Financial Technology and Innovation

♦ ISSN: 2836-5372 Vol: 05, No. 02, 2025 ♦ PP. 28–34

Article DOI: https://doi.org/10.54216/FinTech-I.050204

FULL LENGTH ARTICLE

# From Mobile Adoption to Payment-Rail Use

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Received: March 03, 2025 Revised: May 12, 2025 Accepted: August 11, 2025 ⋆ Corresponding author

## ABSTRACT

Measures of financial-technology adoption often bundle devices, interfaces, accounts, and the payment instruments themselves, which can end up making the transformation of payment rails look bigger than it really is. In other words, it's sort of easy to overstate what changed in the underlying payment rails when you mix everything together. This study builds a friction-aware measurement framework that separates instrument adoption, recent use, payment-count share, and the transaction context. We apply the framework to nationally representative, weighted U.S. consumer-payment tables that were available by 31 March 2025. The analysis follows eight payment instruments from 2015 to 2023, and then links their payment-count shares to consumer rankings of acceptance setup, convenience, cost, record keeping, and security. In 2023, credit and debit cards together made up 62.2% of payment transactions, while stored-value mobile-payment applications were below 1%. So widespread mobile-device adoption seems to have meant a change in the payment interface , not a direct replacement of the card and bank-account rails. Also, credit and debit cards show the highest use-depth ratios among recent users. In a two-way fixed-effects model, a one-standard-deviation decline in the convenience rank lines up with an 8.97-percentage-point drop in payment share ($p = 0.0047$); the other rankings, well, were not independently separable from zero. An expanding-window ridge model didn't beat a persistence benchmark over 2021–2023, even though it did generate a lower forecast error in 2023. Overall the evidence suggests payment-rail transformation is driven by convenience, behavioral persistence, and transaction context rather than interface adoption only. Finally, the study offers a practical measurement architecture that financial institutions, payment platforms, and regulators can use when they're trying to check for genuine rail substitution.

**Keywords:** Digital payments ▪ Mobile payment ▪ Payment choice ▪ FinTech adoption ▪ Payment rails ▪ Consumer behavior ▪ Financial digital transformation

## 1. INTRODUCTION

Digital payments have kind of expanded through mobile wallets , contactless interfaces , embedded checkout, and app based financial services. But the thing is, what you actually see on the screen is not always the underlying payment instrument. Like, a smartphone can kick off a credit card transaction, a debit card transaction, a bank account transfer, or even a stored value payment. So if you treat every little mobile interaction as if it were a brand new payment rail, it starts to blur the customer facing access layer with the funding and settlement machinery underneath it. This separation is important, especially when you evaluate market disruption, competition, operational resilience, and financial inclusion.

Research on financial technology adoption suggests that things like convenience usefulness trust, social influence, and perceived risk steer initial take up and ongoing usage [1, 2, 3, 4]. The payment choice literature, on the other hand, looks more at what people actually do, and it highlights determinants such as transaction value merchant acceptance

income access to banking and the comparative ease of electronic methods [5, 6, 7]. Since these two lines of work sit at different analytical levels, adoption of a mobile interface is often read as substitution between payment rails. In reality though, a lot of wallet or device uptake can happen while people still stay heavily reliant on cards and bank accounts.

This study addresses that measurement problem through a four-layer architecture comprising *adoption*, *recent use*, *payment-count share*, and *transaction context*. It investigates three questions: how strongly these measures differ across payment instruments; which perceived frictions are associated with changes in instrument share after controlling for instrument-specific characteristics and common year shocks; and whether friction indicators improve short-horizon forecasts relative to a persistence benchmark.

So this study does three things, kind of. First it builds a pretty clear instrument-year panel using the official Survey and Diary of Consumer Payment Choice tables. Second, it disentangles mobile-device adoption from substitution happening across the underlying payment rails, and it coins a use depth ratio which ties the payment share to how wide the recent use has been, not just one snapshot. Third, it puts together descriptive analysis, two-way fixed effects, and an expanding-window time check , so it can more convincingly tell apart that explanatory association from something like true out-of-time predictive performance .

## 2. RELATED WORK

### 2.1 From adoption intention to observed use

The adoption literature consistently identifies a gap between intention and realized behavior. Systematic reviews show that digital-payment research has concentrated on acceptance models, with fewer studies observing sustained, transaction-level behavior [2, 4]. Initial trust and service quality affect continuation after first adoption [1], while resistance, switching costs, and status-quo bias can slow movement away from cash [8]. Cross-country evidence also demonstrates that the same technology can face different behavioral and institutional barriers [3, 9].

