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Settlement Liquidity in the Colombian Large-Value Payment System: The Role of Reserve Requirements*

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Abstract

This paper analyzes the intraday timing of transactions in Colombia's large-value payment system (CUD) from 2018 to 2025, focusing on how changes in reserve requirements affect liquidity management by financial institutions. Using high-frequency transaction data, we document that reductions in reserve requirements in April 2020 and September 2024 are associated with a shift of settlement activity toward later hours of the day. The effects are heterogeneous, as smaller institutions remain more dependent on marginal liquidity and incoming payments in an interdependent payment network. We also find that the launch of the new Central Securities Depository (DCV) system in April 2024, along with changes in payment volume and value, further reinforces the move toward later settlements. Greater reliance on intraday repos relative to reserves has also reduced early-day activity while improving liquidity management later in the business day.

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1. Introduction

The Sistema de Cuentas de Depósito (CUD) is Colombia's large-value payment system (LVPS), operated by the Central Bank of Colombia. It provides authorized financial institutions with a secure and efficient platform for processing large-value electronic fund transfers and settling obligations arising from transactions such as securities and foreign exchange trades in local currency, interbank loans, tax payments, and check clearing. Operating under a real-time gross settlement (RTGS) system, CUD ensures immediate and final settlement of transactions, contingent on sufficient account balances.

As in any LVPS, the intraday distribution of payments in Colombia's CUD is central to both operational efficiency and systemic liquidity. This paper investigates the effect of reserve requirement reductions on settlement liquidity and, consequently, how these policy measures have shaped financial institutions' liquidity management. Reserve requirements have traditionally been a straightforward policy instrument, broadly applied and closely tied to the fundamental structure of financial intermediation. These attributes have historically enabled reserve requirements to serve multiple roles, which have evolved alongside the development of the financial system and the changing frameworks for designing and implementing economic policy. For instance, reserve requirements have been employed to mitigate banks' liquidity risk, as observed in April 2020 during the COVID-19 pandemic, and as a monetary policy tool aimed at controlling the growth of broad monetary aggregates and credit. However, advancements in liquidity risk regulation in Colombia, together with the shift in the monetary policy strategy toward an inflation-targeting framework, have reduced the relevance of reserve requirements in fulfilling these roles. It is worth noting that Colombia's reserve requirement calculation period is consistent with IMF recommendations and international central banking practices. Reserve requirements are calculated on a biweekly basis and must be held as cash in vaults or deposits at the Central Bank, a framework that facilitates intertemporal liquidity smoothing while preserving short-term interest rate stability.

In September 2024, the Central Bank of Colombia reduced the reserve requirement for deposits to support the financial deepening of the economy. This decision was consistent with the inflation-targeting framework, under which the policy interest rate serves as the primary monetary policy instrument, and considered the implementation of regulatory standards designed to mitigate liquidity risk at credit institutions. By lowering the costs of financial intermediation, the reduction in reserve requirements was expected to contribute to the deepening of financial markets. Evidence for Colombia (Banco de la República, 2021) suggests that reserve requirements account for less than 0.25 percentage points of banks' intermediation margins, implying that the measure was expected to generate some efficiency and profitability gains for financial institutions.

Theoretical models suggest that lowering reserve requirements may accelerate the timing of settlements by freeing up additional liquidity (e.g., Kollár, 2024; Schulz, 2011). However, lower reserve requirements also imply a higher opportunity cost for holding liquidity at the central bank, potentially incentivizing institutions to deploy excess funds in the broader financial system. This behavior may lead to tighter intraday liquidity conditions within the CUD, resulting in a concentration of payment activity toward the late afternoon. By examining these dynamics related to changes in reserve requirements, our study contributes to the literature on payment system efficiency and the broader implications of monetary policy for intraday liquidity management. To our knowledge, this is the first paper analyzing the main drivers of the timing distribution of transactions in Colombia's LVPS (CUD).

We document clear trends in the timing of payments within CUD between 2018 and 2025. Although intraday payment profiles remain broadly stable across different reserve-requirement regimes—with recurrent peaks in the early morning and near the end of the day—the underlying drivers of these peaks evolve over time. Early-morning activity gradually shifts from being dominated by tax-related payments to reflecting central bank liquidity operations, whereas end-of-day settlement becomes increasingly shaped by securities transactions processed through the Central Securities Depository (DCV), particularly after the introduction of the new DCV system in April 2024. Changes across periods are more pronounced in the intraday distribution of payment values than in volumes, supporting a focus on value-based indicators. In the most recent period, settlement timing displays a clear reallocation: lower value deciles tend to settle earlier in the day, while higher deciles settle later, indicating a redistribution of liquidity usage across the trading day. Consistent with the institutional change, the introduction of the new DCV system is associated with a higher share of settlement value occurring within the *ad valorem* pricing window and with a shift in the intraday settlement profile. Specifically, by 17:00, the cumulative value settled, which was initially at approximately the 90th percentile, decreased to a level between the 70th and 80th percentiles.

Our analysis shows that reductions in reserve requirements have contributed to a pronounced shift in settlement activity toward the late afternoon. The magnitude of this shift differs across institutions, as smaller entities remain more dependent on marginal liquidity and incoming payments in an interdependent payment network. Later settlements have been further reinforced by other factors, such as the implementation of a new DCV framework, and changes in payment volume and value. Additionally, higher levels of repos relative to reserves—an essential source of intraday liquidity—have delayed early-day settlements. Nevertheless, this greater use of repos has contributed to improved liquidity management efficiency during the latter part of the day.

These findings underscore the importance of closely monitoring the impact of monetary policy decisions on LVPS dynamics. In Colombia, the observed delays in payment timing following reserve requirement reductions may reflect structural characteristics of the system, such as high industry concentration, which can lead to asymmetric effects across participants (Schulz, 2011).

This article consists of five sections including this introduction. The second section reviews the literature on settlement activity and its determinants. The third section describes the timing distribution of payments in CUD during the day and over time. Section 4 presents the econometric approach and the main results. The last section summarizes the main findings and discusses policy implications.

2. Literature Review

In LVPS, participants face a fundamental trade-off between settling payments early (which requires holding or obtaining intraday liquidity) and delaying settlement to economize on liquidity at the cost of higher operational risk and coordination frictions. This trade-off underlies the pronounced intraday regularities observed in payment systems, including the concentration of high-value payments at specific times of the day. The settlement-liquidity literature therefore emphasizes payment-timing decisions (McAndrews and Rajan, 2000) and analyzes how institutions balance the costs of early liquidity usage against the risks and costs associated with delayed settlement (Armantier et al, 2008). Becher et al. (2008) extend this discussion by highlighting the role of liquidity recycling in maintaining intraday liquidity flow and coordination, using evidence from CHAPS Sterling.

Empirical studies of RTGS systems illustrate how strategic payment-timing decisions shape intraday patterns. For Fedwire, Armantier et al. (2008) document a shift toward earlier settlement between 1998 and 2006, with more value settled in the morning and tighter clustering around midday, driven by pricing and policy changes affecting intraday credit and banks' liquidity management. Paulick et al. (2024) analyze TARGET2, the Eurosystem's large-value payment system in Europe, and find that tiered payments allow settlement banks to reduce liquidity consumption and manage intraday liquidity more efficiently, highlighting the role of institutional arrangements in shaping payment behavior. Similar effects appear in other systems: Zhang (2015) shows that reforms in Canada's LVPS altered payment timing and concentration, while Alexandrova et al. (2023) document substantial cross-country variation in intraday liquidity usage and reliance on central-bank credit due to differences in institutional frameworks and market structures.

The most influential study for our purposes is Bech et al. (2012), who introduce the concept of settlement liquidity—the ease with which participants meet payment obligations—and analyze its evolution on Fedwire during and after the 2008 global financial crisis. They show that the expansion of reserve balances, coupled with the introduction of interest on reserves, substantially increased intraday liquidity, accelerated settlement processes, and sharply reduced daylight overdrafts, lowering both operational risk and the Federal Reserve's credit exposure. Bech et al. (2012) conclude that a monetary-policy framework with a near-zero opportunity cost of holding reserves promotes earlier payment submission and a safer, more efficient payment system.

Subsequent studies refine these insights by examining how monetary policy implementation and reserve balances affect payment timing. Kroeger and McAndrews (2016) show that abundant post-crisis reserves were associated with earlier and smoother settlement and persistently low daylight overdrafts, while Badev et al. (2021) document a shift of Fedwire payments toward earlier hours between 2009 and 2012 linked to quantitative easing, interest on reserves, and changes in the Payment System Risk policy. Importantly, Badev et al. (2021) show that available liquidity far exceeded daily payment values, indicating that the distribution and pricing of liquidity matter more for payment behavior than aggregate liquidity alone.

Related work combines payment-system data with money-market activity to examine how reserve scarcity and funding frictions translate into settlement delays. Bartolini et al. (2010) show that lower reserve balances and tighter intraday conditions in the U.S. money market are associated with longer delays between trade and settlement, consistent with banks adjusting payment timing to manage reserve uncertainty and liquidity costs. Afonso et al. (2022) further demonstrate that once reserves exceed a certain threshold, additional increases have diminishing effects on money-market rates and liquidity conditions, implying a non-linear relationship between reserve levels and settlement behavior.

