Drivers of Digital Payment Adoption: Lessons from Brazil, Costa Rica, and Mexico*

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Abstract

Digital payment platforms can displace cash and extend financial services to underserved populations, yet many adults worldwide remain unbanked. Leveraging granular microdata on individual transactions and user characteristics, we argue that broad cash substitution via peer-to-peer (P2P) platforms depends on a "rapid low income-gradient"—the speed at which adoption spreads from affluent early users to lower-income groups. In three Latin American cases—Brazil's Pix, Costa Rica's Sinpe Móvil, and Mexico's CoDi—we document that low adoption costs, strong network effects, coordinated supply-side integration, and early awareness efforts enabled Pix and Sinpe Móvil to reach nearly all income segments within five years, whereas CoDi remains characterized by low usage and predominantly high-income adopters.

Keywords: Technology Adoption, Peer-to-Peer Payments, Digital Payments

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1 Introduction

Governments and policymakers have long sought digital payment platforms capable of truly replacing cash, yet conventional payment cards have fallen short: even decades after their introduction, significant segments of low- and middle-income populations remain unbanked or reliant on cash. According to the World Bank, roughly 1.4 billion adults worldwide remain unbanked and rely on cash for everyday transactions (Demirgüç-Kunt et al., 2022). Peer-to-peer (P2P) digital-payment technologies offer a promising alternative because they combine the two core benefits of cash—heightened awareness of one's own spending and immediate settlement—with those of cards: not having to carry physical money, faster transaction speeds, greater ease of use, and enhanced security. Indeed, in countries that have embraced P2P systems, these platforms have largely replaced cash in day-to-day payments.

What determines the success of P2P payment technologies and their ability to substitute cash? There is dramatic variation in both the speed of adoption and the intensity of usage of P2P mobile payment platforms across the globe.[1] Drawing lessons from several case studies, we argue that a necessary condition for widespread success is a *rapid low income-gradient*: within a short window after launch, these technologies must recruit not only the early, high-income adopters—who tend to be young urban men with high skills and financial literacy—but quickly attract a broader base.

Such platforms eliminate upfront barriers by having low adoption costs, so that even the poorest households can sign up without delay, and offering clear benefits to users.[2] Strong network effects ensure that once a modest base of users and agents is

[1] Duarte et al. (2022) document that transactions per capita in the first four years after launch reach thirty to forty in successful cases such as Brazil, Denmark, and Sweden, yet remain below five in less successful contexts like Mexico and Nigeria.

[2] Digital payments rely on mobile phone technology, which itself exhibits a rapid low income-gradient (Aker and Mbiti, 2010).

active, others see benefits from adoption go up. Crucially, all of this is reinforced by a supportive ecosystem—regulation that encourages innovation, plus trusted agent and merchant networks that lower the perceived risks for new users.

These dynamics imply that the *marginal adopter* changes dramatically over a relatively short period of time. In the early stages, adopters are strongly selected—urban, affluent, digitally and financially savvy young men—whereas soon after, the marginal user increasingly resembles the general population. In stark contrast, conventional credit and debit cards have exhibited stubbornly high income gradients even decades after their introduction, leaving large segments of the poor population reliant on cash.[3]

This paper examines three case studies to understand what are key determinants of the success of mobile payment technologies in developing countries. Namely, Pix in Brazil, Sinpe Móvil in Costa Rica, and CoDi in Mexico. Despite having a similar real GDP per capita, these Latin American countries had very different experiences with the introduction of these platforms. Pix and Sinpe Móvil, two success stories, are technologies with rapid low income-gradients: Within five years of their rollout, municipalities in the lowest income quintiles were transacting at nearly the same rates as wealthier areas. Strategic complementarities reinforced their diffusion: as usage spread beyond the initial elite cohort, each additional adopter increased the platform's value for the next wave of users, producing the classic S-curve pattern—where adoption begins slowly, accelerates as network effects take hold, and eventually levels off as saturation is reached.

[3]Conventional card payments exhibit low substitutability with cash, limiting their ability to displace physical currency (Alvarez and Argente, 2024). Thus, mobile payments have the potential to leapfrog legacy card systems. Han and Wang (2021) show that while card payment adoption rises monotonically with per-capita income, a pattern characteristic of technologies with high adoption costs and weak strategic complementarities, mobile-payment uptake follows a non-monotonic pattern, indicating broader accessibility and stronger network effects.

By contrast, Mexico's CoDi remains trapped in the early, high-income segment of its adoption curve. CoDi still struggles to knock down entry barriers—many potential users must first obtain compatible smartphones or bank accounts, and its agent and merchant networks remain sparse outside urban centers—so adoption among low-income communities has lagged behind. Without a rapid low income-gradient, strategic complementarities remain weak, and the network cannot reach the tipping point needed for mass adoption.

We first discuss the features and institutional background behind each technology in Section 3. The platforms share some common characteristics, like requiring users to have a bank account and a mobile phone. They also share a similar origin, as they use real-time interbank "highways" developed by the corresponding central bank decades prior to each platform's launch as a backbone to connect the participants. Leveraging these rails lowered costs and sped up launches. However, accessibility differed across countries, with Pix allowing a broader set of financial institutions to participate directly, while Sinpe Móvil is limited to transaction account providers, and CoDi is yet more restrictive due to security reasons.

We then summarize the barriers to adoption in each country in Section 4, focusing on financial inclusion and technological constraints—namely, mobile phone ownership and internet connectivity. Despite similar levels of GDP per capita, these frictions varied widely across the three countries prior to the introduction of digital payment technologies. While roughly 70% of adults in Brazil and Costa Rica held a bank account by 2017, the figure was under 40% in Mexico, raising the cost of CoDi adoption for a large share of the population. Likewise, both credit and debit card ownership and usage, as well as experience with digital payments, are markedly lower in Mexico than in Brazil and Costa Rica. Technological entry barriers also differ; mobile phone ownership is virtually universal in Costa Rica, about ten percentage points lower in Brazil, and below 70% in Mexico, with substantial geographic variation. While Sinpe

Móvil can route transactions over SMS, Pix and CoDi rely on internet-connected apps, creating an additional hurdle in areas with unreliable connectivity.

We then turn to studying the degrees of adoption in each country and their drivers in Section 5.1, leveraging microdata to compare the speed and extent of uptake. Across countries, S-curves look significantly different. Pix's adoption in Brazil was the fastest, reaching 60% of the adult population within a year and, more recently, encompassing nearly the entire adult population.[4] In Costa Rica, Sinpe Móvil's adoption was slower, but featured steady growth: while it took five years for it to reach 40% adoption rates, it reached an 80% adoption rate in 2024. In contrast, CoDi's adoption in Mexico stagnated, reaching only 2-3% of the adult population since its launch in 2019.

The microdata are particularly well-suited to detailed *within-country* comparisons, which are the focus of the rest of the paper. While the overall adoption and usage rates in Brazil and Costa Rica are very high, take-up did not occur uniformly across space; municipalities with higher income had more users early on. However, both countries also exhibited a flat income gradient of usage—usage intensity equalized across rich and poor—shortly after the countries' launch, even though adoption rates remain higher in wealthier areas. We also show that, conditional on income, internet speed and bank account ownership play a relevant role in explaining regional disparities. Thus, in countries with high dispersion in internet access and financial inclusion, this is a consideration to increase the technology's reach.

As these payment technologies progressed along their adoption S-curve, the characteristics of their marginal adopter changed over time. While this notion is intuitive, exploring it empirically is data-demanding, as it requires dynamic microdata on the characteristics of the adopters. We leverage this granular information on individual characteristics and their usage of Sinpe Móvil for the case of Costa Rica.

[4]This suggests that Pix also increased bank account adoption in Brazil.

First, we document that early adopters tend to be younger—the age of the marginal adopter in 2015 was 35, while its counterpart for 2024 was 40. Second, men tend to adopt first—the share of female adopters was below 40% when the technology first launched and gradually rose until it stabilized at 50% towards 2022. Moreover, the share of adopters who reside in urban areas has been decreasing over time. Finally, the marginal adopter has become increasingly likely to be a low-skilled worker as the technology has become more widely adopted.[5]

Strategic complementarities are an intuitive driver of P2P payments adoption: an individual's benefit from joining the network grows with the number of existing users (Alvarez et al., 2023a; Crouzet et al., 2023). In practice, this relates to why having a rapid low income-gradient is key; a platform must quickly build a critical mass of participants so that each new adopter reaps increasing utility from being able to transact with a larger set of peers. The network structure also changes as a technology becomes more widely adopted; for instance, in the case of Sinpe Móvil, we show how the network became more interconnected as adoption increased. Related to our analysis above, strategic complementarities can also shape how the marginal adopter looks like at each stage. Early on, adopters are a highly selected group—urban, affluent, young men willing to join a thin network. As the system matures and strategic complementarities kick in, successive adopters come from progressively broader demographics, mirroring the flattening of the income gradient we document for Pix and Sinpe Móvil (but not CoDi).[6] In this way, strategic complementarities contribute both to the speed of diffusion and to the evolution of the user profile along

[5]These patterns are consistent with evidence from other national case studies. Jack and Suri (2011) show that within three years of its launch, M-Pesa in Kenya had reached over 40 percent of the adult population, including widespread adoption among rural and low-income users. Similarly, India's Unified Payments Interface surpassed 300 million registrations by 2019 and achieved near-equal adoption rates across income quintiles. In China, Alipay also saw rapid diffusion among rural and lower-income populations, reinforcing the view that mobile payment technologies broaden financial access as adoption deepens.

[6]We also show that homophily plays a role in shaping network formation.

the S-curve.

An analysis of adoption drivers cannot omit the relevance of awareness and trust. Conditional on awareness, user trust is a prerequisite for adoption (Alvarez et al., 2023b). Evidence suggests that in the case of CoDi, and initially for Sinpe Móvil, awareness was lacking and constrained adoption, while Pix was well-advertised early on. Another aspect that is hard to quantify but has been anecdotally key is the value proposition of each technology for *supply-side* participants. We argue that coordination and interoperability features can be key. Without a mandate to participate (as in Brazil) or the initial involvement of large players (as in Costa Rica), the value proposition must be compelling enough to engage commercial banks and fintech firms. Otherwise, the success of the technology is compromised: a patchwork network cannot leverage strategic complementarities, and its limited reach discourages adoption by reducing the potential benefits to end users.

While throughout we focus on P2P payments, we end this section by describing the state of firm adoption in Costa Rica and Brazil to draw lessons about how it relates to P2P adoption.[7] In both cases, adoption by individuals had to reach very high levels (over 70%) for business adoption to accelerate and represent more than a modest fraction of total activity. This is potentially the result of higher adoption costs for firms compared to individuals, which is supported by the evidence from Costa Rican surveys that indicate that difficulties with accounting systems for record keeping and integration are important deterrents for businesses; a result that is echoed by Comin et al. (2025).[8] Finally, Section 6 investigates evidence on the cross-adoption of payment instruments. The data from Brazil and Costa Rica suggest that adopting P2P payment systems incentivizes users to adopt other banking services and also

[7]This topic (P2B payments) has been studied in other contexts; see Alfaro-Serrano et al. (2021); Comin et al. (2025); Gertler et al. (2022).

[8]Cirera et al. (2022) find that small firms are more inclined to adopt online payment platforms than cards or online banking, highlighting fintech's potential to enhance the diffusion to financial instruments.

leads to substitute away from cash.

Ultimately, the contrasting experiences of Pix, Sinpe Móvil, and CoDi underscore that rapid, inclusive diffusion hinges on more than just technology. A low income-gradient, robust strategic complementarities, streamlined supply-side integration, and high levels of user awareness and trust must all align. By unpacking how these factors interact both across and within countries, our analysis provides practical lessons for designing digital payment systems that can truly displace cash and serve large segments of the population.

2 Data

Costa Rica: We leverage comprehensive data on Sinpe Móvil transactions. For each user, we observe the exact date of technology adoption as well as full transaction histories. Each record includes the transaction amount, the unique identifiers of both sender and receiver, and the respective banks involved. To enrich these records with demographics, we merge them with data from the Civil Registry, and employer–employee data from the Central Bank of Costa Rica (BCCR)'s Registry of Economic Variables. This linkage provides individual-level information on age, gender, income, and skill level. Municipal-level GDP data is drawn from BCCR's *Producto Interno Bruto Cantonal (PIBC)* series.

