi.

Reserve Bank of India. 2020. “Digital Payment Transactions – Streamlining QR Code Infrastructure.” Reserve Bank of India, Department of Payment and Settlement Systems, Central Office, Mumbai. https://www.rbi.org.in/scripts/NotificationUser.aspx?Id=11987&Mode=0.

Reserve Bank of India. 2022. “Discussion Paper on Charges in Payment Systems.” https://rbidocs.rbi.org.in/rdocs/Publications/PDFs/DPSSDISCUSSIONPAPER5E016622B2D3444A9F294D07234059AA.PDF.

Rishabh, Kumar, and Jorma Schäublin. 2021. “Payment Fintechs and Debt Enforcement.” Working papers, number: 2021/02, Faculty of Business and Economics - University of Basel.

Rochet, Jean-Charles, and Jean Tirole. 2006. “Two-Sided Markets: A Progress Report.” *RAND Journal of Economics* 37: 645–67.

Tan, Guofu, and Junjie Zhou. 2021. “The Effects of Competition and Entry in Multi-Sided Markets.” *The Review of Economic Studies* 88: 1002–30.

Wang, Lulu. 2025. “Regulating Competing Payment Networks.” *Kilts Center at Chicago Booth Marketing Data Center Paper*. https://ssrn.com/abstract=5262161.

Wright, Richard, Erdal Tekin, Volkan Topalli, Chandler McClellan, Timothy Dickinson, and Richard Rosenfeld. 2017. “Less Cash, Less Crime: Evidence from the Electronic Benefit Transfer Program.” *Journal of Law and Economics* 60: 361–83.

PUBLICATIONS

Growing Retail Digital Payments: The Value of Interoperability

NOTE/2025/004