The distinction is particularly important in mobile payments. A mobile device is an initiation channel, not a unique funding source. Experimental research indicates that mobile payment can increase perceived convenience and willingness to pay [10], and behavioral studies associate mobile payment with altered spending patterns [11, 12]. These effects do not demonstrate that consumers have abandoned cards or bank accounts; the mobile layer may instead make established rails easier to access and use.

### 2.2 Convenience, acceptance, and behavioral persistence

Convenience is a central determinant in both theory and empirical evidence. Contactless functionality can reduce cash demand by lowering transaction friction [6]. Merchant acceptance and ecosystem readiness are equally necessary, as adoption cannot become frequent use where payment acceptance remains uncertain [13]. Trust, usefulness, self-efficacy, and perceived severity were also associated with adoption during the pandemic [14, 15].

At the same time, payment behavior is persistent. Consumers hold portfolios of instruments and select among them by context. Cards are suited to routine purchases, bank-account payments to bills and transfers, and cash to low-value or acceptance-constrained settings. Low-income and unbanked consumers face different constraints, including fees and access limitations [5, 16, 17]. Aggregate platform-adoption statistics can therefore obscure important distributional differences.

## 3. DATA AND METHODS

### 3.1 Source and scope

The empirical evidence is drawn from the 2023 Survey and Diary of Consumer Payment Choice, published by the Federal Reserve Bank of Atlanta in June 2024 [18]. The survey and diary provide nationally weighted estimates of payment-instrument adoption, recent use, payment frequency, value, location, transaction type, and perceived characteristics. The 2023 study included 4,579 respondents and measured payment activity in October 2023. The supplied workbook also reports consistent annual tables from 2015 onward for core instruments.

The analytical panel contains eight instruments observed over nine years: cash, check, money order, debit card, credit card, prepaid card, bank-account-number payment (BANP), and online-banking bill payment (OBBP). Mobile payment is not included as a separate panel rail because the diary category is defined narrowly as stored-value app payment, while mobile-device use can initiate transactions on several other instruments. This treatment is central to the study's measurement argument.

For each instrument $i$ and year $t$, payment-count share is

$$S_{it} = 100 \times \frac{N_{it}}{N_t}, \tag{1}$$

where $N_{it}$ is the weighted monthly number of payments using instrument $i$ and $N_t$ is the weighted number of all payments. Consumer assessments rank eight instruments from 1 (best) to 8 (worst) on acceptance, acquisition and setup, convenience, cost, payment records, and security.

### 3.2 Use-depth metric

Adoption indicates that an instrument is available to a consumer; recent incidence indicates use within the prior 30 days; frequency share indicates how much of the national payment flow the instrument captures. To relate reach to intensity, the use-depth ratio is defined as

$$D_i = \frac{S_{i,2023}}{U_{i,2023}}, \tag{2}$$

where $U_i$ is the percentage of consumers reporting recent use. The ratio is not a transaction rate per user and should not be interpreted as one. It is a normalized population-level measure: high values indicate that an instrument's payment share is large relative to the breadth of its recent-user base.

### 3.3 Fixed-effects specification

The association between perceived payment characteristics and instrument share is estimated using the following two-

**Table 1.** Representative work and the measurement gap addressed in this paper.

| Study | Evidence and method | Primary construct | Main insight | Unresolved measurement issue |
|---|---|---|---|---|
| [1] | Survey; post-adoption model | Trust and continuation | Initial trust and quality shape continued mobile-payment use. | Continuation is not decomposed by underlying funding rail. |
| [8] | Survey; switching framework | Cash-to-mobile switching | Status-quo and resistance factors delay switching. | Mobile payment is treated as a destination category rather than an initiation layer. |
| [6] | Natural experiment | Contactless convenience | Improved electronic-payment convenience reduces cash demand. | Focuses on a specific innovation and setting rather than a multi-instrument portfolio. |
| [7] | Representative household survey; hurdle models | Adoption and usage intensity | Mobile payment complements bank services and differs across households. | Does not compare adoption, incidence, and national payment-count share. |
| [4] | Systematic review | Intention and actual use | Literature remains fragmented across pre- and post-adoption outcomes. | Calls for stronger behavioral measures and longitudinal evidence. |
| Present study | Official weighted tables; descriptive funnel, fixed effects, and temporal forecasting | Rail use and friction | Separates device/interface adoption from frequency and context of underlying instruments. | Aggregate instrument-year evidence cannot identify individual causal effects. |