Brazil: Pix data were obtained from the Pix Dados Abertos portal of the Banco Central do Brasil. The dataset reports monthly counts and values of transactions executed since the system's launch in November 2020, disaggregated by payer and receiver, by municipality, and by account type (individual—PF vs. firm—PJ). Municipal-level GDP figures come from the Instituto Brasileiro de Geografia e Estatística (IBGE)'s *Produto Interno Bruto dos Municípios* series, which decomposes value-added into

agriculture, industry, and services at constant prices for 2010–2021. National population estimates are drawn from the United Nations Department of Economic and Social Affairs (UNDESA) historical population series (annual data, 1800–2020), while municipality-level population counts derive from the 2022 IBGE Census.

Mexico: Information on accounts that have conducted at least one transaction in CoDi is drawn from the Sistema de Información Económica of the Banco de México. We complement this with data from the National Survey of Financial Inclusion (ENIF), a triennial household survey representative at the national level and conducted by the National Institute of Statistics and Geography (INEGI). We use the most recent wave, corresponding to 2024. Lastly, income information comes from the Intercensal Survey of 2015.

Other Data: To complement our main analysis, we incorporate several additional data sources. Country-level GDP per capita is obtained from the World Development Indicators (WDI) database, which provides harmonized macroeconomic and financial-sector statistics for over 200 economies.[9] To measure financial inclusion, we use data from the Global Findex (GFI) database, which offers detailed survey-based indicators.[10] We also use data on the number of depositors with commercial banks (per 1,000 adults) in Brazil and Costa Rica from the WDI database. To capture mobile internet quality, we rely on the Speedtest database from Ookla's Global Fixed and Mobile Network Performance Map Tiles open-data release. This dataset aggregates millions of Speedtest results conducted via Ookla's Android and iOS apps each quarter since early 2019. Each result is assigned to a tile of approximately 610m×610m, reporting metrics such as average download and upload speeds, median latency, num-

[9]WDI collects these estimates annually from national statistical agencies and international organizations, ensuring consistency over time and across countries.

[10]Compiled by the World Bank every three years since 2011, GFI aggregates responses from over 150,000 adults in more than 150 economies.

ber of tests, and number of unique devices. We restrict our analysis to mobile-device tests (i.e., cellular connections) and use average download speed as a proxy for mobile internet quality. To align these tile-level results with municipal GDP per capita data, we compute an area-weighted average for each municipality using national boundary shapefiles.[11]

3 Institutional Background

The spirit behind Pix, Sinpe Móvil, and CoDi is similar: they allow users to conduct electronic payments from their personal devices and facilitate transfers. In fact, the technologies behind these platforms share some common characteristics. For instance, they all require users to have a bank account, which must be linked with the platform, and a mobile phone, which is used to send payments.

These technologies also have similar backbones: real-time interbank "highways" that their central banks in Brazil, Costa Rica, and Mexico built around the 2000s. By standing on the shoulders of decades-old, 24/7 Real-Time Gross Settlement (RTGS) or real-time nets, each country could launch a mobile-first platform years later. These platforms—called STR, Sinpe, and SPEI, in Brazil, Costa Rica, and Mexico, respectively—allowed for a relatively straightforward adaptation of real-time rails for transfers by end-users.

In Brazil, the real-time core—STR (*Reserves Transfer System*)—was first available in 2002, with RTGS for wholesale and high-value payments available 24/7, and was based on a settlement system with central-bank reserves and intraday collateral support. Pix was then launched as an overlay development in 2020 (Banco Central do Brasil, 2020). It consisted of a unified alias directory, in which the Central Bank

[11] Because tests are voluntary, coverage is uneven. Municipalities with no Speedtest results inherit no tiles and are excluded from our dataset. Our municipality coverage spans 88% for Brazil, 98% for Costa Rica, and 80% for Mexico.

maps e-mails, phone numbers, or random keys to any STR-enabled account. The Central Bank of Brazil also created an open API gateway, so that any registered institution could quickly integrate with the system. Pix participants fall into three categories: payment initiation providers (authorized third parties that trigger customer payments but don't settle them); transaction account providers (banks and PSPs offering deposit, savings, or prepaid accounts and connecting to the settlement system); and special intermediaries (other institutions linked to Pix's settlement rails without holding end-user accounts themselves), making it accessible to a broad fintech base. Pix technology supports QR codes, P2G (government collections), scheduled payments, and split transactions.

Costa Rica's real-time core—Sinpe (*National Electronic Payments System*)—dates back to 1997, with an RTGS engine settling individual gross transactions 24/7 (Banco Central de Costa Rica, 2025). This core was open to all banks and to licensed non-banks with reserve accounts. Sinpe Móvil was launched as an overlay development in 2015 (Araujo, 2018). Sinpe's original real-time rails allowed the Central Bank to map mobile numbers to bank accounts straightforwardly. Integration by banks was also smooth, as they simply "plugged" their existing Sinpe connections into a shared mobile-app gateway. Sinpe's immediate settlement meant the app could confirm Sinpe Móvil payments in seconds, and the existing infrastructure facilitated offering end-users zero fees for P2P, P2B, and P2G transactions (Alvarez et al., 2023a).

In Mexico, the real-time core—SPEI (*Interbanking Electronic Payment System*)—was launched by Banco de México in August 2004 via per-transaction real-time net settlements, 24/7, and participants were granted access to a SPEI API to facilitate usage (Banco de México, 2004). CoDi was then built in 2019 (Herrera-Arizmendi and Amezcua-Núñez, 2020), with IDs (phone, email, RFC) mapped to the SPEI directory in real time. Banco de México built a QR-functionality, so any SPEI-connected bank or fintech could scan and pay, and the SPEI settlement meant merchants saw funds

instantly. Participation in CoDi, however, is restricted to financial institutions which are members of SPEI and comply with specific security norms, although non-members can design applications to make payment requests (Corredor et al., 2020).

The development of these platforms follows a clear pattern: central banks first established resilient, around-the-clock interbank settlement systems (STR, Sinpe, and SPEI), creating a solid foundation for end-user mobile-payment overlays (Pix, Sinpe Móvil, and CoDi). Leveraging existing rails accelerated their launch and minimized costs—for both the central banks and other financial players. Accessibility, however, differed across settings, with Pix allowing for a broader base of financial institutions to directly participate, while Sinpe Móvil is limited to transaction account providers, and CoDi, for security reasons that will be discussed further in Section 5.4, is yet more restrictive in allowing providers to participate.

4 Barriers to Adoption

While all technologies require users to hold a bank account and to have access to a mobile phone, these requirements pose different challenges in each country depending on their income. Thus, we begin our exploration of barriers to adoption in each country with a comparison of their per capita GDP. Note that Brazil, Mexico, and Costa Rica all have a relatively similar GDP per capita. As shown in Table 1, this was true around the year 2000, close to the date when the real-time cores were developed, and in later years when Pix, Sinpe Móvil, and CoDi were launched.

4.1 Financial Inclusion

However, despite this similarity, financial inclusion differs significantly among these countries, as summarized in Panel (A) of Figure 1. This figure presents data for 160 countries using the Global Findex 2017, capturing conditions before the introduction

Table 1: GDP per Capita (PPP) by Country

	(1)	(2)	(3)	(4)
	2000	2015	2020	2024
Brazil	9,092	14,821	16,102	22,333
Costa Rica	7,879	17,525	22,100	30,063
Mexico	11,704	19,075	19,354	25,688

Notes: The table shows values for GDP per capita, PPP (current international dollars). The first column is close to the date when the real-time cores were developed in each country. The second column is the year Sinpe Móvil was launched, the third column is close to when Pix and CoDi were launched, and the last column is the latest year available. *Source:* World Bank, World Development Indicators.

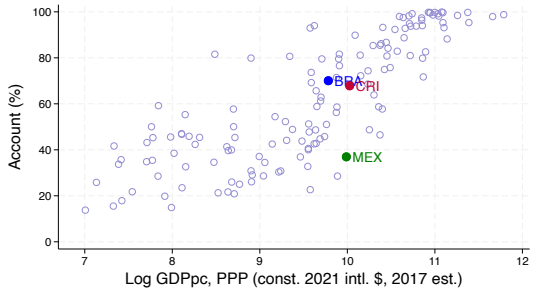
of CoDi and Pix, and during the early stages of Sinpe Móvil. Each panel emphasizes the values corresponding to Brazil, Costa Rica, and Mexico. Panel (a1) shows that about 70% of the adult population in Brazil and Costa Rica owns a bank account at a financial institution. In Mexico, however, less than 40% of adults have a bank account, thereby imposing an upper limit on the share of the population that could adopt CoDi without first overcoming this hurdle.

Panels (a2) and (a3) display credit/debit card ownership and debit card usage, respectively. Although all three countries have comparable GDP per capita, Mexico exhibits markedly lower ownership and usage rates. These panels further show a pronounced income gradient in both card ownership and usage.

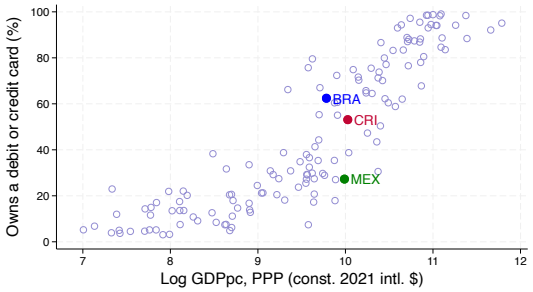
Panel (a4) plots the percentage of the population in each country that has made a digital payment: Brazil and Costa Rica both exceed 40%, whereas Mexico's rate is roughly half that level. In fact, according to Mexico's 2024 National Survey of Financial Inclusion (ENIF), for purchases of 500 pesos or less, 85% of the adult population used cash as their payment method, while for larger amounts this share was 73%.

Figure 1: Financial Inclusion and Technological Barriers Across Countries

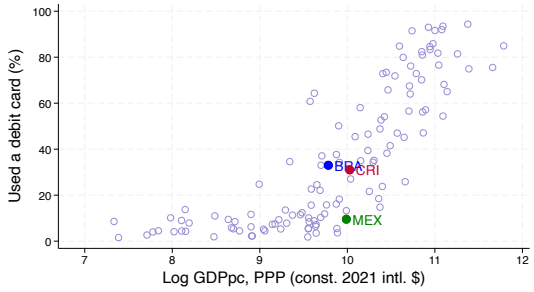
A. Financial Inclusion of End Users



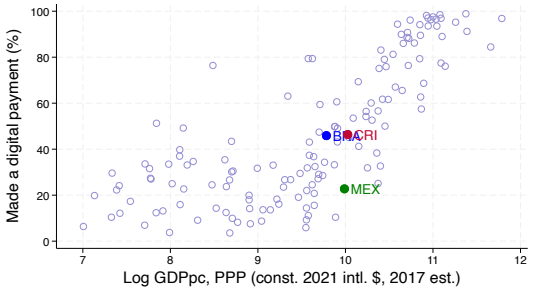
(a1) Owns a bank account (%)



(a2) Owns a credit or debit card (%)

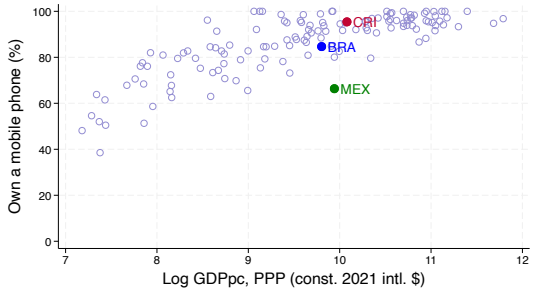


(a3) Has used a debit card (%)

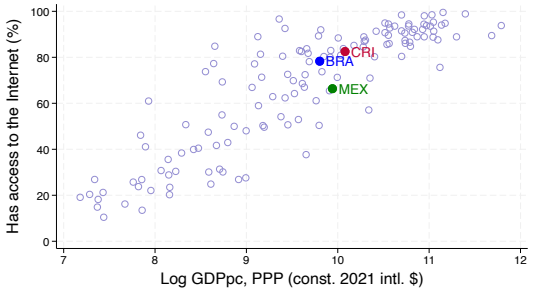


(a4) Has made a digital payment (%)

B. Technological Barriers for End Users



(b1) Owns a mobile phone (%)



(b2) Has access to internet (%)

Notes: The figure shows differences in financial inclusion and technological barriers across countries, highlighting Brazil, Costa Rica, and Mexico in each panel. Panels (a1) and (a2) focus on ownership of a bank account or card, respectively, in percentages. Panels (a3) and (a4) plot the percentage of individuals who have used a debit card or made a digital payment. Panels (b1) and (b2) are related to technology access, focusing on percentages of individuals with mobile phones and internet access. *Source:* World Bank, World Development Indicators and Global Financial Inclusion Database 2017.