Another strand of the literature emphasizes heterogeneity across banks. Glowka (2020) demonstrates the use of cluster analysis to identify distinct payment behavior profiles among participants in large-value payment systems. Using Mexican RTGS data, Alexandrova-Solis (2013) shows that immediate settlement would substantially increase liquidity needs for some institutions but not for others, highlighting cross-sectional differences in the use of payment delays. Consistent with this, Badev et al. (2021) document that Fedwire payments are highly concentrated among a small group of large institutions, which also drive much of the shift toward earlier settlement, while Alexandrova et al. (2023) show that central-bank money and collateral are similarly concentrated among "too-connected-to-fail" banks. Together, these findings suggest that monetary policy and liquidity regulations have asymmetric effects, with large institutions better able to internalize system-wide incentives than smaller banks facing tighter funding constraints.

Despite these contributions, the literature explicitly linking reserve-requirement changes to settlement liquidity and intraday payment timing remains relatively small. Kollár (2024) shows that in the Hungarian RTGS system, reserve-requirement reductions and subsequent increases affected account balances but had limited effects on queuing because their impact on settlement timing depended on interactions with other liquidity tools, such as collateral eligibility and intraday credit. Consistent with this, Schulz (2011) finds for the German RTGS system that tighter liquidity constraints increase payment delays for some institutions, with heterogeneous effects across participants rather than system-wide outcomes.

Our paper builds on this literature but differs in two key respects. First, rather than focusing on broad changes in monetary-policy implementation, we analyze discrete adjustments in reserve requirements in an emerging-market RTGS—Colombia's CUD—and examine their effects on the intraday distribution of payments over a long horizon (2018–2025). Second, we explicitly study asymmetries across participants by distinguishing between large, medium-sized, and small institutions, consistent with evidence that liquidity access, collateral availability, and strategic behavior vary systematically by size (e.g., Schulz, 2011).

While prior work shows that abundant reserves and low opportunity costs tend to accelerate settlement and reduce overdrafts, it provides limited evidence on how targeted reductions in reserve requirements combined with greater reliance on repos as a source of intraday liquidity affect payment timing in highly concentrated systems. By documenting these mechanisms for Colombia, where intraday overdrafts are not permitted, our study offers new evidence on how reserve-requirement policy and central-bank liquidity provision jointly shape settlement liquidity and intraday payment behavior in LVPS.

3. Stylized Facts

In this section, we analyze value and volume time distributions of payment transactions settled in Colombia´s large-value payment system (CUD).

3.1. Intraday Timing of Payments

Charts 1 and 2 compare the average intraday distribution of payment values and volumes across three periods defined by changes in reserve-requirement policy. The first period spans from January 1, 2018 to April 21, 2020, when the reserve requirement ratio was 11% for demand deposits and 4.5% for longer-term deposits. [1] The second period begins on April 22, 2020, following a reduction in the ratio to 8% and 3.5%, respectively, as part of the liquidity measures implemented during the COVID-19 pandemic. [2] The third period starts on September 11, 2024, when the reserve requirement ratio was reduced from 8% to 7% and from 3.5% to 2.5%, respectively, under the central bank's 2022–2025 Strategic Plan, which aimed to support financial deepening and reduce intermediation costs. [3] This adjustment released an estimated COP 6 trillion (approximately USD 1.5 billion) in bank reserves and reflects the declining policy role of reserve

[1] Banco de la República (2015).
[2] Banco de la República (2020).
[3] Banco de la República (2024).

requirements amid strengthened liquidity-risk regulation and an inflation-targeting framework in which the policy rate is the primary instrument. This final period extends through April 30, 2025 in our sample.

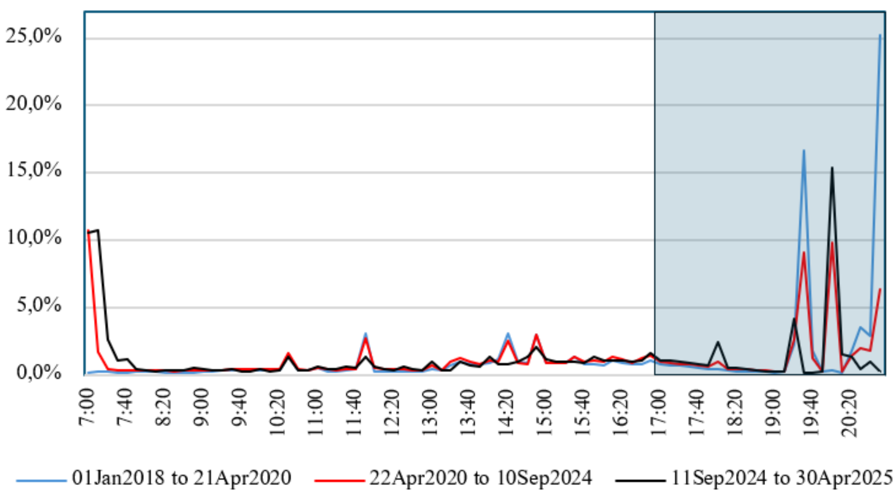
In Charts 1 and 2, each point represents the average value (Chart 1) or volume (Chart 2) of payments settled in the CUD within ten-minute intervals under each reserve-requirement regime. Across the three periods, the intraday profiles exhibit broadly similar structures, with a sharp concentration of activity at the market opening (7:00–7:30 am) and a pronounced rise toward the end of the operational day (7:30–9:00 pm). The early-morning spike is consistently larger in value terms than in volume terms, indicating that high-value transactions cluster immediately after opening, while smaller-value, higher-frequency payments dominate the intervals after midday. In the late afternoon and evening, however, the patterns begin to diverge across reserve-requirement regimes. In value terms, the post-17:00 intervals show a particularly steep increase in the first and second periods, suggesting a greater concentration of large-value transactions closer to system closure. By contrast, the volume distribution displays a smoother and more gradual increase after 17:00, with peaks that are less extreme and more evenly distributed.

Early-morning peaks in the first period are primarily driven by tax payments, whereas in the later periods they are mainly associated with the unwinding of repurchase agreements and the return of interest-bearing deposits conducted by the central bank. However, these payments are not part of the "intraday game" and are excluded from the empirical analysis in Section 4. End-of-day peaks in the first period reflect the unwinding and constitution of remunerated deposits, as well as transfers to leading and financial-backup accounts. In the second period, the settlement of securities transactions in the DCV—an infrastructure designed for asset servicing and for the deposit and custody of securities in electronic form—becomes an additional driver of late-day activity. In the third period, which coincides with the launch of the new DCV on April 1, 2024, the end-of-day peak is largely driven by the settlement of DCV securities transactions, with smaller contributions from financial-backup transfers and the constitution of remunerated deposits.

For analytical purposes, Charts 1 and 2 highlight the interval between 17:00:59 and 21:00:00, during which the system applies an *ad valorem* fee rather than a per-transaction charge—a pricing structure that would reinforce the concentration of high-value settlements earlier in the day. However, in the most recent period, it appears that the financial system delayed some payments even when faced with a higher fee. One possible explanation is that the timing of many large-value payments is determined by the underlying money market transactions that generate them. Since the profitability of these trades depends primarily on interest rate conditions, settlement fees typically represent a secondary consideration. In addition, institutions often need to complete funding and liquidity adjustments before the end of the business day, limiting their ability to advance certain payments and contributing to the concentration of settlements late in the day despite higher fees.[4]

A comparison of Charts 1 and 2 shows that temporal changes are more pronounced in the distribution of payment values than in transaction volumes. Moreover, because payment values are more directly related to intraday liquidity usage in an RTGS system—determining funding needs at each point in time and influencing queuing, delay, and liquidity-saving behavior— the analysis that follows focuses on the evolution of payment values.

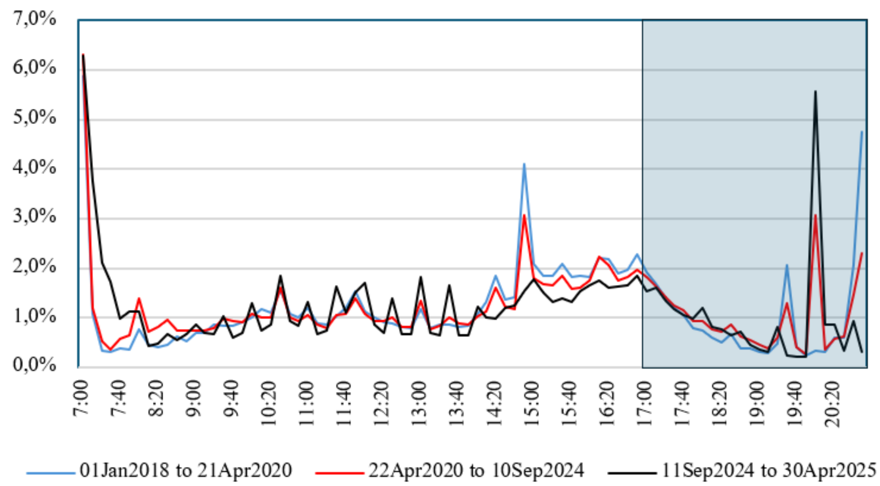
Chart 1. Intraday Distribution of CUD Payment Values across Reserve-Requirement Regimes



Sources: CUD; authors' calculations. Notes: The chart shows the mean daily percentage of the total payment value settled per ten-minute interval. The shaded area corresponds to the variable fee interval, which runs from 17:01:00 until 5:59:59 the following day, or until the opening of the next business day.