way fixed-effects model:

$$S_{it} = \alpha_i + \lambda_t + \beta' \mathbf{R}_{it} + \varepsilon_{it}, \tag{3}$$

where $\alpha_i$ controls for stable instrument attributes, $\lambda_t$ captures common year shocks, and $\mathbf{R}_{it}$ contains standardized rank measures. Heteroskedasticity-consistent HC3 standard errors are reported. Because ranks and shares are aggregate estimates, the model identifies within-panel association, not a causal consumer response.

### 3.4 Out-of-time forecasting design

A ridge-regression model evaluates whether friction indicators improve prediction beyond simple market-share persistence. For each of 2021, 2022, and 2023, the model is trained only on earlier years. Predictors comprise the lagged payment share and six characteristic rankings. The regularization parameter is selected within each training window by leave-one-instrument-out cross-validation. The benchmark predicts that the next year's share equals the preceding year's share. Mean absolute error (MAE), root mean squared error, and $R^2$ are computed on the untouched year. This expanding-window design prevents future information from entering model selection.

## 4. RESULTS

### 4.1 A wide gap between access and transaction share

Figure 1 shows that access, recent use, and frequency are not interchangeable. Cash was adopted by 95.4% of consumers and used recently by 87.2%, but represented 16.0% of payment count. Credit cards were adopted by 81.8%, used recently by 72.7%, and captured 32.4% of payment count. Debit cards displayed a similar pattern, with 29.8% of count. By contrast, checks remained available to 71.3% of consumers but accounted for only 2.7% of payment count.

The use-depth ratio reinforces this distinction. Credit and debit cards reached 0.446 and 0.445, respectively, roughly four times the prepaid-card ratio and more than six times the check ratio. BANP had a lower recent-user base but a relatively high ratio because it is repeatedly used for scheduled or remote payments. OBBP had wider incidence but lower relative depth. These differences reflect role specialization, not a single adoption hierarchy.

The official tables report mobile phone or tablet payment adoption of 69.5% in 2023. However, the stored-value mobile-payment-app category represented only 0.74% of payment count. The apparent contradiction disappears once the device is separated from the rail: most mobile transactions are funded by cards or bank accounts and are recorded under those instruments. Mobile adoption is therefore evidence of interface transformation, not direct evidence that mobile balances have replaced incumbent rails.

### 4.2 Cards gained share, but substitution was uneven

Figure 2 traces payment-count shares from 2015 through 2023. Credit-card share increased by approximately 14.2 percentage points and debit-card share by 0.3 points. Cash declined by 17.3 points, checks by 3.3 points, and OBBP by 0.6 points. BANP increased by 3.7 points. The transition was therefore not simply from paper to "mobile." It combined a large cash-to-card shift with growth in bank-account payments for particular contexts.

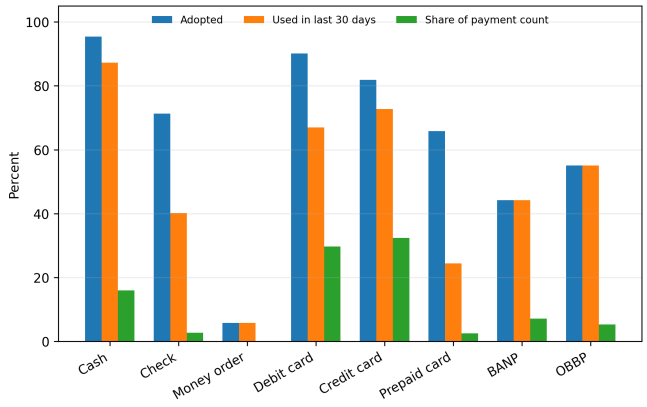
The pandemic produced a pronounced but not permanent break. Cash share reached its low point in 2020 and partially recovered thereafter. Card shares continued to expand. This pattern is consistent with coexistence rather than complete displacement [19]. Payment portfolios adjust around acceptance, transaction type, rewards, liquidity, and habit.