4.2 Technological Barriers

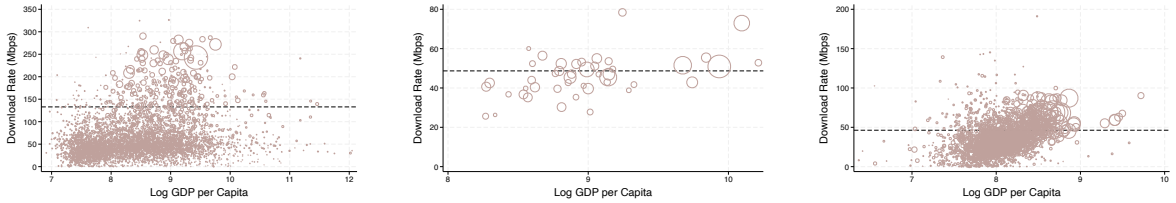
Tech-related entry barriers for end-users vary greatly across countries. A basic requirement to take advantage of these platforms is owning a mobile phone. As shown in Panel (b1) of Figure 1, this is not a given: while nearly 100% of adults in Costa Rica own a mobile phone, the share is over ten percentage points lower in Brazil and below 70% in Mexico.

Sinpe Móvil runs over multiple electronic-banking channels—including SMS, mobile web, and banking apps—so users can send transfers via simple text messages without needing data (Banco Central de Costa Rica, 2024). This is not the case for Pix or CoDi: both require, in addition to a mobile phone, access to the Internet. For CoDi, users must install a CoDi-enabled app on a smartphone and have data or Internet connectivity (Banco de México, 2019). Similarly, Brazil's Pix operates exclusively through Internet-connected channels (Banco Central do Brasil, 2024). Access to the Internet is, again, not a given, representing an additional adoption barrier: as shown in Panel (b2), close to 80% of Brazil's population has Internet connectivity, while in Mexico the rate is about 70%. Furthermore, internet quality is also relevant.

Figure 2 plots average mobile download speeds against municipal GDP per capita for each country, with national averages indicated by horizontal dashed lines. Brazil stands out with mobile download speeds nearly three times higher than those of Costa Rica and Mexico. These differences are especially relevant for the performance of real-time digital payment platforms like Pix and CoDi, where mobile connectivity affects the ease of opening apps, confirming transactions, loading QR codes, and checking balances. While most transactions require minimal bandwidth, faster speeds reduce the likelihood of timeouts and failed payments. Importantly, as we discussed below, mobile speed shapes adoption patterns by income group, as slower networks in poorer areas can reinforce digital exclusion. In Costa Rica, where Sinpe Móvil also

supports SMS-based transfers, mobile speed is less of a limiting factor, and speeds are relatively uniform across municipalities. By contrast, Mexico and Brazil exhibit greater variation in connectivity by local income, with Brazil achieving both higher overall speeds and more pronounced income-related disparities.

Figure 2: Internet Connectivity



(a) Brazil (b) Costa Rica (c) Mexico

Notes: The figures show download speeds in megabits per second for each country across municipalities. The dashed horizontal line in each figure represents the mean download speed, which is equal to 132.9, 48.7, and 46.3 for Brazil, Costa Rica, and Mexico, respectively.

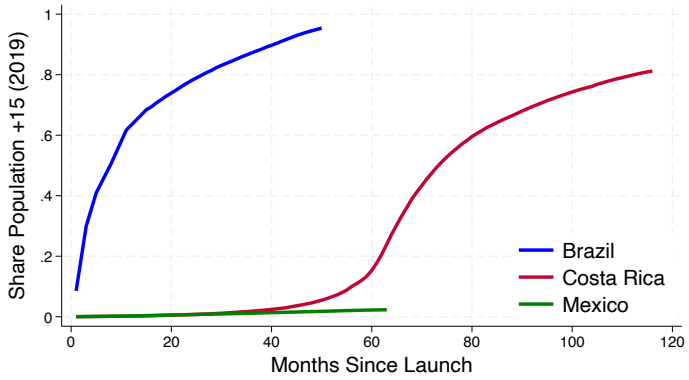
5 Adoption and Its Drivers

5.1 Adoption and Usage

We now compare the speed and rate of adoption of the technologies both across and within countries.

Comparing Adoption Across Countries Across countries and over time, adoption—the classic S-curves—looks sharply different. Figure 3 depicts these curves, defining adoption as participating in a transfer, as opposed to merely downloading an app or subscribing. As shown, adoption in Brazil was relatively fast just after its launch in 2020, reaching 60% within a year, and most recently, take-up has almost reached the entirety of the adult population. Sinpe Móvil's adoption was steady but slower; after its launch in 2015, it took about five years to reach 40% adoption rates in 2020. This

Figure 3: Adoption Dynamics: S-Curves Across Countries



Notes: The figure shows adoption rates over time for Pix (Brazil), Sinpe Móvil (Costa Rica), and CoDi (Mexico). For Brazil, the rate is the stock of individual DICT-registered accounts on the last day of each month (Banco Central do Brasil), divided by the population aged 15 and over in 2019 (World Bank). For Costa Rica, it is the number of users who have made or received at least one payment via Sinpe Móvil, divided by the adult population (Registro Civil de Costa Rica). For Mexico, it is the total number of accounts that have made at least one payment (Sistema de Información Económica, Banco de México), divided by the 2019 population aged 15 and over (World Bank). Data for all countries extends through the end of 2024.

in part is explained by the fact that, according to the 2017 Survey of Payment Methods conducted by the Central Bank of Costa Rica, only about 4% of adults reported knowing about Sinpe Móvil two years after its launch. Since then, growth has continued, reaching a more concave segment of the curve at an 80% adoption rate in 2024. The slowest adoption rate in our sample occurs in Mexico, where CoDi has reached only 2–3 percent of the adult population since its 2019 launch. Although over 18 million accounts have been validated—meaning they are enabled to send payment requests, implying an enrollment rate of roughly 20 percent—only 2.11 million of these accounts have executed at least one payment, and approximately 1.05 million have generated at least one collection request by the end of 2024.[12] This pattern stands

[12]The use of digital payments in Mexico is limited. According to the National Survey of Financial Inclusion, in 2021, only 1.6% (4.4%) of payments of less (more) than 25 dollars were made using electronic transfers or mobile phones, which include bank-based rails (SPEI), CoDi, DiMo, and private wallets (e.g., Mercado Pago, PayPal, BBVA Wallet, Oxxo Pay). These numbers had increased by 2024 but remained low: 2.8% for payments under 25 dollars and 7.6% for payments above 25 dollars.

in stark contrast to the pronounced S-shaped adoption trajectories observed for Pix and Sinpe Móvil, neither of which exhibits such a large gap between enrollment and active usage.

It is worth noting that the COVID-19 pandemic coincided with the ongoing adoption of these platforms. Notably, the pandemic prompted relief payments into bank accounts in Brazil and Costa Rica, directed at households who faced income loss. In Brazil, Auxílio Emergencial was launched in April 2020 and channeled through newly created Caixa Tem digital accounts, which later integrated with Pix upon its introduction in November 2020.[13] The use of Caixa Tem created digital accounts for millions of previously unbanked households, which became fully interoperable once Pix was launched. This coupling of transfers and infrastructure was important in accelerating adoption. In contrast, Costa Rica's temporary monetary transfer, Bono Proteger, was more modest in scale and delivered mainly through existing accounts, without direct ties to Sinpe Móvil and at a time when the app was not widely accepted by merchants (as detailed in Section 5.6).[14] Although Sinpe Móvil adoption rose during the pandemic, this reflected the broader move to digital transactions rather than a direct effect of the subsidies.[15] In Mexico, no comparable relief transfer was linked to CoDi. Overall, while relief programs played a role in driving adoption in Brazil, they did not in Costa Rica or Mexico.

Heterogeneity in Usage Within Countries There are substantial differences in adoption and usage rates across space. We begin by examining how adoption varies

[13] Auxílio Emergencial was one of the largest transfer programs in the world during the pandemic, reaching about one-third of the Brazilian population, with monthly benefits initially set at R$600 (roughly USD 115) (Lara De Arruda et al., 2021).

[14] The emergency transfer ranged between CRC 62,500 and CRC 125,000 (between USD 110 and USD 220), and reached about 14% of the population.

[15] Using administrative data on account ownership in a financial institution and the payments related to Bono Proteger, we estimate that approximately 92% of beneficiaries already had an account before the COVID-19 outbreak.

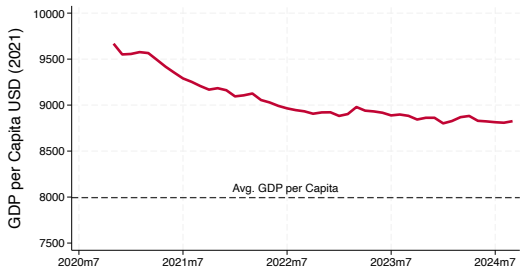
with regional income in Brazil and Costa Rica, where such data are available. Panels (a1) and (a2) of Figure 4 plot the time series of the usage-weighted average GDP per capita across municipalities that have adopted Pix and Sinpe Móvil, respectively. The clear downward slope in both panels shows that the platforms were first taken up in higher-income regions and only gradually reached the poorer areas. In other words, users tend to live in progressively lower-income regions as we move up the S-curve: at launch, the average GDP per capita in adopting municipalities was about 8% higher than it was four years later, in both Brazil and Costa Rica.

Next, panels (b) and (c) illustrate the intensive margin of adoption by showing, at each point in time, the relationship between log payments per capita and municipal GDP per capita. Over time, these curves have become markedly flatter, indicating that usage intensity (measured by transactions per person) has equalized across rich and poor regions. This flattening reinforces the story of regional convergence: although wealthier areas still lead, less-affluent municipalities now use the apps nearly as actively.

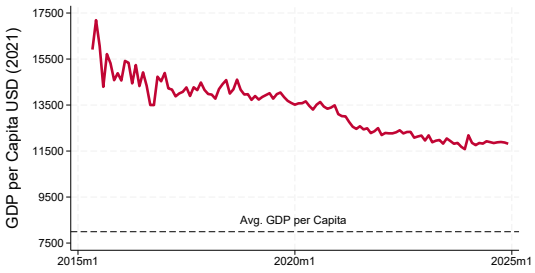
Panels (e) and (f) focus on the extensive margin of adoption, showing the share of adults who sent money via the platforms plotted against municipal GDP. While overall adoption rates rise over time, the slope of these curves remains steep as when the platforms launched, particularly in Brazil, indicating that poorer municipalities continue to lag. Combined with our previous findings, this suggests that although existing users in low-income areas use Pix and Sinpe Móvil as intensively as those in wealthier regions, barriers still prevent a segment of the poorer population from adopting the services in the first place.