[4] In the CUD, the central bank has not imposed specific settlement timing requirements on participants. However, it applies fees to debit entries in deposit accounts that vary according to the time window in which a transaction is recorded. During the first pricing window, which runs from 6:00:00 am (or the system's opening time on a business day) until 17:00:59, the applicable fee is COP 3,570 per debit transaction. During the second pricing window, which runs from 17:01:00 until 5:59:59 am the following day, or until the opening of the next business day, the fee is COP 2.5 per million pesos debited with a minimum fee of COP 5,170 per transaction. For example, sending COP 5,000 million would cost COP 3,570 in the first pricing window and COP 12,500 in the second window; therefore, the second-window fee would be about 3.5 times higher. These rules are established in Banco de la República (2025).

Chart 2. Intraday Distribution of the Number of CUD Payments across Reserve-Requirement Regimes



Sources: CUD; authors' calculations. Notes: The chart shows the mean daily percentage of the total number of payments settled per ten-minute interval. The shaded area corresponds to the variable fee interval, which runs from 17:01:00 until 5:59:59 the following day, or until the opening of the next business day.

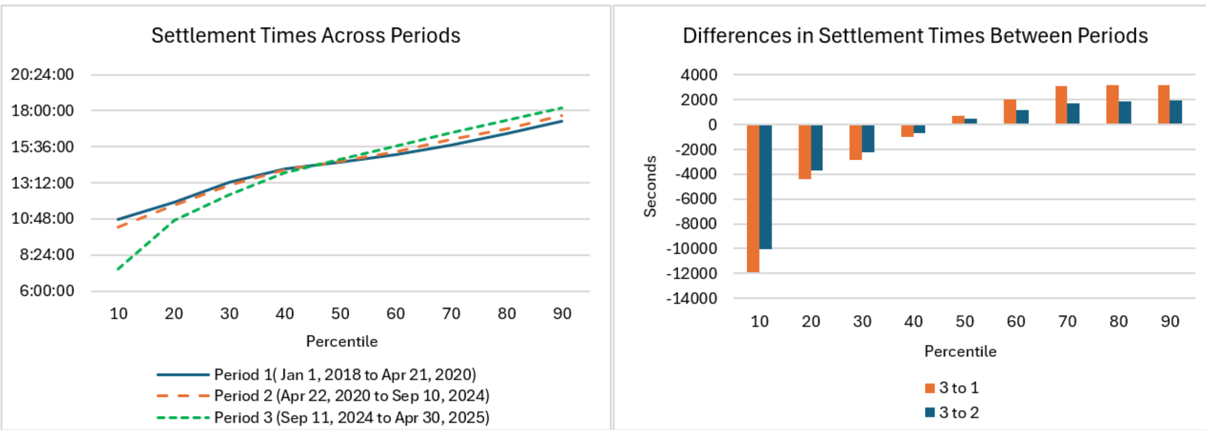
3.2. Distribution of Payment Values During the Day

Table A1 reports the mean and standard deviation of settlement times for each percentile of cumulative payment value from January 1, 2018 to April 30, 2025 across the three reserve-requirement regimes. The data is presented visually in Chart 3. Chart 4 complements these results by illustrating the evolution of these decile-specific settlement times over the full sample period. The data reveal a marked reallocation of settlement timing during the most recent regime (Period 3). At lower percentiles—particularly the 10th through the 40th—payments are settled substantially earlier in the day, while at higher percentiles (from the 50th onward) payments tend to shift later in the daily cycle.

A comparison between Periods 1 and 2 shows that at lower percentiles, payments experienced modest gains in settlement timing following the April 2020 reserve-requirement reduction: at the 10th percentile, payments settle 32 minutes earlier, and at the 40th percentile approximately 5 minutes earlier. From the 50th percentile onward, however, settlement times begin to shift later in the day. For instance, payments at the 70th percentile settle 24 minutes later, and at the 90th percentile are delayed by 21 minutes relative to Period 1. These patterns suggest that the liquidity released through the 2020 measure facilitated somewhat earlier settlement at lower-percentiles but had mixed effects in the upper part of the distribution, with settlement times above the median shifting toward later hours of the business day.

The most substantial adjustments in settlement behavior occur in Period 3, coinciding with the launch of the new DCV on April 1, 2024. Relative to Period 1, payments at the 10th percentile are settled 3 hours and 19 minutes earlier, and 2 hours and 47 minutes earlier relative to Period 2. At the 40th percentile, payments are settled relatively quickly, with settlement times 16 minutes earlier than in Period 1 and 12 minutes earlier than in Period 2. These shifts are clearly visible in Chart 4: the curves for the lower deciles experience a marked downward shift immediately after the introduction of the new securities-settlement infrastructure, indicating that participants began allocating early-day liquidity in a manner that facilitates quicker discharge of their payment obligations.

Chart 3. Percentile-Specific Settlement Times of Payments across Reserve-Requirement Regimes

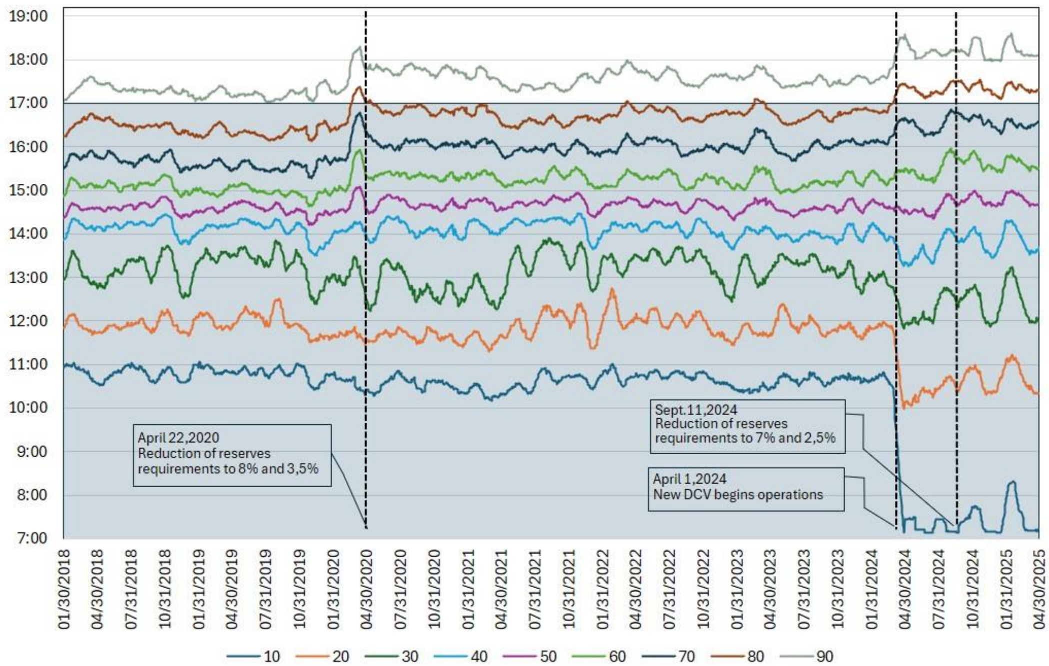


Sources: CUD; authors' calculations.

A further notable observation from Chart 3 is that, at the beginning of the second pricing window at 17:00, the cumulative proportion of settled value in Period 3 lies between the 70th and 90th percentiles. In earlier regimes, this point was closer to the 90th percentile. Chart 4 reinforces this finding by showing that the slopes of the 80th and 90th percentiles steepen after 17:00 in Period 3, reflecting a growing concentration of large-value transactions during the *ad valorem* pricing window. The chart also displays a clear structural break after April 2024, with the settlement curves of the lower deciles dropping sharply toward earlier times of day, while the upper deciles exhibit sustained late-day clustering. Seasonal fluctuations—such as slightly later settlement at month-end—also appear intermittently across deciles, suggesting periodic liquidity pressures.

Overall, the evidence indicates that the combination of reduced reserve requirements and the adoption of the new DCV meaningfully reshaped intraday liquidity usage in the CUD. The resulting pattern involves earlier settlement for lower-value payments, increased dispersion among high-percentile transactions, and a persistent concentration of large-value settlements late in the operational day.

Chart 4. Intraday Distribution of Payment Values: Decile-Specific Settlement Times across Reserve-Requirement Regimes



Sources: CUD; authors' calculations. Notes: The figure is based on 20-day moving averages.

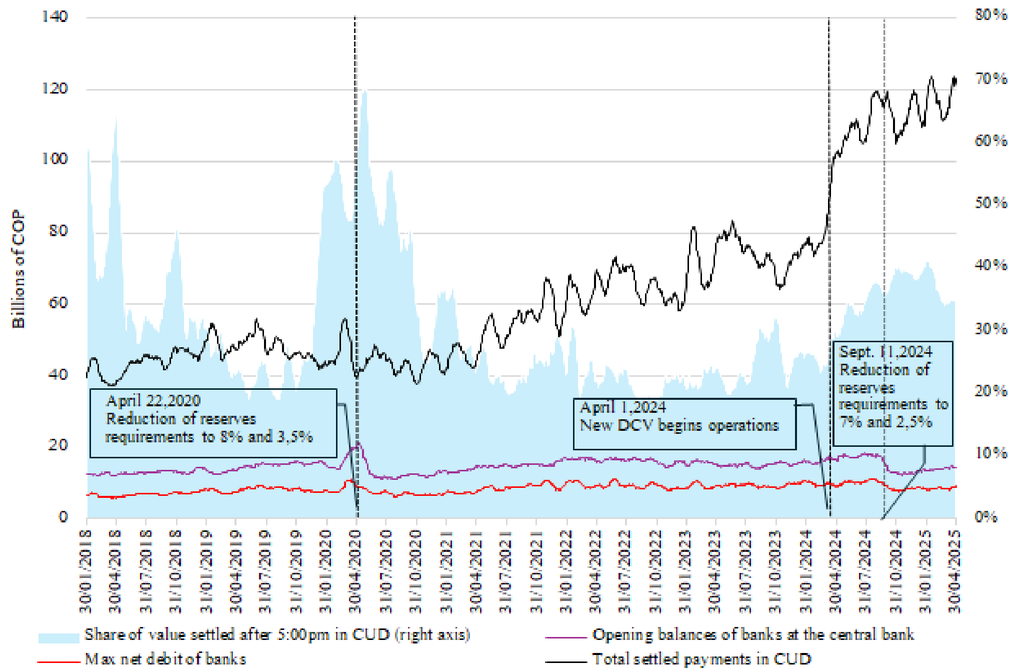
Chart 5 shows that periods characterized by lower opening balances and tighter maximum intraday debit[5] for credit institutions[6] —specifically those surrounding the reserve requirement reduction episodes of 2020 and 2024, as well as the period following the introduction of the new DCV—are associated with systematic changes in settlement patterns in the CUD. These periods are characterized by an increase in the proportion of total payment value settled after 17:00, consistent with a shift in the intraday distribution of settlements toward later hours of the operating day.