### 4.3 Convenience is the only independently robust rank

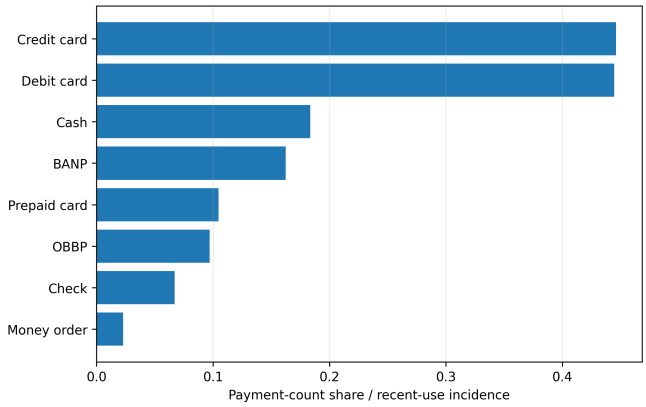
The 2023 rank matrix in Figure 3 illustrates the trade-offs embedded in instrument choice. Credit cards ranked first in acceptance, payment records, and security, while cash ranked first in setup and cost. Debit cards ranked second on several dimensions. Money orders and cash performed poorly on record keeping, and bank-account payments had weaker acceptance rankings despite their usefulness for bills.

Table 2 reports the fixed-effects estimates. Since a higher rank is worse, negative coefficients imply that deterioration in perception is associated with lower share. Convenience has a coefficient of $-8.97$ percentage points for a one-standard-deviation worsening in rank, with a 95% confidence interval from $-15.19$ to $-2.75$ and $p = 0.0047$. Acceptance is negative but imprecise. Setup, cost, records, and security are not independently distinguishable from zero once instrument and year effects and the other rankings are included.

This result should not be read as evidence that security or cost is unimportant. The ranks are relative, correlated, and slow moving; stable differences are absorbed by instrument

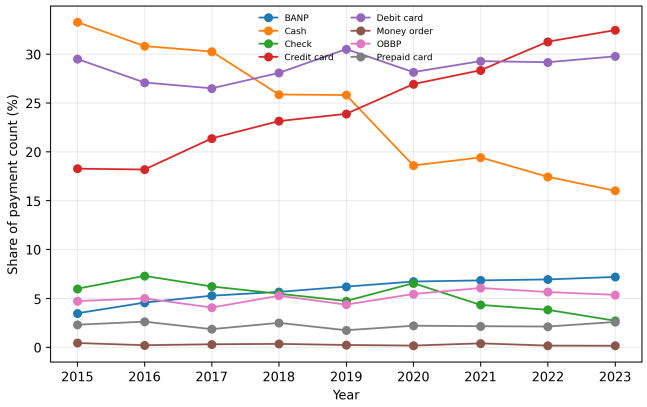



**(a)** Adoption, recent use, and payment-count share.

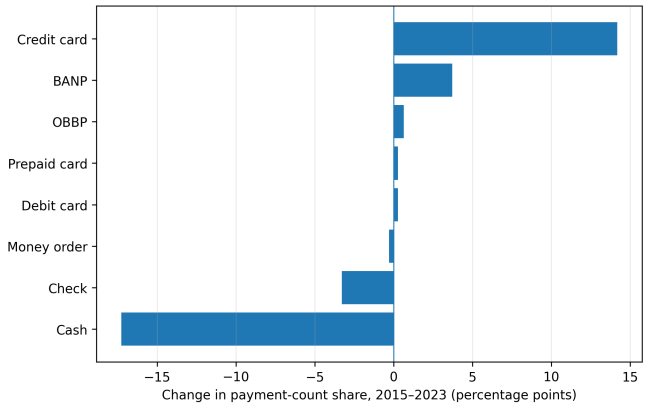



**(b)** Use depth among recently used instruments.

**Figure 1.** The 2023 payment funnel. BANP denotes bank-account-number payment; OBBP denotes online-banking bill payment.