Figure 4: Income and Adoption Dynamics

A. Adoption and Regional GDP

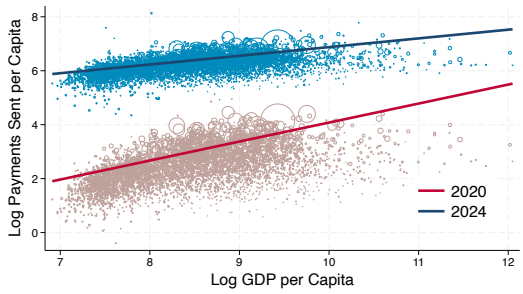


(a1) Pix

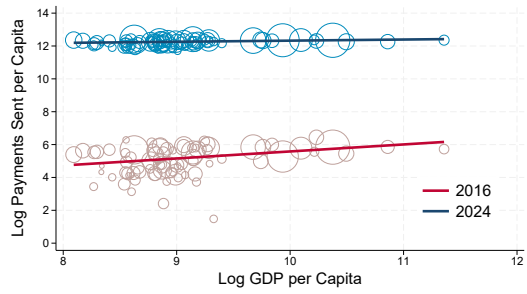


(a2) Sinpe Móvil

B. Payments per Capita and Regional GDP

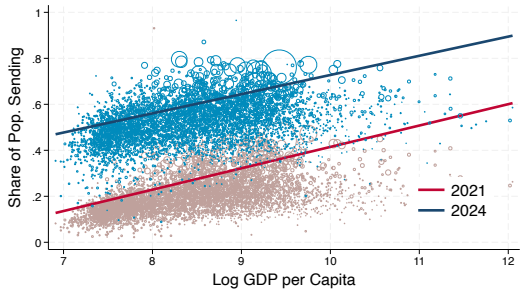


(b1) Pix

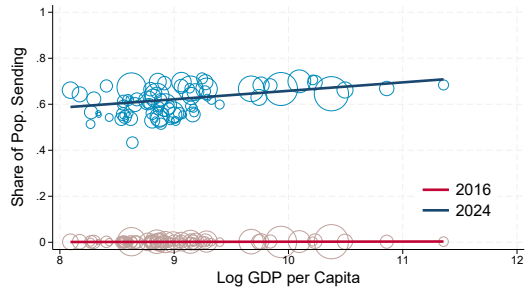


(b2) Sinpe Móvil

C. Share of Adopters and Regional GDP



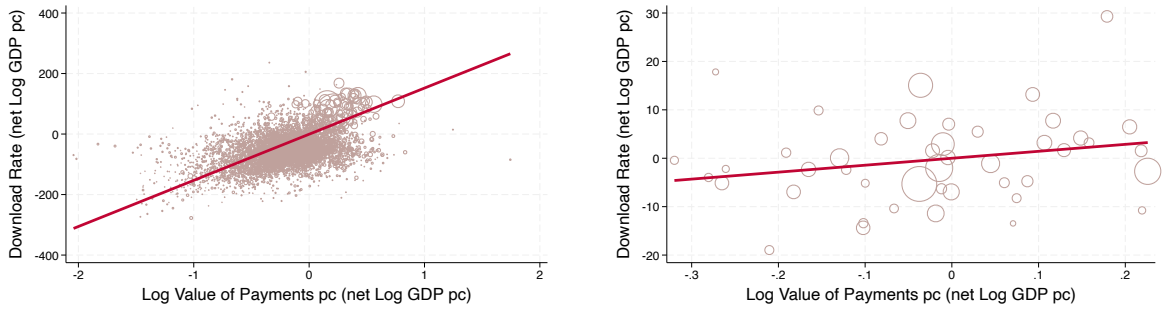
(c1) Pix



(c2) Sinpe Móvil

Notes: Regions correspond with municipalities. GDP per capita per municipality corresponds with year 2021. Panels (a1) and (a2) depict the GDP of the municipalities where someone had adopted, defined as having made at least one transaction, over time. Panels (b1) and (b2) compare payments per capita and regional GDP for the earliest and latest year in which data is available. Panels (c1) and (c2) also make a comparison across years, but for the share of adopters per region against regional GDP.

Figure 5: Usage and Internet Speed



(a) Pix in Brazil

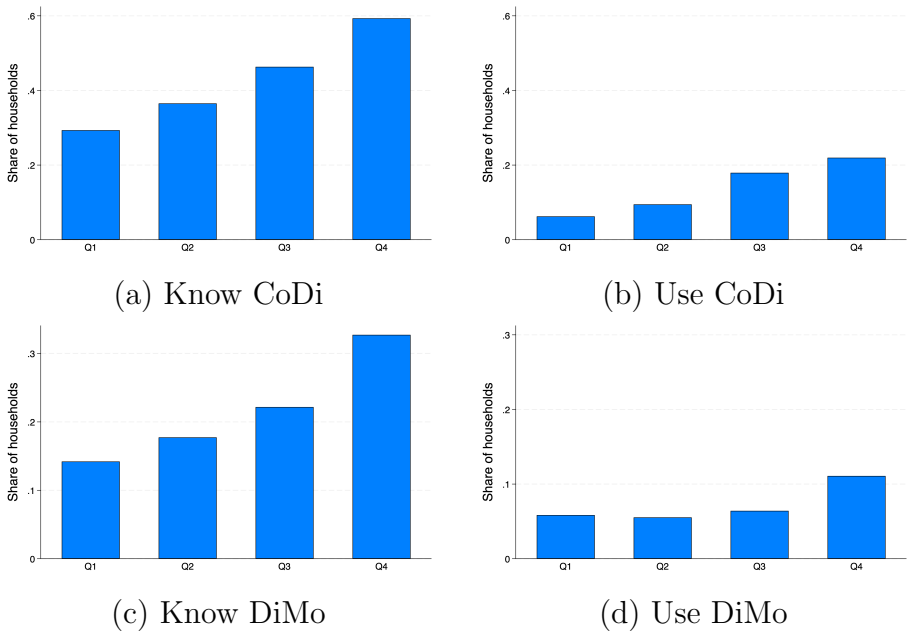
(b) Sinpe Móvil in Costa Rica

Notes: The horizontal axis in each panel is the residual from a regression of the average download speed (Mbps) on log(GDP per capita). The vertical axis is a residual from a regression of log(Payments per capita) on log(GDP per capita).

Finally, we compare adoption across municipalities by internet speed and bank account ownership, conditional on income. To do so, we first regress log payments per capita on log GDP per capita at the municipal level and save the residuals. We then regress average download speed (in Mbps) and bank account ownership (in 2010) on log GDP per capita and save those residuals as well. Plotting the payment residuals against the speed residuals isolates the relationship between adoption intensity and internet performance (Figure 5) or account ownership (Figure A.1). Despite controlling for income, we find these two pre-requisites posed binding adoption barriers.

The relevance of internet speed for app usage intensity in Brazil underscores a critical constraint for Mexico's CoDi, which depends on QR codes and thus on stable connectivity. To address these barriers, Banxico launched Dinero Móvil (DiMo) in March 2023. DiMo enables instant, commission-free transfers using only the recipient's phone number. According to the 2024 National Survey of Financial Inclusion, over 35 percent of adults are aware of CoDi, while 7 percent know about DiMo. Importantly, awareness in the highest income quartile is about twice that in the lowest

Figure 6: Knowledge and Use of CoDi and DiMo by Income Quartile



(a) Know CoDi (b) Use CoDi

(c) Know DiMo (d) Use DiMo

Notes: Panel (a) shows the share of respondents who report having heard of CoDi; Panel (b) those who report having used CoDi to make payments; Panel (c) the share who report having heard of DiMo; and Panel (d) those who report having used DiMo to make payments. All data are drawn from the 2024 National Survey of Financial Inclusion (ENIF).

for both CoDi and DiMo (Panels a and b of Figure 6), indicating comparable information gaps. By contrast, the income-based disparity in actual usage is much larger for CoDi: high-income individuals are 3.5 times more likely to have used CoDi than those in the lowest quartile, whereas the corresponding ratio for DiMo is only 1.9 (Panels c and d), reflecting higher adoption costs for CoDi and suggesting that DiMo may be lowering adoption barriers for low-income individuals.[16]

[16]The share of individuals reporting app usage in the 2024 National Survey of Financial Inclusion exceeds the 2–3 percent active-account estimate from administrative data. This discrepancy likely arises because many accounts are validated but never transacted upon, and survey questions such as "Have you used CoDi to make payments?" may capture test uses or receipt of payment notifications even when no transaction was initiated.

5.2 Adoption Stage and User Characteristics

In this section, we examine how, as these payment technologies progress along their adoption S-curve, the characteristics of the marginal adopter change over time. For instance, if we look at the adoption curves in Figure 3, those who adopted when a technology was just launched might differ significantly from those who adopted once it was more mature.

This exploration is data-demanding, as it requires microdata on the characteristics of the *individuals* who are adopting these technologies. For the case of Sinpe Móvil, this data is available, so that we can precisely identify adopters' observables over time. For the case of Pix, however, data is collapsed at the municipality level, which poses some limitations. For the case of CoDi, data is also aggregated, and overall take-up is relatively low. For these reasons, we will mainly focus on lessons from Sinpe Móvil in this section.

Figure 7 summarizes characteristics of the marginal adopters over time. First, Panel (a) illustrates how the average age of the marginal adopter has increased over time. For instance, early adopters were about 35 years old in 2015, on average, while the corresponding number was over 40 years old by 2024. In other words, younger adults tend to adopt first.

Second, as shown in Panel (b), the share of adopters who were women was below 40% when Sinpe Móvil first launched in 2015—men were initially adopting the app more than women. The share of women who had adopted then continuously increased until 2021, even surpassing 50% during the COVID-19 pandemic, and finally stabilized at 50% towards the end of the sample period. Thus, while women were not early adopters, the gender gap in adoption eventually closed, even though it took about seven years for the convergence to occur. Third, Panel (c) shows that, consistent with Figure 4, early adopters mostly resided in urban (high-GDP) regions.

Figure 7: Characteristics of the Marginal Adopters: Sinpe Móvil

(a) Age

(b) Share of Women

(c) Share of Urban

(d) Share of Low Skill

Notes: The figure summarizes how the characteristics of the marginal adopters have changed over time. Panel (a) focuses on the mean age of the marginal adopter of Sinpe Móvil. Panels (b), (c), and (d) instead show the dynamics of the share of adopters of Sinpe Móvil who are women, urban residents, and low-skilled workers, respectively.

Finally, we study how the likelihood of adopting varies depending on whether the person is a low- or high-skilled worker. A worker is classified as "low-skilled" if her occupation requires *at most* a high-school diploma. Instead, if a worker's occupation requires education or training beyond high school, it is labeled as "high-skilled." Details on each occupation's educational requirements are obtained from Costa Rica's Social Security Administration.[17] Leveraging this classification, Panel (d) shows how

[17]The Social Security Administration has a manual describing the educational attainment that a worker must have to belong to an occupational category. More details on this

the share of adopters of Sinpe Móvil classified as low-skilled has dramatically increased over time. Less than 30% of early adopters were classified as low-skilled, while towards the end of the period a majority of adopters—about 60%—are low-skilled workers. These findings are echoed by Table 2, which summarizes the average characteristics of adopters vs. non-adopters as of December 2024.

Table 2: Sinpe Móvil: Average Characteristics of Adopters and Non-Adopters

	Age	Female	Low-skilled	Wage	Bank Account
	(1)	(2)	(3)	(4)	(5)
Adopters	41.2	51.4%	62.4%	1,575	100%
Non-Adopters	57.5	47.5%	87.1%	965	82.9%

Notes: The table shows the average characteristics of Sinpe Móvil adopters and non-adopters as of December 2024. Age is reported in years in column (1), and wage is reported in USD in column (4). Columns (2), (3), and (5) show the percentage of adopters and non-adopters who are classified as female, low-skilled workers, and bank account owners, respectively.

5.3 Network Analysis and Network Effects

It is natural to think that the process of diffusion of payment technologies that we have studied so far is, at least partially, shaped by network effects or strategic complementarities (Alvarez et al., 2023a). Strategic complementarities emerge when an agent's benefit from adopting a technology increases with the number of adopters. In the case of payment technologies like Pix, Sinpe Móvil, and CoDi, this would imply that the wider the user base, the higher the potential from becoming a user.