The aggregate value of payments settled in the CUD displays a gradual upward trend over the sample period and exhibits some discrete level shifts around the policy and infrastructure changes considered. This suggests that the adjustments observed primarily reflect changes in the timing of settlement rather than changes in the overall level of payment activity. Overall, the evidence points to a higher concentration of settlement activity toward the end of the operating day during periods of relatively tighter intraday liquidity.

[5] The maximum intraday debit of an entity is defined as the minimum amount of opening liquidity required to settle all payment obligations over the business day, given the realized chronological sequence of payments. This measure captures intraday liquidity needs and does not imply the availability or use of intraday credit.

[6] Credit institutions—namely commercial banks, financial corporations, finance companies, and financial cooperatives—constitute the only financial entities subject to reserve requirements.

Chart 5. Settlement Values, Payment Timing, and Opening and Maximum Net Debit Positions of Credit Institutions in the CUD



Sources CUD; authors' calculations. Notes: The calculations are based on 20-day moving averages.

4. Regression Analysis

4.1. Econometric Approach and Data

Our regression analysis identifies the main drivers of the timing distribution of daily transactions in Colombia's large-value payment system (CUD) from January 2, 2018 to April 30, 2025. We extend the analyses of Armantier et al. (2008), and Bech et al. (2012) to the Colombian case, focusing on the impact of changes in reserve requirements on the liquidity management of financial institutions.

To analyze the timing of payment settlements, we run nine individual regressions, each corresponding to a specific percentile of payment values below 100%. The dependent variable in each regression captures the settlement time for the respective percentile on a given day, measured in seconds from the opening of the CUD system. All nine regressions use the same set of explanatory variables.

The analysis uses transaction-level data from the CUD, Colombia's LVPS. All metrics are constructed from a transformed dataset designed to capture effective liquidity usage and actual settlement behavior. The dataset includes only transactions settled between 7:00 and 20:00 and incorporates exclusively the values that effectively settle. For netting processes conducted through the DCV, only the settlement of resulting net positions is retained, excluding underlying gross flows that do not generate additional liquidity demands.

To avoid distortions in the measurement of payment activity and intraday liquidity usage, several transaction categories are excluded. Transfers between accounts owned by the same institution are removed because they do not represent inter-institutional liquidity flows. Likewise, the constitution and unwinding of remunerated deposits are omitted, as well as transfers executed by the General Directorate of Public Credit and the National Treasury (DGCPTN) and by the General System of Royalties (SGR). These filtering criteria ensure that the final dataset reflects only economically meaningful payment flows between distinct participants and accurately represents settlement activity relevant for analyzing intraday timing, value concentration, and liquidity dynamics in the CUD.

Our analysis focuses on the impact of changes in reserve requirements on settlement liquidity, which we measure using dummy variables capturing the two regulatory reductions implemented by the Central Bank of Colombia in April 2020 and September 2024. Building on the literature, we incorporate a set of additional variables that may influence the availability and use of settlement liquidity. These include the daily value of payments processed in the CUD, the number of payments, the number of active entities on each payment day, and the ratio between daily repos and available reserves. We also consider the interest rate differential between the interbank rate and the policy rate as a measure of liquidity tensions in money markets that may influence the timing of payments. In addition, we include the Herfindahl-Hirschman Index (HHI) of payments across credit institutions to capture the concentration of payment activity among financial institutions, a dummy variable for the adoption of the new DCV in April 2024 and calendar effects. All dependent and explanatory variables are sourced from the Central Bank of Colombia. Summary statistics for the independent variables are presented in Table 1.

Table 1. Summary Statistics of Independent Variables

Variable	Mean	Median	Standard deviation	Minimum	Maximum
Payments (billions of pesos)	63,8	55,7	19,6	29,6	154,5
Transactions (thousands)	6.074,4	5.946,0	744,6	3.404,0	11.617,0
Members (number)	121,7	121,0	4,8	104,0	150,0
Repos/Reserves (percent)	20,2	19,2	9,3	0,3	70,1
IBR-MPR (percent)	-0,003	0,001	0,018	-0,344	0,085
HHI	450,7	443,7	43,0	338,9	946,1

Source: Authors´s calculations. Notes: Payments is the daily payments value settled in the system; transactions are the number of daily payments; members are the number of active entities in the payment system; Repos/Reserves is the ratio between daily repos and available reserves; IBR-MPR is the interest rate differential between the interbank rate and the monetary policy rate; HHI is a measure of payment concentration across active institutions.

We apply the method proposed by Newey and West (1987) to adjust the estimated standard errors, addressing potential issues of serial correlation and heteroskedasticity. The estimation is performed in levels, as unit root tests (including the Phillips-Perron and augmented Dickey-Fuller tests) reject the null hypothesis of non-stationarity in the settlement time for the respective percentile on a given day. We estimated the following equation:

$$p_t^i = \beta_0^i + \beta_1^i RR2020_t + \beta_2^i RR2024_t + \beta_3^i Payments_t + \beta_4^i Transactions_t$$
$$+\beta_5^i Members_t + \beta_6^i \, Repos/Reserves_t + \beta_7^i HHI_t + \beta_8^i DCV_t + \beta_9^i EOM_t + \beta_{10}^i t + \varepsilon_t^i \qquad (1)$$

where p_t^i denotes the time in seconds at which the *i*-th percentile (where *i* equals 10, 20, …, 90) of the daily total payment value is submitted on day *t*; $RR2020_t$ is a dummy variable equal to 1 from April 22, 2020 to September 10, 2024, during which the reserve requirement ratio for checking and saving accounts decreased from 11% to 8% and for time deposits (CDs) with maturities under 18 months decreased from 4.5% to 3.5%; $RR2024_t$ is a dummy variable equal to 1 from September 11, 2024 onward, when the reserve requirement ratio for checking and saving accounts decreased from 8% to 7% and for CDs with maturities under 18 months decreased from 3.5% to 2.5%; $Payments_t$ is the daily payments value settled in the system on day *t*; $Transactions_t$ is the number of daily payments on day *t;* $Members_t$ is the number of active entities in the payment system on day *t*; $Repos/Reserves_t$ is the ratio between daily repos and available reserves on day *t*; HHI_t is a measure of payment concentration across active institutions on day *t*; DCV_t is a dummy variable equal to 1 from April 1, 2024, when a new Central Securities Depository (DCV) was adopted; EOM_t is a dummy variable equal to 1 at the end of each month; and *t* is the time trend.

In addition to Equation (1), and following Alexandrova et al. (2023), we examine the overall effects of the reduction in reserve requirements on the ease of payment settlement by estimating the value-weighted average settlement time of payments made on any given day t as follows:

$$T_s = \frac{\sum_{t=1}^{T} t P_s(t)}{\sum_{t=1}^{T} P_s(t)} \qquad (2)$$

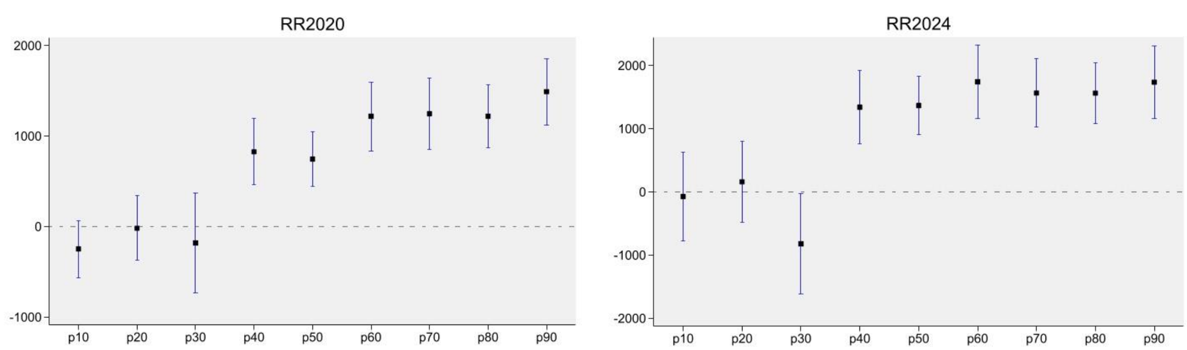
where $P_s(t)$ is the aggregate value of payments made on day s during time interval *t,* and the denominator represents the total value of payments settled through the system on day s. Under this measure, late payments are assigned a greater weight than early payments, as the weighting factor—the number of seconds elapsed since 7:00:00 a.m.—increases with the settlement time of the payment.