**(a)** Payment-count shares, 2015–2023.




**(b)** Net change between 2015 and 2023.

**Figure 2.** Long-run changes in the composition of consumer payments.

**Table 2.** Two-way fixed-effects estimates.

| Rank | Coefficient | HC3 SE | $p$ |
|---|---|---|---|
| Acceptance | −3.826 | 4.260 | 0.369 |
| Setup | −0.440 | 1.164 | 0.705 |
| Convenience | −8.968 | 3.172 | 0.005 |
| Cost | −1.504 | 3.004 | 0.617 |
| Payment records | 2.624 | 3.390 | 0.439 |
| Security | −0.692 | 1.664 | 0.677 |

Notes: Outcome is payment-count share. Rank variables are standardized; a higher value is a worse rank. Instrument and year fixed effects are included. $n = 72$.

**Table 3.** Out-of-time forecasting performance.

| Period | Model | MAE | RMSE |
|---|---|---|---|
| 2021 | Ridge | 1.202 | 1.539 |
| | Persistence | 0.825 | 1.081 |
| 2022 | Ridge | 0.780 | 0.931 |
| | Persistence | 0.788 | 1.274 |
| 2023 | Ridge | 0.468 | 0.524 |
| | Persistence | 0.669 | 0.821 |
| Pooled | Ridge | 0.816 | 1.082 |
| | Persistence | 0.760 | 1.075 |

Notes: Errors are percentage points. Each year is forecast using only earlier observations. Ridge tuning is confined to the training window.

fixed effects. The estimate instead indicates that within the available panel variation, convenience is the characteristic most closely aligned with changes in national payment share.

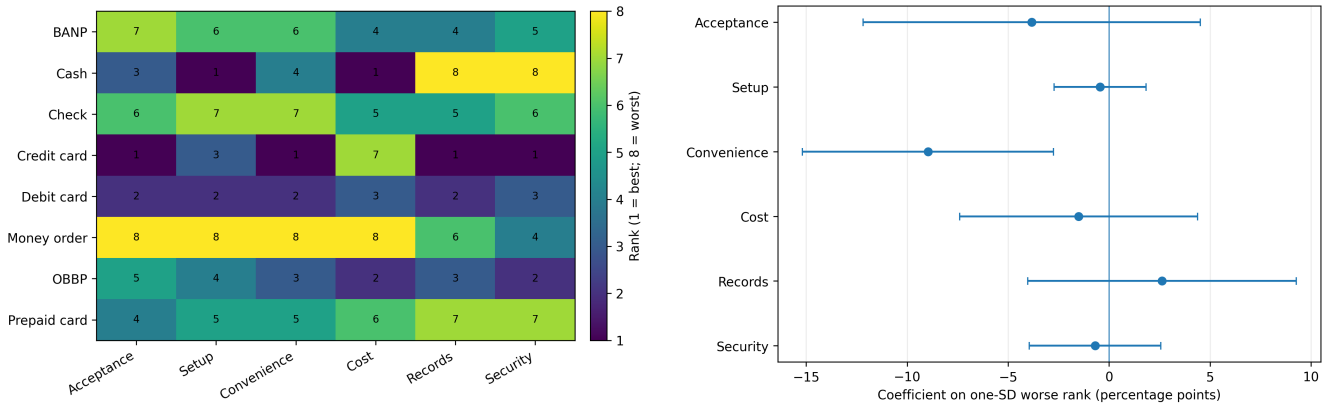
### 4.4 Inertia remains a formidable forecast benchmark

The out-of-time results are deliberately reported against a demanding benchmark. Across 24 instrument-year forecasts for 2021–2023, the friction-aware ridge model achieved an MAE of 0.816 percentage points and an RMSE of 1.082. Persistence achieved an MAE of 0.760 and an RMSE of 1.075. Both models produced pooled $R^2$ values above 0.99 because instrument shares are highly persistent and differ substantially in level.

The yearly pattern is more informative. Ridge MAE fell from 1.202 in 2021 to 0.780 in 2022 and 0.468 in 2023. Persistence was better in 2021, approximately tied in 2022, and worse in 2023, with MAE of 0.669. Friction measures therefore did not deliver a universal forecasting advantage, but they added useful information in the most recent year. The honest conclusion is that payment rails are path dependent: perceived characteristics can help explain and sometimes anticipate change, yet last year's market structure remains difficult to beat.