Figure 3 showed the overall user base per country has increased over time. In fact, not only the number of adopters has gone up, but alongside with this increase, the network structure has changed and become tighter. Figure 8, which results from an individual-level analysis of yearly transactions across users, shows the network

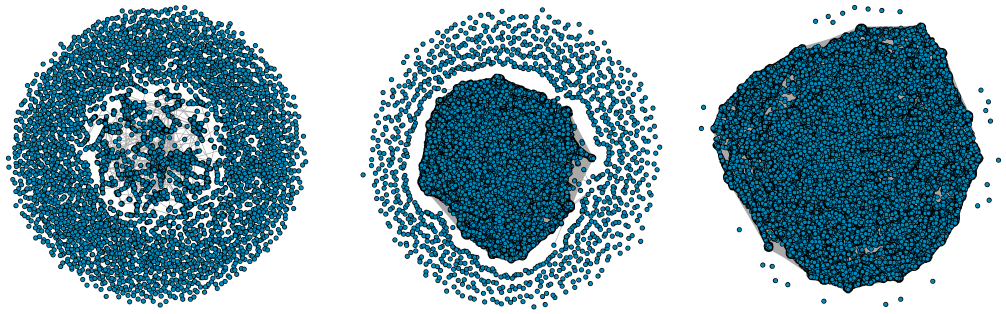
classification are available in Méndez and Van Patten (2025).

structure dynamics for the case of Sinpe Móvil.

Panel (a) depicts the network in 2016, when just 0.6% of adults had adopted Sinpe Móvil. The figure shows a tight core of highly connected users surrounded by a cloud of isolated nodes. Those peripheral points represent one-off or very infrequent transactions—most users at this early stage had not joined the main network, so they remain disconnected. Strategic complementarities were low, especially for users in this periphery.

Panel (b) shows how the network looked in 2020, after adoption climbed to 38%. The core expanded into a dense and large component, that now includes most active users. Around the edges, small satellite clusters are still present—groups who began transacting among themselves before integrating into the broader network—but the majority of formerly isolated nodes are now part of the main cluster, thereby benefiting more from strategic complementarities.

Figure 8: Network Structure Dynamics of Sinpe Móvil



(a) 2016 (0.6% adoption) (b) 2020 (38% adoption) (c) 2024 (77% adoption)

Notes: The figures show the network structure of Sinpe Móvil for peer-to-peer payments by year. Figures result from an individual-level analysis of yearly transactions across users. Panel (a) pertains to 2016, one year after the platform's launch, while Panels (b) and (c) correspond with the years 2020 and 2024. In parentheses, we show the percentage of adults who have adopted Sinpe Móvil at the end of each year.

By 2024, with adoption at 77%, Panel (c) reveals an almost completely unified network: nearly every user sits inside one large, interlinked component. This near-

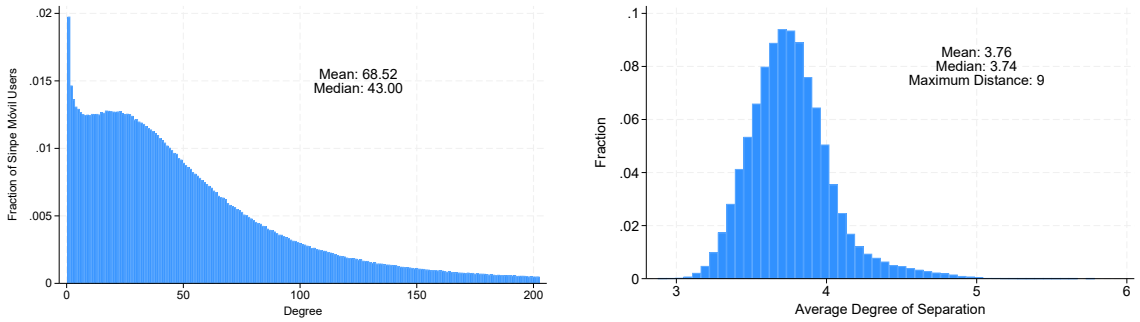
complete large component aligns with Sinpe Móvil achieving deep penetration and strategic complementarities gaining traction, with most users now transacting with each other in a richly interconnected system. To formalize this notion, a typical measure in network analysis is the number of connections a unit i has within the network, called *degree*. We compute the degree distribution of Sinpe Móvil users for 2024. As shown in panel (a) of Figure 9, the median connections per user is 43 (mean 69). This median was 1 in 2016, and 10 in 2020, indicating an increase in the interactions via Sinpe Móvil. Table A.2 shows that females, young people, low-income people, who live in urban areas tend to have more connections on Sinpe Móvil.

We also compute a related measure: the degrees of separation, which is the minimum number of links that separate two random people in the network. For 2024, the average person in Sinpe Móvil is connected to every other user by an average of 3.8 steps (median: 3.7). Panel (b) of Figure 9 shows the corresponding distribution.[18] For comparison, Facebook had an average degree of separation of 3.6 in 2016 (Edunov et al., 2016). The maximum number of links to reach any person in Sinpe Móvil has also decreased from 32 in 2016 to 9 in 2024.

Relation to Characteristics of Marginal Adopters Strategic complementarities would imply that there is selection in who adopts the technology first—early adopters must value the technology enough to adopt, despite the initial user base being relatively small. Through the lens of the theoretical model developed by Alvarez et al. (2023a), the latter would rationalize the dynamics observed in Figure 7 in our previous section, where the characteristics of the marginal adopters were changing over time as one climbed the S-curve of adoption. More precisely, it would

[18]To estimate the degrees of separation, we take a 5 percent random sample of Sinpe Móvil users and estimate, for each person, the minimum distance with respect to all other users on the platform using Dijkstra's algorithm. For 2024, there is an (undirected) path starting with person i and ending with person j in 99.998% of cases.

Figure 9: Average Degree and Degrees of Separation Between Users of Sinpe Móvil, 2024



(a) Degree Distribution

(b) Degrees of Separation

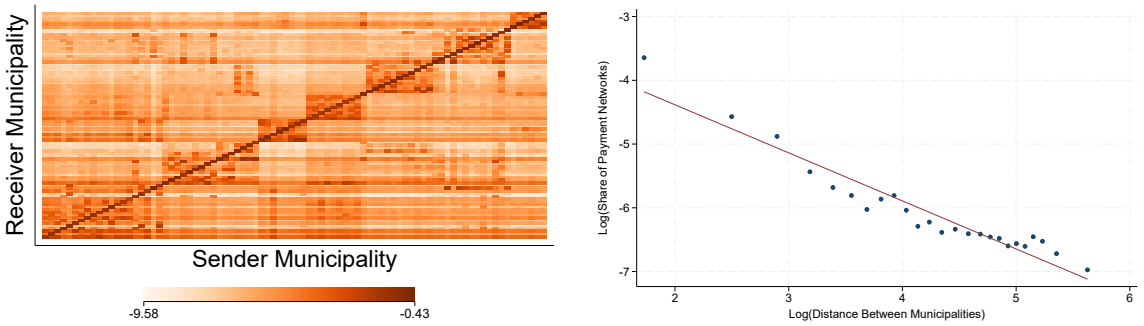
Notes: Panel (a) shows the distribution of degrees; the number of connections a unit i has within the network. Panel (B) shows the distribution of the average degree of separation—the minimum number of links that separate two random people—for a random sample of Sinpe Móvil users.

imply that older individuals, women, and low-skilled workers valued the technology relatively less than younger, high-skilled men, and therefore waited until the benefits of the technology—emerging from strategic complementarities—were greater before adopting.

Homophily in Network Formation Network evidence suggests homophily—the tendency to match with people of similar characteristics—is relevant for network formation. First, we find that most transactions occur between people within close geographic proximity. Panel (a) of Figure 10 shows a heat map of the number of sender-receiver links between municipalities.[19] The darker diagonals indicate that most payment connections occur between people living in the same municipality. There are also notorious square-like patterns that correspond to close-by municipalities. Indeed, panel (b) shows that the share of connections between municipality i and j is a decreasing function of their distance.

[19]The number of links is normalized by the total number of sending connections in each municipality.

Figure 10: Payment Connections and Spatial Distance in Sinpe Móvil, 2024



(a) Municipality Adjacency Matrix (b) Share of Connections and Distance

Notes: Panel (a) shows the normalized municipality adjacent matrix shown on a log scale for Sinpe Móvil in 2024. Panel (b) shows the relationship between the (log) distance between municipalities and their (log) share of payment connections.

In line with Figure 10, Table A.1 shows that those living in the same municipality are more likely to interact via Sinpe Móvil.[20] Working for the same firm has a comparable effect, while being members of the same family has the largest coefficient predicting ties. The fourth most relevant variable is similarity in age. Meanwhile, having the same sex, being in the same wage quintile, or living also in an urban/rural area are less prominent, albeit significant, and their impact is statistically equal in explaining network formation by 2024.

5.4 Awareness and Trust

A pre-requisite for users to adopt the technology is for them to be aware of it. Given awareness, individuals must trust a payment technology in order to use it. For instance, in the case of El Salvador's Chivo Wallet and bitcoin, Alvarez et al. (2023b) found that only 68% of potential users knew about the app's existence, and out of those who knew about the app, one of the most cited barriers to adopting was

[20]This aligns with previous work showing that even for technologies enabling social interaction, physical space still plays a central role in the formation of social ties (Small and Adler, 2019).

distrust—60% of survey respondents reported they did not trust the system or bitcoin itself. Such concerns about privacy, data security, and transaction integrity are central to debates around CBDCs and private digital currencies, and help explain why even technically sound platforms can struggle without strong confidence from end users.[21]

Mexico's experience with CoDi similarly suffered from persistently low awareness. The primary challenge has been that many people simply do not know about the platform. According to the 2021 National Survey of Financial Inclusion (ENIF), conducted two years after CoDi's launch, only 34% of adults reported being aware of it. Strikingly, this figure had barely increased three years later: the 2024 ENIF finds that just 38% of adults nationwide know of CoDi, nearly five years after its introduction. This stagnation highlights a major informational barrier to adoption. Additional constraints stemmed from early limitations in the platform's network. In 2018, Mexico's SPEI system experienced a major cyber-attack that diverted several hundred million pesos before Banxico implemented tighter security protocols later that year (Banco de México, 2018; Forbes México, 2024). While these reforms greatly strengthened SPEI's fraud controls, they also delayed smaller banks and fintechs from participating in the initial CoDi rollout, limiting the system's early reach and slowing its expansion (Banco de México, 2019).[22] Moreover, supply-side adoption

[21]Trust plays a central role in the adoption of digital financial services, especially among low-income users. In Mexico's Oportunidades program, recipients often used debit cards to repeatedly check account balances in order to monitor that funds were not being reduced unexpectedly. Over time, as trust in the system increased, balance checks declined and account savings rose (Bachas et al., 2021). Similarly, in the context of mobile money, Breza et al. (2020) show that inexperienced users often begin with small, low-risk transactions to "test the waters" before scaling up use.

[22]Important players in Mexico's fintech ecosystem, such as Mercado Pago, have played a limited role in P2P payments. At the infrastructure level, SPEI remains dominant, with CoDi and DiMo serving as government-backed P2P innovations. Initially, Mercado Pago attempted to integrate CoDi as a digital payment solution, but because it operates outside the traditional banking system and CoDi's QR codes lacked interoperability, implementation proved unsuccessful. Instead, it enrolled businesses in its own QR system, which it phased

costs remain significant: to add CoDi capabilities, each software vendor must register with the Bank of Mexico, run their code in a sandbox testing environment, pass formal security audits, and sign confidentiality agreements before being allowed to connect. This added friction may have further constrained CoDi's growth; while it enhanced security and oversight, it also introduced delays that limited participation.

The case of Sinpe Móvil exemplifies the relevance of awareness. It was launched in 2015, and it was adopted only slowly at first, but according to the 2017 Survey of Payment Methods conducted by the Central Bank of Costa Rica, only about 4% of adults reported knowing about Sinpe Móvil almost three years after its launch. Adoption rates reached 40% adoption rate in 2020, when the platform became more popular, and continued increasing at a high pace afterward. By contrast, Pix in Brazil benefited from public-sector marketing, with a large share of the population becoming aware of it within a month.