4.2. Results

Regression results for each of the nine deciles (Equation 1) and for the weighted measure of payment timing (Equation 2) are reported in Table A2. We present the estimated coefficients on reserve requirement reductions across percentiles graphically in Chart 6 and those on the remaining control variables in Charts 7–10. Each panel corresponds to an explanatory variable and shows the estimated coefficients for the 10th to 90th percentiles, along with the 95% confidence intervals. The x-axis represents the percentile of the payment value, and the y-axis represents the time in seconds at which the payment is settled for each percentile. If the confidence interval crosses zero, the point estimate is not statistically significant.

As illustrated in Chart 6, the reduction in the reserve requirement ratios appears to have increased the time required for payment settlement, particularly from the 40th to 90th percentiles. Although a more abundant liquidity environment is often associated with reduced payment delays and lower liquidity and credit risk, the actual timing of payments depends on how institutions allocate the liquidity released by policy changes. In practice, some participants may allocate part of the additional liquidity to short-term money market operations, whose profitability depends primarily on prevailing interest rate conditions, before executing other payments, thereby shifting settlement activity toward later hours of the day. Furthermore, given that intraday liquidity usage depends on the degree of payment recycling (Alexandrova et al, 2023), which itself is determined by payment timing, the results reported in the last column of Table A2 indicate that changes in reserve requirements, especially the reform implemented in 2024, caused payments to be settled later in the day. This result is consistent with the evidence from the percentile-based estimations. The literature suggests that these effects are asymmetric across institutions (Schulz, 2011). Large participants may experience limited improvements if their liquidity needs already exceed the threshold at which delays are eliminated, meaning that additional funds simply increase posted liquidity or collateral without altering settlement patterns. In contrast, smaller institutions are more likely to benefit, as their relatively modest payment volumes make them more sensitive to marginal changes in available liquidity. Additionally, the reserve-requirement reduction implemented during the COVID-19 pandemic coincided with several additional liquidity measures, complicating efforts to isolate financial institutions' liquidity-management behavior during this period. In the following section, we examine how the reduction in the reserve requirement ratios affects settlement timing across large, medium, and small participants to assess the extent and nature of these heterogeneous responses.

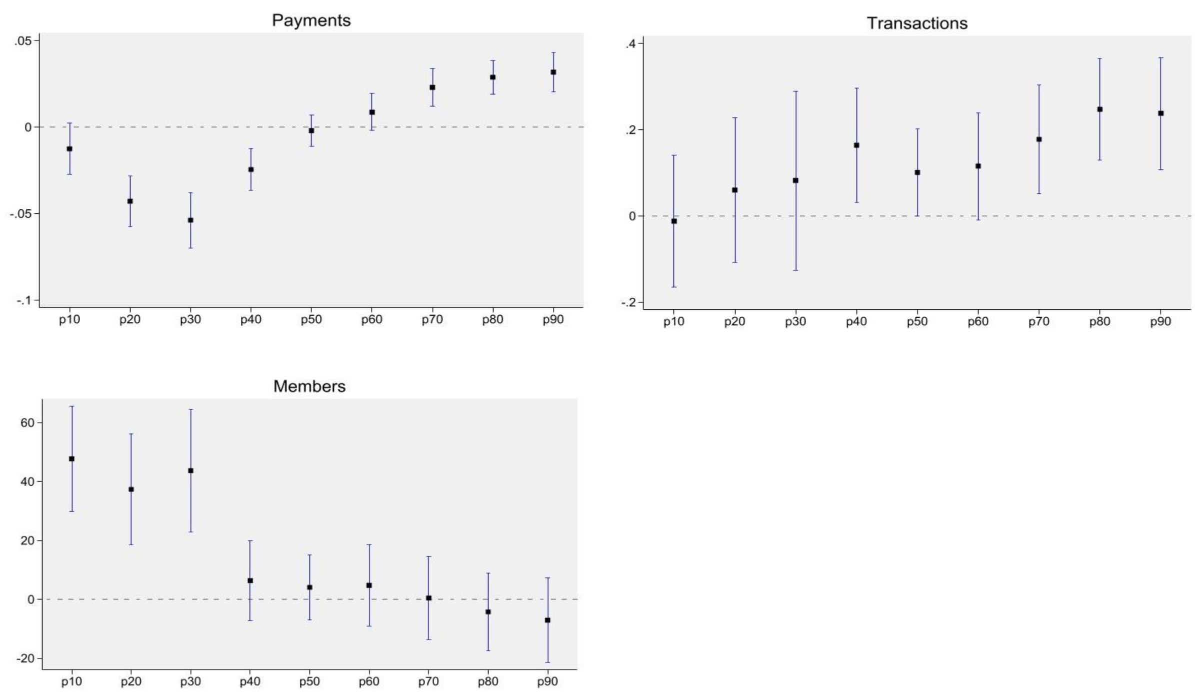
Chart 6. Regression Estimates of Reserve-Requirement Reductions in 2020 and 2024



Notes: RR2020 is a dummy variable equal to 1 from April 22, 2020 to September 10, 2024, corresponding to the reserve requirement reduction implemented in April 2020; RR2024 is a dummy variable equal to 1 from September 11, 2024 onward, corresponding to the reserve requirement reduction implemented in September 2024.

Chart 7 shows the coefficients for the value of payments, the number of transactions, and the number of active members. The coefficients associated with the value of payments are significant and negative for the 10th to 40th percentiles, and significant and positive for the 70th to 90th percentiles. This suggests that earlier in the day, higher payment values reduce settlement time, while closer to the system's closing time, higher payment values delay settlement. For the number of transactions, the coefficients are significant and positive after the 40th percentile, indicating that a higher volume of transactions delays payment settlement in the system. The results for both the value and volume of payments suggest that the additional return required for accepting liquidity risk increases later in the day, possibly due to time-critical payments requiring more intraday liquidity and longer processing times (Zhang, 2015). The results for the number of active institutions indicate that when the number of participants in the payment system increases earlier in the morning, settlement slows down, likely because only a few entities are more efficient in sending payments than others.

Chart 7. Regression Estimates of Values, Volumes, and Active Entities

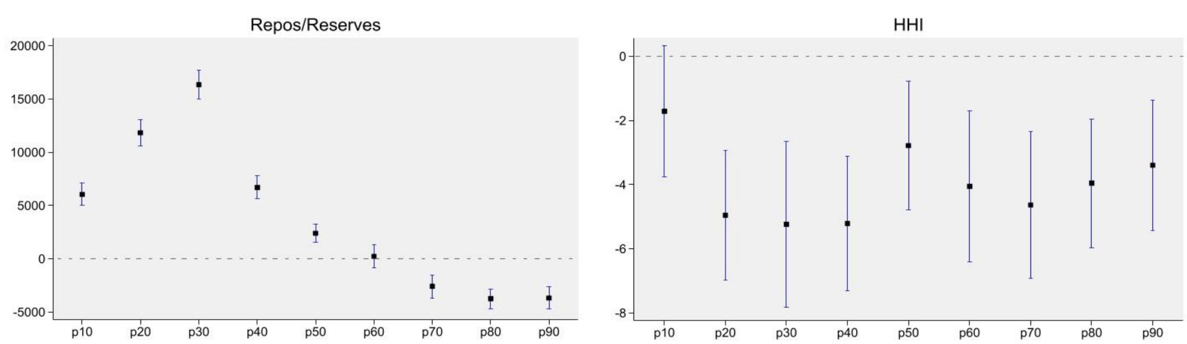


Notes: Payments denote the daily payments value settled in the system on day t; transactions are the number of daily payments on day t; members are the number of active entities in the payment system on day t.

Regression results in Chart 8 suggest that higher ratios of repos to available reserves in the 10th to 50th percentiles put more pressure on the payment system, increasing the time at which payments are settled. However, by the end of the day, the ease of settling payments improves as the central bank fulfils the system´s demand for repos, thereby facilitating market participants in meeting their settlement and payment obligations. In Table A3, we replace in the regressions the ratio of repos to available reserves with the interest rate differential between the interbank rate and the monetary policy rate, given the correlation between these variables. The interest rate differential captures liquidity pressures in the money market and can be interpreted as the opportunity cost of holding reserves. We find that an increase in this opportunity cost is associated with payment delays between the 10th and 40th percentiles, consistent with the hypothesis of Alexandrova et al. (2023) that deteriorating market conditions make liquidity more expensive and may lead participants to delay outgoing payments. However, later in the day—specifically between the 60th and 90th percentiles—the opportunity cost of reserves becomes less relevant, likely because participants have already met their liquidity needs, reducing its impact on payment timing. We also observe in Chart 8 that a higher degree of concentration in payment activity across active institutions accelerates settlement. This result is in line with Armantier et al. (2008), who argue that increased industry concentration can enhance coordination and facilitate intraday payment flows.