### 4.5 Context explains why several rails coexist

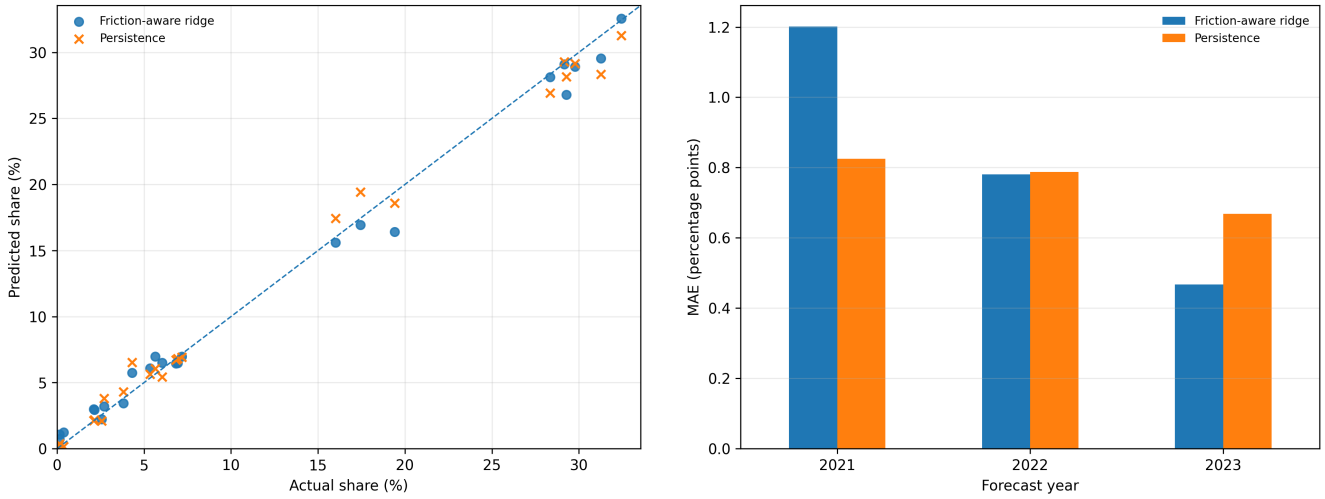
Figure 5 separates purchases from bills and other payments. Cards represented 75.9% of the eight-instrument purchase count, led by credit cards at 38.7% and debit cards at 34.1%. Cash represented 19.4%. The composition of bills and other payments differed substantially: BANP and OBBP jointly




**(a)** Consumer characteristic rankings in 2023.

**(b)** Coefficient estimates with 95% intervals.

**Figure 3.** Perceived payment frictions and payment-count share.




**(a)** Actual and out-of-time predicted shares.

**(b)** Mean absolute error by forecast year.

**Figure 4.** Temporal validation of the friction-aware model.

represented 54.1%, while debit and credit cards together represented 31.0%. Checks retained 8.5%.

This contextual specialization explains why aggregate adoption measures are insufficient. A consumer may use a mobile interface for a card purchase, an online bank interface for a recurring bill, and cash for a small in-person transaction. The interface changes, but the rails persist because each solves a different problem. Platform strategy should therefore be evaluated by the transactions it migrates, not simply by downloads, registrations, or device-enabled status.

## 5. IMPLICATIONS FOR FINANCIAL TECHNOLOGY

### 5.1 Measure migration at the rail level

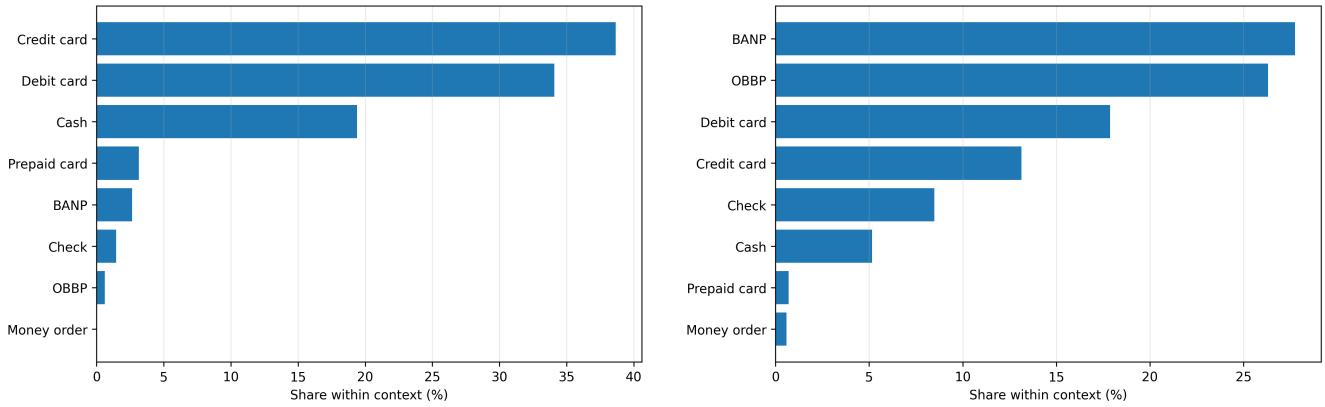
Banks and payment platforms should distinguish at least four dashboard layers: enabled users, recently active users, transactions initiated through the interface, and transactions settled on each underlying rail. A wallet can achieve high adoption while remaining a thin orchestration layer over cards. That can still be strategically valuable, but it is different from capturing deposits, interchange, credit risk, or settlement economics.