In terms of trust, Pix and Sinpe Móvil were both launched under the backing of their central banks and without any major security incidents. This combination of institutional endorsement and a clean security record helped foster user trust.

5.5 Supply-Side Value Proposition

A technology offering enough value to financial institutions and other settlement participants so that they choose to integrate their own systems into the network is more likely to succeed. Without strong supply-side buy-in, end-user adoption might stall. Thus, coordination and interoperability features can be key.

In Brazil, the Central Bank mandated universal participation in STR for Pix, effectively removing coordination hurdles from financial participants. All banks and licensed payment service providers had to connect early on, creating an interoperable

out for in-store payments by July 2023. Today, Mercado Pago offers P2P transfers only when both users have the app installed or through DiMo.

network. In terms of fees, while Pix is free for individual users, the Central Bank allows financial institutions to charge merchants a small transaction cost of around 0.22%, which creates a revenue line on instant payments. Moreover, the Central Bank's open Pix API lowered technical barriers and allowed fintechs to plug in rapidly, further reinforcing the value proposition. As a result, participants can build new merchant portals, enterprise-resource-planning integrations, or mobile wallet features fast, sparking a wave of innovation and rapid uptake.

Costa Rica took a more voluntary approach: Sinpe participation was not compulsory, yet large public financial entities which served most of the market helped coordinate early integration. The interoperable design among entities meant that once the largest players were on board, the network effect kicked in, and smaller participants followed suit. By 2024, the number of financial entities that provided Sinpe Móvil reached 38, outgrowing the 11 who provided the service in 2015. High bank participation reinforced the platform's utility, even if fintech entry remained limited.

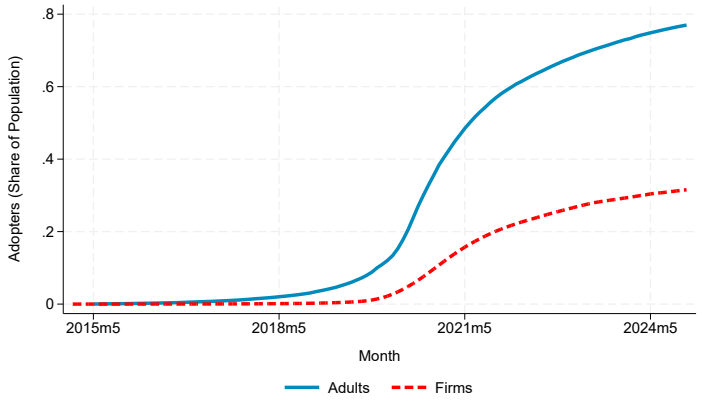
In Mexico, participation was voluntary and largely confined to incumbent banks; fintechs and non-bank PSPs faced higher technical and regulatory hurdles to join. Without a mandate or large players opting-in early on, commercial banks saw little incremental revenue and potential costs from everyday CoDi transactions and accordingly invested only slowly in integration. In fact, Mexican banks derive roughly 30% of their operating revenues from fee income. Because CoDi transactions carry no interchange or service charges, they generate no new fee revenue, forcing banks to forgo earnings. Although CoDi can lower cash-handling costs and strengthen customer engagement, it had a weak short-term value proposition from a pure-revenue standpoint (Comisión Nacional para la Protección y Defensa de los Usuarios de Servicios Financieros (CONDUSEF), 2018, 2025).

Without a mandate or the initial participation of large players, the value proposition must be attractive enough to engage commercial banks and fintechs. Otherwise,

the success of the technology is compromised by fragmentation and delayed network effects: each institution faces high integration costs relative to uncertain usage benefits, resulting in a patchwork network with limited reach and sluggish adoption.

5.6 Adoption by Businesses

Figure 11: Sinpe Móvil Adoption Dynamics: Individuals versus Firms



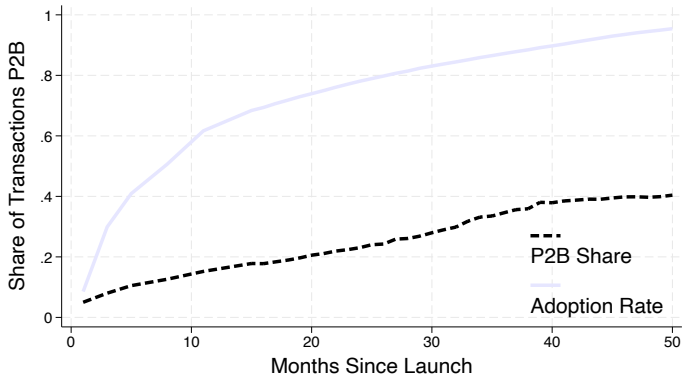
Notes: The figure shows adoption rates over time for Sinpe Móvil for individuals and firms. For individuals, it corresponds with the share of the adult population who have made or received at least one payment via Sinpe Móvil. For firms, it is the share of firm tax IDs that have accepted a payment via Sinpe Móvil.

The drivers of person-to-business (P2B) adoption are beyond the scope of this paper, and have been studied in other contexts (Alfaro-Serrano et al., 2021; Comin et al., 2025; Gertler et al., 2022). However, this section aims to describe the state of firm adoption in Costa Rica and Brazil to draw lessons about how it relates to– and differs from—P2P adoption. Sinpe Móvil and Pix were conceived as a real-time payment method for low-value P2P payments, and their adoption by firms has been relatively slow; as shown in Figures 11 and 12. Figure 13 decomposes the number and value of Sinpe Móvil transactions by sender-receiver type, showing the relevance of P2P transactions.[23] The same pattern holds in Pix, as decomposed by Duarte et al.

[23]By December 2024, the median share of payments received through Sinpe Móvil for the adopters' firms is 3%.

(2022).

Figure 12: Person-to-Business Share of Total Pix Transactions



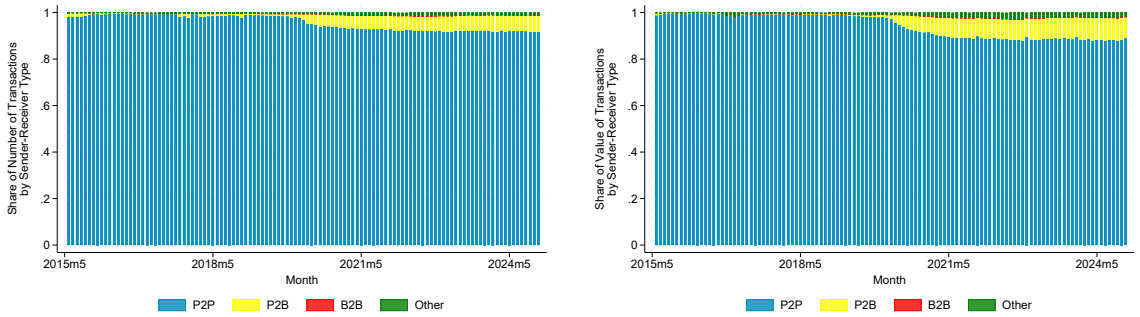
Notes: The figure shows the share of all transactions that are person-to-business over time for Pix. For reference, the figure also shows the adoption rates over time for Pix: the rate is the stock of individual DICT-registered accounts on the last day of each month (Banco Central do Brasil), divided by the population aged 15 and over in 2019 (World Bank).

Firms that adopted Sinpe Móvil were initially small, in terms of sales and number of workers, while larger firms started adopting only recently (see Figure A.2). According to the results of a survey on payment methods carried out by the Central Bank of Costa Rica during the first half of 2025 to a nationally representative sample of retailers, among the main reasons that prevent a higher rate of adoption of Sinpe Móvil by firms are the difficulty of recording the payments and registering them into their accounting systems, and that there is a maximum limit to the monthly amount the firm can receive through this payment method.[24] Also, accepting a payment through Sinpe Móvil for a large firm might be difficult because the transfer notification happens through a text message or an email.[25]

[24]The financial institutions should guarantee a minimum commission-free *monthly* limit for receiving funds through Sinpe Móvil of about USD 4.000. See Bigio et al. (2025) for details on B2B transactions.

[25]Moreover, in Costa Rica, estimates suggest no displacement of card payments by Sinpe Móvil; Table A.3 shows a positive elasticity of substitution between Sinpe Móvil and card payments at the firm level.

Figure 13: Sinpe Móvil: Share of Transactions by Sender-Receiver Type



(a) Number of Transactions

(b) Value of Transactions

Notes: The figures show the share of the number and value of transactions by sender-receiver type in Sinpe Móvil. P2P stands for person-to-person, P2B for person-to-business, and B2B for business-to-business. The category others include person-to-goverment (P2G), firm-to-person (F2P), firm-to-goverment (F2G), goverment-to-business (G2P), goverment-to-firm (G2F) and goverment-to-goverment (G2G).

While the documented lack of firm adoption could, in principle, reflect adoption by informal firms (or small firms relying on personal accounts), we find no evidence consistent with this interpretation. First, informal workers in Costa Rica represent a relatively small share of the labor force (27.4%), well below the Latin American average of 53% (Méndez and Van Patten, 2025). Second, to further explore this possibility, we use the degree measure in Sinpe Móvil developed in Section 5.3 and used in Table A.2, which describes the number of connections an individual has within the network. Namely, we define users above the 99th percentile of the degree distribution as merchants under a personal account—the 99th percentile corresponds with people who transact with 1.1 new individuals per day. We then re-classify the transactions received by these "potential merchants" from P2P to P2B transactions and re-do the breakdown that was presented in Figure 13 in Figure A.3. As shown, P2B transactions remain low throughout the sample period.

Finally, indirect externalities have been shown to encourage firm adoption of alternative payment methods such as cards (Higgins, 2024). We find little evidence of

similar dynamics so far for digital payment platforms like Sinpe Móvil and Pix. Cards were designed as merchant-facing instruments, supported by POS infrastructure and integration with accounting systems, which eased their incorporation into daily operations. By contrast, survey evidence shows that real-time payment systems began as low-cost P2P tools with limited integration into firms' operations, difficulties in recording payments, caps on monthly commission-free receipts, and reliance on text or email notifications to confirm transactions. These differences may help explain why P2B adoption of Sinpe Móvil and Pix has lagged behind their rapid diffusion in P2P use.

6 Cross-Adoption of Payment Instruments

Adopting instant payment systems might incentivize users to adopt other banking services. Figure 14 suggests this might be the case of deposits at commercial banks, both for Brazil and Costa Rica, with an acceleration in the share of adults making deposits after each platform was launched.[26] Indeed, Sampaio and Ornelas (2024) finds evidence that Pix contributed to an increase in the number of bank accounts, their use, and access to credit.

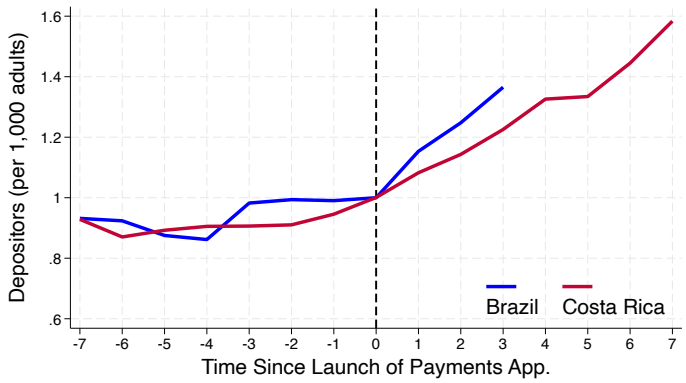
These platforms might also engage users with other, potentially more sophisticated, financial services. In Pix, for instance, existing features available to users include recurring payments, digital wallets, and collecting payments using QR codes.[27]

For the case of Sinpe Móvil, we observe a correlation between its adoption and the usage of other digital payments designed for larger value payments. We focus on

[26]For Mexico, the data is not available from this source.

[27]Several advanced tools are also forthcoming: Pix Parcelado, set to launch in September 2025, will allow users to split payments into credit-based installments; the Special Return Mechanism (MED), arriving in October 2025, will let users contest transactions directly through their banking app; and Pix em Garantia, expected in 2026, will enable companies to use future Pix receivables as loan collateral.