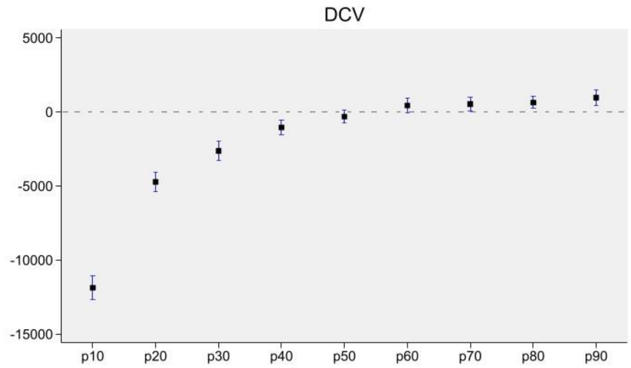
On April 1, 2024, a new DCV system came into operation. This financial market infrastructure is essential for the custody, clearing, and settlement of transactions involving public debt securities, the fiduciary management of government securities, and the implementation of the central bank's monetary policy. The point estimates associated with the adoption of this new market infrastructure (Chart 9) indicate that, although the adoption of this new operating framework has decreased the time at which payments are settled for the 10th to 40th percentiles, the speed with which payments are settled later in the day has declined, particularly for the 70th to 90th percentiles. These changes may be explained, at least in part, by a learning curve among participants as they adapt to the new DCV's functionalities and operational features, As a result, this pattern may not persist over time, as participants become more familiar with the system and adjust their liquidity-management and operational practices to achieve earlier settlement across payment deciles.

Chart 8. Regression Estimates of Repo Use and Payment Concentration across Institutions



Notes: Repos/Reserves is the ratio between daily repos and available reserves on day t; HHI is a measure of payment concentration across active institutions on day t.

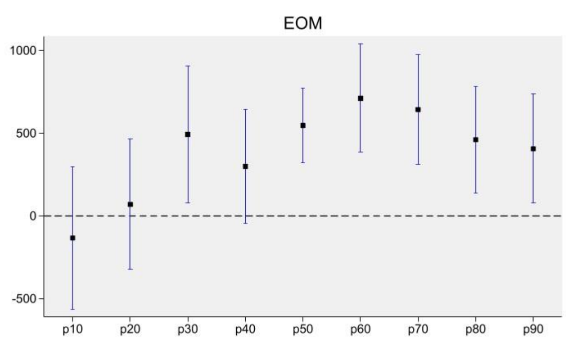
Chart 9. Regression Estimates of the New DCV Payment-Settlement System Adopted in April 2024

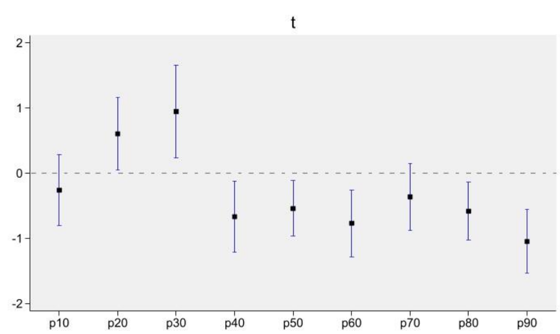


Notes: DCV is a dummy variable equal to 1 from 1 April 2024 onward, corresponding to the adoption of the new Central Securities Depository (DCV) system.

Our findings indicate that the ease of settling payments declines toward the end of the month, particularly after the 30th percentile (Chart 10). This outcome is likely linked to the payment commitments that financial institutions are required to process at month-end. Additionally, the time trend is observed to be significantly negative for most percentiles throughout the day. This suggests that over time, the timing of CUD transfers has improved. The influence of the time trend on the timing of CUD transfers lends support to the hypothesis that advancements in technology—such as the implementation of improved queuing mechanisms by various banks—may have played a role in expediting transfers over the CUD system. These findings are consistent with the results reported by Armantier et al. (2008) for the Fedwire large-value payment system.

Chart 10. Regression estimates of Calendar Effects and Time Trends





Notes: EOM is a dummy variable equal to 1 at the end of each month; t is the time trend.

4.3. Effects of Reductions in Reserve Requirements across Different Types of Participants

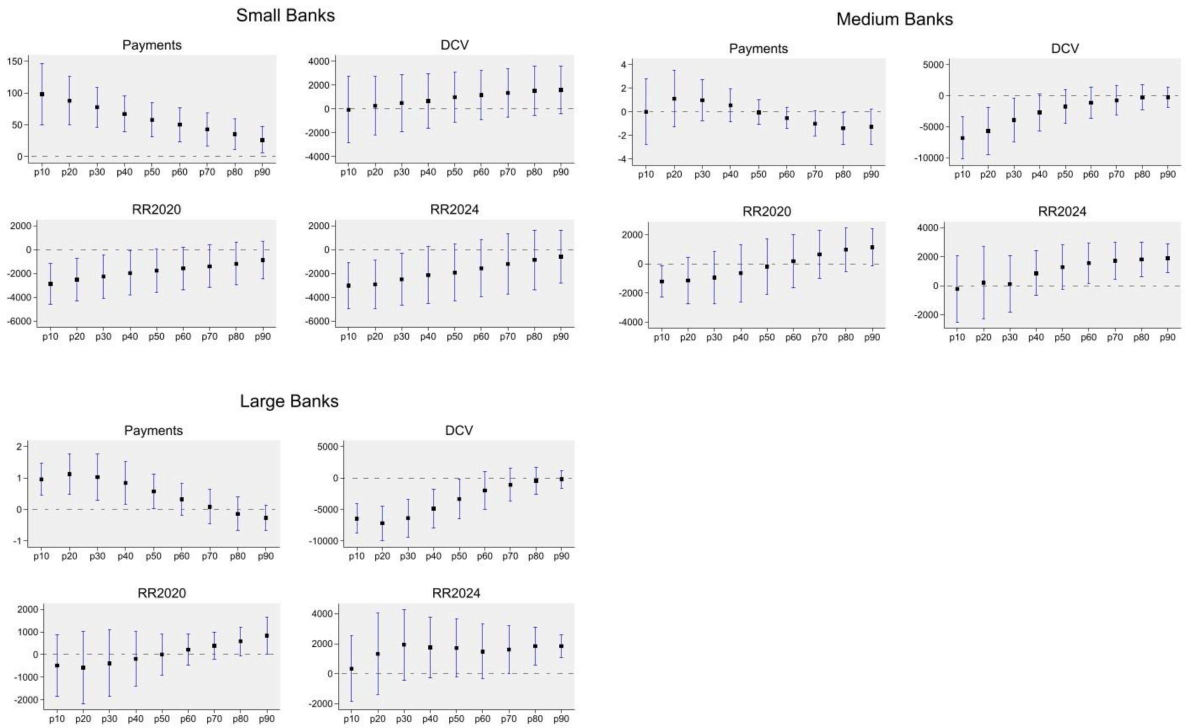
Given that reductions in reserve requirements may generate heterogeneous adjustments among large, medium, and small institutions, this section examines the asymmetric impact of these policy measures across banks. To classify banks by size, we construct three groups—small, medium-sized, and large—based on their average daily payment activity. Specifically, we rank banks based on their average daily payment values and divide this distribution into three equally sized categories (terciles), reflecting the structure of the banking sector in Colombia. Banks in the lowest tercile are labeled as small, those in the middle tercile as medium, and those in the highest tercile as large. Since the entities included in this analysis are credit institutions, it is important to note that while reserve requirements apply directly and exclusively to this type of institutions, other participants may also be indirectly affected through changes in the settlement behavior of credit institutions acting as their counterparties.

This procedure ensures that the size groups are determined consistently and are comparable across institutions. Chart 11 reports the coefficient estimates from the nine decile regressions for each group. Because variables such as the concentration of payment values or the number of active entities exhibit limited variation when the sample is restricted to specific institution sizes, the regressions are estimated only with the value of payments and the dummy variables capturing the changes in reserve requirements and the adoption of the new DCV system.

The results displayed in Chart 11 reveal clear heterogeneity across participants. Additional liquidity stemming from reductions in reserve requirements shortens settlement times for small banks at the lower percentiles, relative to the effects observed for large banks. By contrast, both medium-sized and large banks exhibit a systematic increase in settlement times, particularly at the upper percentiles, with the impact being more pronounced following the 2024 reserve-requirement change. Moreover, higher payment values for small banks are associated with a delay in settlement timing, in contrast to the patterns documented for medium-sized and large institutions. The introduction of the new DCV system also produces significant effects between the 10th and 50th percentiles for medium-sized and large banks, indicating that the operational change influenced their timing behavior during the earlier portions of the distribution.

Taken together, these results confirm the presence of asymmetric responses across institution sizes to the policy measures adopted by the central bank, underscoring the importance of heterogeneity when assessing the transmission of liquidity-related interventions in large-value payment systems.

Chart 11. Regression Estimates by Bank Size (Based on Payment Activity)



Notes: Payments denote the daily payments value settled in the system on day t; DCV is a dummy variable equal to 1 from April 1, 2024 onward, corresponding to the adoption of the new Central Securities Depository (DCV) system; RR2020 is a dummy variable equal to 1 from April, 22 2020 to September 10, 2024, corresponding to the reserve requirement reduction implemented in April 2020; RR2024 is a dummy variable equal to 1 from September 11, 2024 onward, corresponding to the reserve requirement reduction implemented in September 2024.

4.4. Robustness analysis

Since government deposits at the central bank and the constitution and unwinding of remunerated deposits could affect settlement liquidity in the system, it is important to verify that our main findings are not sensitive to these types of deposits. To assess the robustness of our empirical findings, Table A4 presents ordinary least squares estimates with Newey–West standard errors using the non-transformed data.