Rail-level measurement also improves competitive analysis. FinTech can alter the distribution of value without replacing the regulated balance sheet or payment infrastructure [20, 21, 22]. An interface provider may own the customer relationship while incumbent institutions continue to provide funding and settlement. Regulators need visibility into both layers to assess concentration, operational dependency, and consumer recourse.

### 5.2 Design for convenience without ignoring inclusion

The convenience result supports continued investment in low-friction authentication, reliable acceptance, and streamlined payment initiation. Yet convenience can change spending salience and increase willingness to pay or overspending risk [10, 12]. Product design should therefore combine speed with transparent funding-source display, real-time balance cues, configurable limits, and accessible transaction records.

Inclusion requires maintaining usable alternatives. Cash remains important to unbanked and lower-income consumers, while fees and account access affect the feasibility of card and bank-based payments [16, 17]. A digital-first system that preserves nominal cash acceptance but makes cash inconvenient may impose a hidden burden. The relevant policy objective is not maximal digitization but reliable, affordable choice.




**(a)** Instrument mix for purchases.

**(b)** Instrument mix for bills and other payments.

**Figure 5.** Payment-rail specialization by transaction context in 2023.

### 5.3 Treat persistence as a strategic fact

The forecasting results show that payment shares evolve slowly. Product teams should be cautious about extrapolating rapid interface adoption into immediate rail displacement. Switching requires simultaneous change in consumer habit, merchant acceptance, rewards, recurring-payment setup, and trust. Short-run forecasts should retain a strong persistence baseline, and new models should be judged by whether they beat it out of time rather than by in-sample fit.

## 6. LIMITATIONS

This study leans on published aggregate weighted estimates, not respondent level microdata. so, it's tough to treat the patterns between rankings and shares as individual level effects. Because of that, ecological inference is something we should steer away from. The rankings themselves are ordinal, and they're also relative; standardization lets you compare across places but it still doesn't magically turn them into cardinal utility measures. The eight instrument panel, in turn, drops categories that don't have fully comparable annual rankings. On top of that, mobile device adoption, and stored value mobile app payments use different definitions, which is exactly why they're talked about separately, not merged into one statistical exercise.

Then, the fixed effects model is built on a small panel with correlated predictors. HC3 standard errors help with sensitivity to heteroskedasticity but they don't resolve every dependency issue. The forecasting part has only three test years, so its main role is to stop leakage and to show how persistent the signal is, rather than to claim a definitive forecasting system. For later work, the next step is to tie together diary transactions, device channel, merchant context, and funding rail at the respondent level.

## 7. CONCLUSION

Financial technology has been quick to impact the payment system but even faster at doing so indirectly, by replacing the rails of the payment system itself. The latest U.S. data through 2023 reveals that the use of mobile devices has been widespread, and that credit cards, debit cards and bank-account payments are still the preferred payment method. These dimensions of transformation cannot, therefore, be bundled into a single digitalization indicator: adoption, recent use, payment-count share, and transaction context.

The only perceived characteristic showing a statistically significant within-panel relationship with payment share was convenience, whereas the persistence benchmark had a slightly better relationship with payment share than the friction-aware model across the whole forecast horizon. The two conclusions are all the same: convenience affects the trend of change, but entrenched habits, accepted networks, the routines of recurring payments, and transaction-specific requirements slow down the pace of change. Therefore, financial institutions, platform providers and regulators should consider assessing their transformation at the rail level, benchmark against credible persistence models, and accept coexistence as a structural characteristic of today's payment systems, not a shortcoming of adoption.

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