Figure 14: Depositors with Commercial Banks



Notes: The figure plots the number of depositors with commercial banks (per 1,000 adults) in Brazil and Costa Rica, using data from the WDI database. The x-axis represents time since the launch of each country's real-time payment system: year 0 corresponds to the introduction of Pix in Brazil (2020) and Sinpe Móvil in Costa Rica (2015).

two services: Direct Credit Compensation (CCD) and Immediate Payments (PIN).[28] We consider first-time Sinpe Móvil users and then estimate the probability of these people adopting CCD or PIN for the first time within the next three months. Table A.4 shows that new Sinpe Móvil users are about 4 percentage points more likely to also start using other types of digital payments.

6.1 Digital Payments as Substitutes for Cash

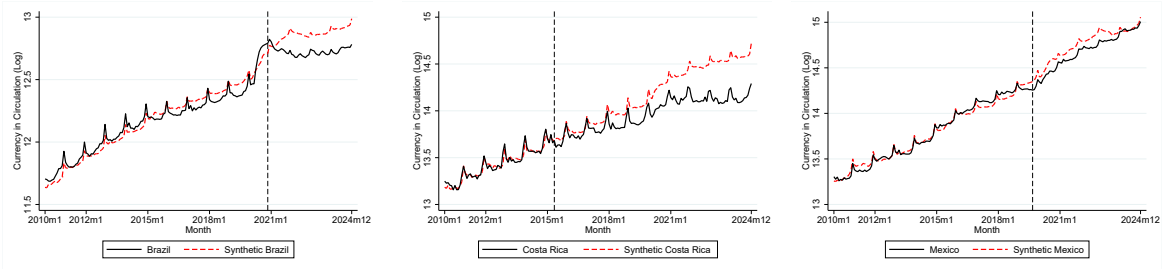
While digital payment technologies might lead to cross-adoption spillovers, they could also substitute for existing payments. In particular, Pix, Sinpe Móvil, and CoDi aim to offer efficient alternatives to cash. Figure 15 presents the log of currency in circulation in Brazil, Costa Rica, and Mexico around the time of each platform's introduction. In both Brazil and Costa Rica, the introduction of Pix and Sinpe Móvil coincides with a clear flattening in the trend of cash in circulation, a pattern that is

[28]CCD transfers are credited by 10:00 PM on the business day they are sent, with an average fee of 1 USD. In contrast, PIN is a real-time transfer service with an average fee of 3 USD.

not observed in Mexico following the launch of CoDi.[29]

To further investigate the relationship between digital payments and cash usage, we apply the synthetic control method developed by Abadie and Gardeazabal (2003). For each country, we construct a synthetic counterfactual using a weighted average of 13 Latin American and Caribbean countries that did not experience a comparable surge in low-value digital payment platforms over the same period.[30] The outcome variable is currency in circulation, and the comparison countries are matched on macroeconomic indicators relevant to cash usage, such as annual inflation and GDP per capita in PPP.[31]

Figure 15: Synthetic Control: Currency in Circulation



(a) Brazil (b) Costa Rica (c) Mexico

Notes: The figure shows the evolution of cash in circulation (in logs) for Brazil, Costa Rica, and Mexico. The red dashed line represents the evolution of cash in circulation for the synthetic country constructed using the synthetic control method. The black dashed vertical line marks the launch date of Pix, Sinpe Móvil, or CoDi.

Figure 15 plots the evolution of actual versus synthetic currency in circulation before and after the introduction of Pix, Sinpe Móvil, and CoDi. In all three cases, the synthetic control closely tracks the pre-intervention trends and seasonal fluctuations.

[29] According to estimates made by the Central Bank of Costa Rica, the cost of cash transactions was equivalent to 0.55% of GDP (Cerdas Jaubert and Rodríguez Solís, 2018). This includes costs such as transportation, safety, replacement of unfit currency, fraud, and time devoted to managing and obtaining cash.

[30] The countries are Bolivia, Chile, Colombia, Dominican Republic, Guatemala, Guyana, Haiti, Honduras, Jamaica, Paraguay, Peru, Trinidad and Tobago, and Uruguay.

[31] Appendix A.3 provides further details on the implementation of the synthetic control method.

However, following the rollout of Pix and Sinpe Móvil, actual cash in circulation diverges downward from the synthetic control, indicating a significant reduction. No such divergence is observed for CoDi. While we cannot attribute the entire change to digital payments—for instance, card usage has also expanded in Costa Rica in recent years—the timing and magnitude of the shift are consistent with a substitution away from cash facilitated by these mobile payment platforms.

Additional evidence from Costa Rica further supports this hypothesis. We use regional data on cash inventories collected through the Auxiliary Cash Custody system (CAN), a decentralized cash management network operated by the Central Bank of Costa Rica. CAN allows commercial banks to store cash locally, and fluctuations in these inventories provide a geographically detailed picture of cash demand. We match municipalities to CAN zones and examine the correlation between Sinpe Móvil adoption and cash withdrawals. As shown in Figure A.4, municipalities with higher Sinpe Móvil adoption systematically exhibit lower cash demand, as approximated by reduced withdrawals from local CAN vaults.

Survey data from the Central Bank of Costa Rica offers further support. A nationally representative survey conducted in late 2024 and early 2025 asked respondents: "How many days could you make payments without using cash?" Sinpe Móvil adopters reported an average of 15.59 days, compared to just 6.44 days for non-adopters, a difference that is statistically significant at the 1% level.[32] Taken together, this evidence suggests that mobile payment platforms are effective substitutes for cash. They not only reduce currency in circulation at the national level, but also correlate with lower local cash withdrawals and greater individual capacity to

[32]Median responses were 10 days for adopters and 1 day for non-adopters. As shown in Table A.9, this gap remains robust after controlling for respondent characteristics such as sex, income, age, education, card ownership, and municipality fixed effects. Across specifications using Poisson Pseudo Maximum Likelihood, Negative Binomial Regression, and Ordinary Least Squares, Sinpe Móvil adopters appear able to go roughly five more days without using cash than non-adopters.

transact without physical money.

7 Concluding Remarks

Our comparative analysis of Pix, Sinpe Móvil, and CoDi shows that technology alone does not guarantee inclusive, rapid diffusion of digital payments. Success hinges on a *rapid low income-gradient*, whereby platforms overcome initial elite-bias to recruit middle- and lower-income users within a few years. Strong strategic complementarities and supply-side coordination via open or mandated connectivity further reinforce take-up. Finally, high levels of trust, enhanced by central-bank endorsement and robust security protocols, ensure that once awareness barriers are cleared, end users feel confident transacting on the platform.

These lessons carry direct implications for the design of central bank digital currencies (CBDCs) and next-generation payment systems. First, policymakers should prioritize interoperability from day one, whether through mandatory participation rules or open API frameworks, to avoid fragmented networks that fail to deliver sufficient benefits. Second, platforms must minimize upfront costs and complexity to maintain a flat adoption gradient across income levels. Third, robust security and fraud-resilience measures should be visible and credible before launch, helping to build trust early and prevent high-profile breaches from undermining confidence. By embedding these design principles, future CBDCs and digital-payment initiatives may achieve the breadth of adoption necessary to transform how societies transact.

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Online Appendix for

Drivers of Digital Payment Adoption: Lessons from Brazil, Costa Rica, and Mexico

September 15th, 2025

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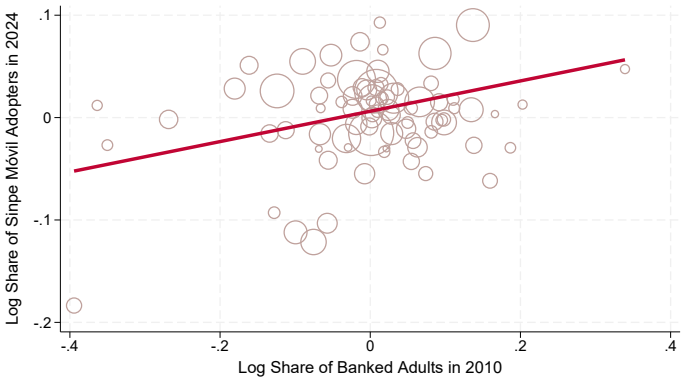
A Additional Figures and Tables

A.1 P2P Adoption Dynamics

Figure A.1: Adoption of Sinpe Móvil in 2024 and Banked Population in 2010 (by Municipality, Controlling for 2010 Income)



Notes: The figure shows the share of banked adults as of December 2010 (roughly five years before Sinpe Móvil was launched) against the share of Sinpe Móvil adoption as of December 2024, both statistics at the municipal level and controlling for 2010 wage income.

Table A.1: Homophily in Sinpe Móvil (2024)

Dependent variable: Individual i and Individual j have a direct link in Sinpe Móvil

Same Sex	0.058***	(0.007)
Same Age	0.082***	(0.008)
Same Civil Status	-0.002	(0.008)
Both Urban/Rural	0.046***	(0.011)
Same Municipality	4.914***	(0.360)
Same Wage Quintile	0.058***	(0.008)
Same Firm	5.378***	(0.222)
Same Family	1822.936***	(79.488)
Adjusted R^2	0.007	
Observations	397,352,145	
Clusters	1,718	

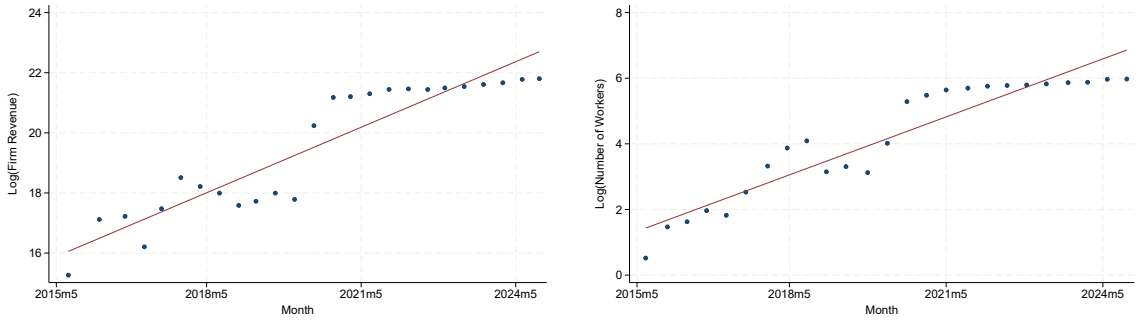
Notes: The unit of observation is the direct link between person i and person j. The dependent variable is a dummy variable equal to one if a direct link between person i and person j exists in Sinpe Móvil during 2024, and zero otherwise. To estimate homophily, we took a random sample of 2% of Sinpe Móvil users as of December 2024 who work in the formal sector; 28,191 persons. Then we estimate a regression explaining the presence of a direct link through the similarity between the individuals. To measure similarity, we include dummies for whether the two persons have the same sex, have an age gap at most of 10 years (in absolute value), have the same civil status, both live in an urban/rural area, live in the same municipality, belong to the same wage quintile, work for the same firm, or belong to the same family (i.e., the individuals are first-degree, second-degree, or third-degree relatives). We multiply the coefficients by 10,000. Standard errors (clustered by sender and receiver neighborhood) are in parentheses. We denote: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.2: Degree of Sinpe Móvil Users and Observable Characteristics in 2024

Dependent variable: Degree of individual i	
Age	-0.156***
	(0.014)
Female (=1)	5.958***
	(0.352)
(Log) Wage	-4.675***
	(0.364)
Married (=1)	10.511***
	(0.323)
Divorced (=1)	14.484***
	(0.475)
Widower (=1)	5.955***
	(1.538)
Urban Area (=1)	7.446***
	(0.884)
Share Adopters in Municipality	108.109***
	(7.398)
Adjusted R^2	0.010
Observations	1,409,541
Clusters	1,981

Notes: The unit of observation is the individual. The dependent variable is the degree centrality of individual i: the number of connections she has. All regressions control for municipality fixed effects. To estimate the degree centrality we consider all connections during 2024, and the observable characteristics are as of December 2024. Standard errors (clustered by neighborhood) are in parentheses. We denote: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure A.2: Characteristics of Firms that Adopted Sinpe Móvil Over Time



(a) Firm Revenue (b) Number of Workers

Notes: The figure summarizes how the characteristics of the marginal firms that adopted Sinpe Móvil have changed over time. Panel (a) focuses on the mean firm revenue in real amounts. Panel (b) displays the dynamics of the number of workers.