The results closely mirror the patterns documented in Charts 6–10. In particular, the reductions in reserve requirements in 2020 and 2024 are linked to delays in settlement primarily from the 40th to the 90th percentiles, consistent with the idea that additional liquidity may be reallocated to short-term market operations before being used for settlement. The estimated coefficients for payment value remain negative and significant for the 10th to 40th percentiles, positive and significant for the 70th to 90th percentiles, reproducing the asymmetric intraday effect described earlier. The coefficients on the number of transactions display positive and significant effects at the lower percentiles. This indicates that increases in transaction volume are associated with earlier settlement during the first part of the day, when the data used in the estimation incorporates all transactions in the system. The number of active institutions also displays the expected pattern of positive and significant at the lower percentiles, indicating slower settlement early in the morning when participation is higher, and small or insignificant effects thereafter.

Liquidity conditions show a comparable degree of consistency. The ratio of repos to available reserves is positive and highly significant at most percentiles, with larger coefficients around the 30th to 40th percentiles and a noticeable attenuation later in the day. This aligns with our interpretation that liquidity pressures are most acute in the middle of the distribution, while the system becomes more efficient once the central bank meets the outstanding demand for repos. The effect of payment concentration measured by the HHI is negative and significant across the distribution, confirming that greater concentration facilitates earlier settlement and supports the coordination mechanism discussed in Armantier et al. (2008).

The adoption of the new DCV system is associated with earlier settlement for the 10th to 40th percentiles and later settlement for the 70th to 90th percentiles, reproducing the pattern described in Chart 9. Finally, the end-of-month dummy produces positive and significant coefficients after the 40th percentile, indicating delayed settlement at month-end, while the time trend is negative and significant at most mid-to-late percentiles, supporting the conclusion that settlement times have improved over the sample period.

Overall, the strong alignment between the non-transformed estimates in Table A4 and the results derived from Charts 6–10 confirms that our empirical findings are robust. The consistency in signs, magnitudes, and percentile patterns across specifications reinforces our interpretation of the underlying mechanisms driving intraday settlement dynamics in Colombia's large-value payment system.

5. Conclusions

This paper analyzes the intraday timing of settled transactions in Colombia's RTGS LVPS (CUD) over 2018–2025, with a focus on how reserve requirement reductions shape intraday liquidity usage. Using both descriptive evidence on intraday payment profiles and regression models that explain the settlement time of cumulative value percentiles (from the 10th to the 90th), we document a clear reallocation of settlement activity within the operational day.

Three empirical results stand out. First, discrete reductions in reserve requirements are associated with a pronounced shift of settlement activity toward later hours, particularly in the upper part of the value distribution. While low cumulative value percentiles may settle relatively early, the system increasingly concentrates large-value settlements toward late afternoon and the end of the operating day following these policy changes. Consistent with this pattern, estimates based on the value-weighted average settlement time of payments indicate that reductions in reserve requirements led to later payment settlement, a finding that corroborates the evidence from the percentile-based estimations.

Second, the results also highlight substantial heterogeneity across participants. When institutions are grouped by size (based on average daily payment activity), smaller participants exhibit stronger timing responses in the lower percentiles, while medium-sized and large participants show more systematic delays in the upper percentiles. This asymmetric response is consistent with the view that, in a concentrated and interdependent LVPS, timing decisions by major participants shape the system settlement path, while smaller institutions remain more sensitive to marginal liquidity conditions and incoming-payment dependence.

Third, other institutional and liquidity-related factors play an important role in shaping settlement liquidity. The introduction of the new DCV system in April 2024 coincides with a structural change in intraday settlement patterns: payments at lower value percentiles tend to settle earlier, whereas higher percentile payments shift later, increasing the concentration of large-value settlements late in the day. Moreover, liquidity sourcing matters. Greater reliance on intraday repos relative to reserve balances is associated with slower settlement early in the day, while later in the day settlement becomes faster as liquidity is distributed through central bank operations. Additional determinants reinforce these patterns. Higher daily payment values and volumes are associated with different timing effects across the distribution, consistent with an increasing premium on liquidity risk later in the day. Calendar effects at month-end are linked to slower settlement beyond early percentiles, suggesting periodic liquidity and operational pressures. Finally, a negative time trend indicates that settlement timing has improved gradually over the sample, consistent with ongoing technology and process improvements in participants' internal payment management.

Overall, these findings emphasize that changes in available liquidity need not translate mechanically into earlier settlement; payment timing reflects how participants allocate liquidity intraday and how institutional design affects coordination incentives.

From a payment system oversight and policy perspective, the documented shift toward later settlement raises two considerations. The first is operational: a higher concentration of large value flows late in the day can increase exposure to disruptions close to system closure. The second is systemic: in an interconnected RTGS system, strategic delays by one participant can propagate through liquidity recycling channels, potentially amplifying coordination frictions. These results therefore motivate close monitoring of intraday timing metrics (particularly the behavior of upper value percentiles) when reserve requirement policy, collateral frameworks, or related financial market infrastructures (such as a securities settlement system) are adjusted.

A natural avenue for future research is to move beyond size-based heterogeneity toward behavioral heterogeneity by clustering participants according to their intraday payment strategies. This approach would distinguish "early payers" from more liquidity-dependent "wait-and-pay" participants that rely on incoming payments to fund outgoing obligations. Future research could also examine the temporal adjustment of participants' behavior following changes in reserve requirements. The effects observed immediately after a policy change may differ from those that emerge over longer horizons, as participants gradually learn about the responses of other institutions and adapt their own liquidity management strategies, eventually converging to a new equilibrium. In addition, the biweekly maintenance framework provides an opportunity to investigate whether payment timing differs systematically between the first and second weeks of the reserve requirement cycle, shedding further light on the interaction between reserve management and settlement behavior.

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Appendix

Table A1. Percentile-Specific Settlement Times of Payments across Reserve-Requirement Regimes

Period	1		2		3		Difference (minutes)	
	Jan 1, 2018 to Apr 21, 2020		Apr 22, 2020 to Sep 10, 2024		Sep 11, 2024 to Apr 30, 2025		Between periods	
Percentile	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	3 to 1	3 to 2
10	10:47:19	0:25:39	10:15:50	1:05:53	7:28:32	0:37:29	-03:18:47	-02:47:19
20	11:54:16	0:30:33	11:41:44	0:43:54	10:40:25	0:36:34	-01:13:51	-01:01:19
30	13:12:52	0:41:45	13:02:55	0:44:43	12:25:44	0:42:03	-00:47:09	-00:37:11
40	14:07:17	0:23:39	14:02:52	0:26:32	13:51:12	0:31:21	-00:16:05	-00:11:40
50	14:35:12	0:18:17	14:39:11	0:19:06	14:47:22	0:21:32	+00:12:10	+00:08:11
60	15:03:41	0:22:37	15:16:56	0:23:04	15:37:02	0:24:42	+00:33:21	+00:20:05
70	15:41:04	0:25:50	16:04:30	0:23:31	16:33:17	0:21:41	+00:52:14	+00:28:47
80	16:27:20	0:23:04	16:48:47	0:22:28	17:20:18	0:20:46	+00:52:58	+00:31:31
90	17:18:32	0:23:22	17:39:46	0:23:57	18:11:51	0:25:49	+00:53:18	+00:32:05

Sources: CUD; authors' calculations.

Table A2. Estimated Coefficients and Timing Effects (in Seconds)

	Percentile									
Explanatory variables	10	20	30	40	50	60	70	80	90	T
RR2020	-246.7	-17.66	-180.3	827.6***	745.9***	1,219***	1,249***	1,220***	1,491***	624.8***
	(161.1)	(181.9)	(282.8)	(187.0)	(155.1)	(193.8)	(202.4)	(177.1)	(186.2)	(134.4)
RR2024	-73.20	160.8	-820.4**	1,339***	1,367***	1,744***	1,566***	1,564***	1,737***	838.4***
	(357.0)	(329.1)	(401.9)	(294.5)	(233.8)	(293.4)	(275.5)	(244.8)	(291.4)	(191.8)
Payments	-0.0125*	-0.0428***	-0.0538***	-0.0245***	-0.00196	0.00867	0.0229***	0.0289***	0.0318***	-0.00333
	(0.00758)	(0.00770)	(0.00835)	(0.00638)	(0.00464)	(0.00551)	(0.00554)	(0.00503)	(0.00591)	(0.00413)
Transactions	-0.0116	0.0605	0.0822	0.164**	0.101**	0.116*	0.178***	0.247***	0.238***	0.126***
	(0.0779)	(0.0853)	(0.106)	(0.0675)	(0.0515)	(0.0633)	(0.0644)	(0.0598)	(0.0661)	(0.0443)
Members	47.71***	37.35***	43.69***	6.372	4.074	4.806	0.480	-4.244	-7.061	13.02***
	(9.074)	(9.568)	(10.65)	(6.903)	(5.677)	(7.037)	(7.175)	(6.771)	(7.316)	(4.907)
Repos/Reserves	6,049***	11,835***	16,348***	6,699***	2,398***	235.5	-2,586***	-3,751***	-3,676***	3,582***
	(529.0)	(625.5)	(693.7)	(550.8)	(446.5)	(566.0)	(549.0)	(468.5)	(537.6)	(370.1)
HHI	-1.714*	-4.955***	-5.239***	-5.210***	-2.781***	-4.055***	-4.635***	-3.955***	-3.393***	-3.941***
	(1.041)	(1.029)	(1.317)	(1.072)	(1.028)	(1.201)	(1.163)	(1.024)	(1.035)	(0.802)
DCV	-11,864***	-4,715***	-2,628***	-1,037***	-310.7	443.4*	552.4**	646.0***	983.7***	-1,984***
	(408.4)	(345.7)	(338.8)	(266.4)	(212.8)	(257.6)	(236.2)	(208.3)	(264.2)	(181.4)
EOM	-134.1	69.03	491.1**	299.1*	545.5***	710.6***	641.6***	460.2***	405.2**	341.5***
	(219.9)	(201.2)	(211.5)	(174.7)	(114.1)	(166.7)	(169.8)	(165.0)	(168.0)	(105.9)
t	-0.260	0.605**	0.949***	-0.666**	-0.541**	-0.768***	-0.361	-0.583**	-1.047***	-0.287
	(0.277)	(0.283)	(0.360)	(0.279)	(0.217)	(0.261)	(0.260)	(0.227)	(0.249)	(0.181)
Constant	8,236***	14,631***	18,140***	26,303***	27,249***	29,327***	31,725***	34,343***	37,542***	25,248***
	(1,044)	(1,064)	(1,180)	(811.7)	(633.2)	(778.1)	(769.5)	(713.1)	(784.9)	(544.4)
Observations	1,789	1,789	1,789	1,789	1,789	1,789	1,789	1,789	1,789	1,789
Adjusted R-squared	0.885	0.567	0.431	0.242	0.089	0.194	0.404	0.486	0.453	0.315