A.2 Firm Adoption Dynamics

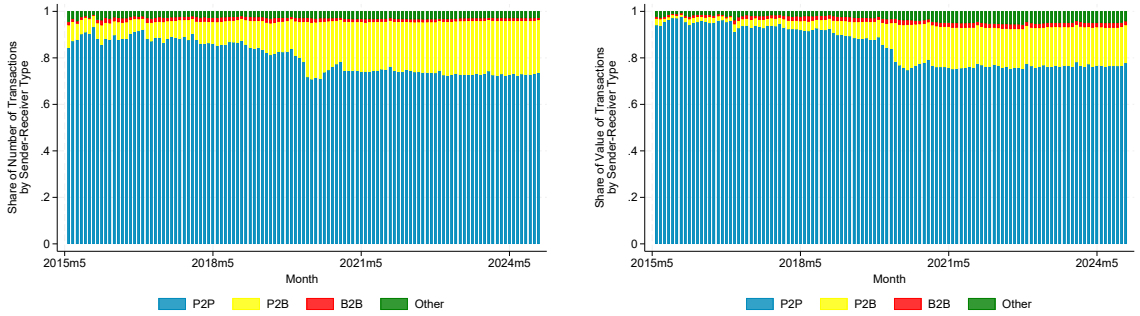
Table A.3: Relationship between Value of Card Payments and Payments Received through Sinpe Móvil in Firm i (IHS)

Dependent variable: Value of Card Payment Transactions (IHS)

Value of Sinpe Móvil Transactions (IHS)	0.011***
	(0.001)
Firm Revenue (Log)	0.366***
	(0.018)
Adjusted R^2	0.893
Observations	457,507
Clusters	342

Notes: The unit of observation is the firm. The dependent variable is the inverse hyperbolic sine (IHS) of the value of card payment transactions, in real terms. All regressions control for firm fixed effects and province × four-digit sector × month × year fixed effects. Standard errors (clustered by province × two-digit sector) are in parentheses. We denote: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure A.3: Sinpe Móvil: Share of Transactions by Sender-Receiver Type
Reclassifying People With High Degree Centrality As Merchants

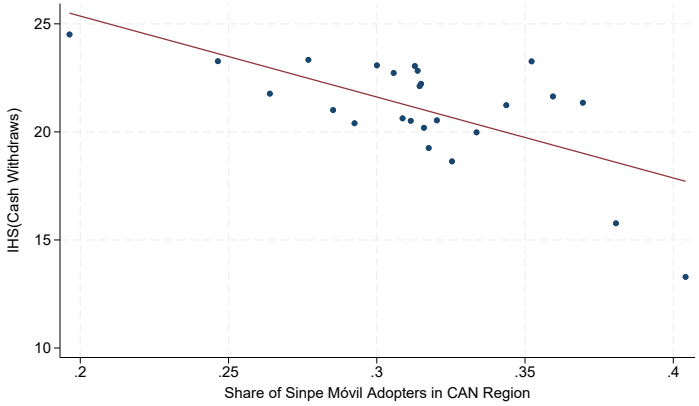


(a) Number of Transactions (b) Value of Transactions

Notes: The figures correspond with those in Figure 13, but re-classifying personal accounts above the 99th percentile in degree centrality as merchant accounts—i.e., re-classifying some transactions from P2P to P2B in the figures. P2P stands for person-to-person, P2B for person-to-business, and B2B for business-to-business. The category others include person-to-goverment (P2G), firm-to-person (F2P), firm-to-goverment (F2G), goverment-to-business (G2P), goverment-to-firm (G2F) and goverment-to-goverment (G2G).

A.3 Adoption of Other Payment Instruments

Figure A.4: Sinpe Móvil: Substitution of Cash at the Regional Level



Notes: The figure shows the relationship between cash withdrawals in Auxiliary Cash Custodies (*Custodias Auxiliares de Numerario*—CAN) and the percentage of adults who have adopted Sinpe Móvil in the corresponding region that the CAN serves. We residualize both variables on month × year fixed effects.

Table A.4: Adoption of other Digital Payment Services after Adopting Sinpe Móvil

Dependent variable: Individual began using CCD or PIN

	CCD	PIN
Post Sinpe Móvil Adoption (=1)	0.035***	0.040***
	(0.0005)	(0.0004)
Adjusted R^2	0.911	0.920
Observations	2,373,348	1,925,296
Clusters	1,981	1,980
% Variation w.r.t Mean	22.960	15.694

Notes: CCD stands for Direct Credit Compensation (*Compensación de Créditos Directos*) and PIN for Immediate Payments (*Pagos Inmediatos*). The unit of observation is the individual. The dependent variable is a dummy variable equal to one if the person sent a payment using CCD or PIN for the first time. Post Sinpe Móvil Adoption is a dummy variable equal to one during the three months following the first time Sinpe Móvil was used for sending funds, and equal to zero the three months before the adoption. All regressions control for wages (log), individual fixed effects, and Sinpe Móvil adoption month effects. Standard errors (clustered by neighborhood) are in parentheses. We denote: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

A.3.1 Synthetic Control Method Implementation

To implement the synthetic control method, we use monthly data from January 2010 to December 2024. Our sample consists of 13 Latin American and Caribbean countries. For the country characteristics before the launch of the digital payment system, we rely on variables related to annual inflation and the GDP per capita in PPP. The data on the currency in circulation and the consumer price index were obtained from the IMF International Financial Statistics database, while GDP per capita comes from the World Development Indicators (WDI) database.

Table A.5 shows the weights of each country in the synthetic version of Brazil, Costa Rica, and Mexico. Tables A.6, A.7, and A.8 compare the prelaunch characteristics of each country to those of its synthetic version.

To assess the significance of our estimates, we conduct a series of placebo studies by iteratively applying the synthetic control method to every other country in the donor pool. Figure A.5 displays the results for the placebo test. The gray lines represent the difference in the log of the currency in circulation between each country in the donor pool and its respective synthetic version. The superimposed black line denotes the gap estimated for Brazil, Costa Rica, or Mexico. The figure shows that the estimated gap for Brazil and Costa Rica is large relative to the distribution of the gaps for the countries in the donor pool, but this does not happen for Mexico.

Table A.5: Synthetic Control Weights

Country	Brazil	Costa Rica	Mexico
Bolivia	0.21	0	0
Chile	0.34	0	0
Colombia	0	0.19	0.49
Dominican Rep.	0	0	0
Guatemala	0.32	0.10	0
Guyana	0	0	0
Haiti	0	0	0.40
Honduras	0	0.28	0
Jamaica	0	0.05	0
Paraguay	0.02	0.34	0
Peru	0	0	0
Trinidad and Tobago	0.11	0	0.11
Uruguay	0	0.04	0

Notes: The synthetic weight is the country weight assigned by the synthetic control method.

Table A.6: Currency in Circulation Predictor Means for Brazil before the Launch of Pix

	Brazil	Synthetic Brazil
Currency in circulation (log)		
January 2010	11.705	11.637
January 2011	11.837	11.794
January 2012	11.913	11.892
January 2013	12.030	11.993
January 2014	12.123	12.078
January 2015	12.203	12.190
January 2016	12.243	12.280
January 2017	12.268	12.327
January 2018	12.339	12.395
January 2019	12.395	12.457
January 2020	12.459	12.503
Inflation rate	5.606	3.695
GDP per capita (log)	9.631	9.496

Notes: GDP per capita and inflation rate are averaged for the 2010-2020 period.

Table A.7: Currency in Circulation Predictor Means for Costa Rica before the Launch of Sinpe Móvil

	Costa Rica	Synthetic Costa Rica
Currency in circulation (log)		
January 2010	13.249	13.184
January 2011	13.336	13.336
January 2012	13.448	13.440
January 2013	13.487	13.484
January 2014	13.611	13.575
January 2015	13.703	13.705
Inflation rate	4.848	4.851
GDP per capita (log)	9.592	9.042

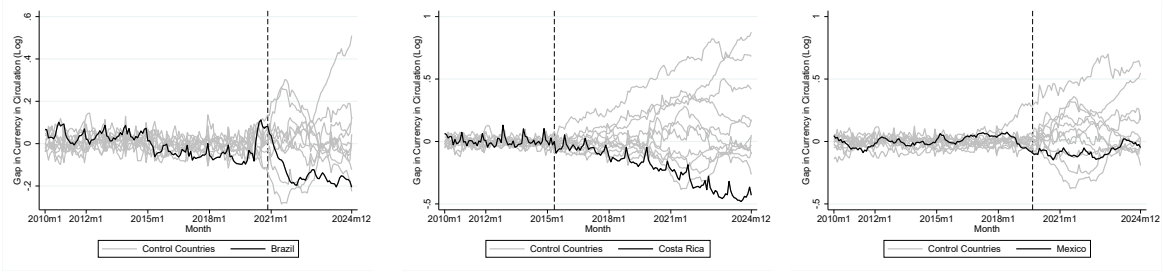
Notes: GDP per capita and inflation rate are averaged for the 2010-2015 period.

Table A.8: Currency in Circulation Predictor Means for Mexico before the Launch of CoDi

	Mexico	Synthetic Mexico
Currency in circulation (log)		
January 2010	13.305	13.2587
January 2011	13.382	13.436
January 2012	13.494	13.507
January 2013	13.576	13.584
January 2014	13.675	13.684
January 2015	13.840	13.825
January 2016	14.001	14.001
January 2017	14.140	14.082
January 2018	14.208	14.161
January 2019	14.287	14.307
Inflation rate	3.998	5.587
GDP per capita (log)	9.844	8.991

Notes: GDP per capita and inflation rate are averaged for the 2010-2019 period.

Figure A.5: Synthetic Control: Gap in Currency in Circulation



(a) Brazil (b) Costa Rica (c) Mexico

Notes: The figure shows the currency in circulation gaps in Brazil, Costa Rica, and Mexico (black line) versus placebo gaps in the control countries (gray lines). The black dashed vertical line marks the launch date of Pix, Sinpe Móvil, or CoDi.

Table A.9: Number of Days Spend without Using Cash

Dependent variable: Number of Days without Using Cash

	PPML	NBRM	OLS
Sinpe Móvil Adopter (=1)	0.604***	0.612***	5.696***
	(0.103)	(0.110)	(0.951)
Card Ownership (=1)	0.323**	0.373***	2.610**
	(0.134)	(0.126)	(1.029)
Female (=1)	0.120*	0.123*	1.622*
	(0.061)	(0.066)	(0.845)
Age (years)	-0.007***	-0.007***	-0.093***
	(0.002)	(0.002)	(0.020)
College Education (=1)	0.162**	0.202***	2.752**
	(0.078)	(0.071)	(1.310)
1^{st} Income Quintile	Ommited	Ommited	Ommited
2^{st} Income Quintile (=1)	0.221**	0.252***	2.198**
	(0.088)	(0.085)	(0.876)
3^{st} Income Quintile (=1)	0.446***	0.455***	5.631***
	(0.113)	(0.101)	(1.553)
4^{st} Income Quintile (=1)	0.417***	0.461***	5.525***
	(0.131)	(0.118)	(3.630)
5^{st} Income Quintile (=1)	0.720***	0.732***	12.190***
	(0.120)	(0.141)	(2.609)
Urban (=1)	-0.099	-0.194*	-1,430
	(0.137)	(0.113)	(1,613)
Adjusted R^2	-	-	0.171
Observations	1,784	1,784	1,784
Clusters	52	52	52

Notes: The unit of observation is the individual. Regressions are weighted using sample weights. The dependent variable is the number of days a person spends without making a cash transaction. All regressions control for municipality fixed effects. Standard errors (clustered by municipality) are in parentheses. We denote: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.