Source: Authors´s calculations. Notes: Ordinary least squares (OLS) regressions with Newey-West standard errors reported in parentheses. Percentile denotes the time in seconds at which the i-th percentile (where i equals 10, 20, …, 90) of the daily total payment value is submitted on day t. The dependent variable, T, in the last column is the value-weighted average settlement time of payments made on any given day, as defined in Equation (2). RR2020 is a dummy variable equal to 1 from April 22, 2020 to September 10, 2024, during which the reserve requirement ratio for checking and saving accounts decreased from 11% to 8% and for CDs with maturities under 18 months decreased from 4.5% to 3.5%; RR2024 is a dummy variable equal to 1 from September 11, 2024, when the reserve requirement ratio for checking and saving accounts decreased from 8% to 7% and for CDs with maturities under 18 months decreased from 3.5% to 2.5%; payments is the daily payments value settled in the system on day t; transactions are the number of daily payments on day t; members are the number of active entities in the payment system on day t; Repos/Reserves is the ratio between daily repos and available reserves on day t; HHI is a measure of payment concentration across active institutions on day t; DCV is a dummy variable equal to 1 from April 1, 2024, when a new Central Securities Depository (DCV) was adopted; EOM is a dummy variable equal to 1 at the end of each month; t is the time trend.

*** p<0.01, ** p<0.05, * p<0.1

Table A3. Estimated Coefficients and Timing Effects (in Seconds) Using the Interest Rate Differential (IBR – MPR)

	Percentile									
Explanatory variables	10	20	30	40	50	60	70	80	90	T
RR2020	-354.6**	-213.1	-460.2	737.5***	741.6***	1,282***	1,364***	1,347***	1,607***	593.6***
	(175.6)	(213.5)	(331.3)	(195.9)	(143.7)	(169.7)	(180.8)	(164.8)	(177.6)	(128.5)
RR2024	194.6	752.3**	-31.16	1,701***	1,548***	1,879***	1,572***	1,509***	1,661***	1,055***
	(386.1)	(379.0)	(494.2)	(341.1)	(241.4)	(286.7)	(266.3)	(237.6)	(290.9)	(209.0)
Payments	0.0198***	0.0218***	0.0344***	0.0148**	0.0156***	0.0183***	0.0178***	0.0162***	0.0185***	0.0199***
	(0.00738)	(0.00756)	(0.00857)	(0.00622)	(0.00460)	(0.00518)	(0.00527)	(0.00492)	(0.00556)	(0.00413)
Transactions	-0.126	-0.168*	-0.229**	0.0193	0.0302	0.0655	0.179***	0.278***	0.272***	0.0352
	(0.0776)	(0.0927)	(0.113)	(0.0701)	(0.0523)	(0.0626)	(0.0635)	(0.0613)	(0.0681)	(0.0453)
Members	48.50***	39.01***	45.93***	7.335	4.484	4.994	0.289	-4.594	-7.437	13.56***
	(9.328)	(10.82)	(12.36)	(7.429)	(5.816)	(6.977)	(7.102)	(6.827)	(7.423)	(5.195)
IBR-MPR	6,219***	11,049***	16,209***	3,757**	-1,794	-7,346***	-10,604***	-10,591***	-9,578***	-45.71
	(1,436)	(1,985)	(3,234)	(1,840)	(1,755)	(1,987)	(1,840)	(1,680)	(1,857)	(1,379)
HHI	-0.0582	-1.660	-0.705	-3.345***	-2.096**	-3.948***	-5.309***	-4.945***	-4.376***	-2.943***
	(1.154)	(1.315)	(1.525)	(1.011)	(0.895)	(0.991)	(0.980)	(0.898)	(0.946)	(0.719)
DCV	-12,618***	-6,264***	-4,736***	-1,955***	-707.6***	249.0	712.2***	967.2***	1,325***	-2,509***
	(406.6)	(365.9)	(377.3)	(292.5)	(219.5)	(257.6)	(240.4)	(213.9)	(269.1)	(190.2)
EOM	-48.36	233.6	722.8***	377.7**	556.5***	672.4***	560.9***	370.2**	320.9*	371.7***
	(225.0)	(217.8)	(242.1)	(186.1)	(112.3)	(155.3)	(163.8)	(165.4)	(168.8)	(109.6)
t	-0.784***	-0.467	-0.496	-1.360***	-0.902***	-1.060***	-0.420*	-0.500**	-0.935***	-0.730***
	(0.289)	(0.308)	(0.418)	(0.286)	(0.212)	(0.246)	(0.249)	(0.223)	(0.245)	(0.183)
Constant	7,892***	13,892***	17,144***	25,866***	27,050***	29,212***	31,776***	34,466***	37,684***	24,998***
	(1,113)	(1,266)	(1,392)	(846.7)	(635.8)	(766.4)	(771.8)	(741.8)	(817.0)	(573.6)
Observations	1,788	1,788	1,788	1,788	1,788	1,788	1,788	1,788	1,788	1,789
Adjusted R-squared	0.874	0.449	0.221	0.127	0.063	0.217	0.425	0.490	0.452	0.243

Source: Authors´s calculations. Notes: Ordinary least squares (OLS) regressions with Newey-West standard errors reported in parentheses. Percentile denotes the time in seconds at which the i-th percentile (where i equals 10, 20, …, 90) of the daily total payment value is submitted on day t. The dependent variable, T, in the last column is the value-weighted average settlement time of payments made on any given day, as defined in Equation (2). RR2020 is a dummy variable equal to 1 from April 22, 2020 to September 10, 2024, during which the reserve requirement ratio for checking and saving accounts decreased from 11% to 8% and for CDs with maturities under 18 months decreased from 4.5% to 3.5%; RR2024 is a dummy variable equal to 1 from September 11, 2024, when the reserve requirement ratio for checking and saving accounts decreased from 8% to 7% and for CDs with maturities under 18 months decreased from 3.5% to 2.5%; payments is the daily payments value settled in the system on day t; transactions are the number of daily payments on day t; members are the number of active entities in the payment system on day t; IBR-MPR is the interest rate differential between the interbank rate and the monetary policy rate on day t; HHI is a measure of payment concentration across active institutions on day t; DCV is a dummy variable equal to 1 from April 1, 2024, when a new Central Securities Depository (DCV) was adopted; EOM is a dummy variable equal to 1 at the end of each month; t is the time trend.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A4. Estimated Coefficients and Timing Effects (in Seconds) Based on Non-Transformed Data

	Percentile								
Explanatory variables	10	20	30	40	50	60	70	80	90
RR2020	-25.32	350.6**	-298.8	672.2***	532.6***	999.0***	1,278***	1,107***	1,390***
	(186.2)	(151.1)	(308.3)	(221.9)	(147.7)	(214.9)	(233.4)	(206.2)	(206.7)
RR2024	283.7	831.4***	-918.9**	1,473***	1,091***	1,318***	1,537***	1,378***	1,562***
	(398.3)	(299.0)	(425.0)	(334.7)	(223.3)	(305.7)	(308.9)	(268.7)	(307.9)
Payments	-0.0347***	-0.0310***	-0.0568***	-0.0358***	-0.00112	0.00420	0.0178***	0.0226***	0.0262***
	(0.0104)	(0.00745)	(0.00924)	(0.00663)	(0.00461)	(0.00607)	(0.00616)	(0.00570)	(0.00699)
Transactions	0.457***	0.319***	0.0453	0.348***	0.0378	-0.0235	-0.0620	-0.0523	-0.0823
	(0.0806)	(0.0633)	(0.106)	(0.0675)	(0.0454)	(0.0634)	(0.0672)	(0.0630)	(0.0668)
Members	38.90***	10.80*	20.81*	-7.286	-0.294	3.811	3.101	10.74*	15.63**
	(7.773)	(6.274)	(10.93)	(6.317)	(4.542)	(5.928)	(6.655)	(6.166)	(6.446)
Repos/Reserves	6,636***	7,340***	18,070***	8,025***	2,499***	1,693***	-964.1*	-2,754***	-2,909***
	(591.0)	(545.7)	(717.2)	(553.7)	(366.8)	(525.4)	(540.8)	(465.2)	(519.8)
HHI	0.570	-4.859***	-9.806***	-7.474***	-3.662***	-4.797***	-5.707***	-5.211***	-4.335***
	(1.170)	(0.939)	(1.500)	(1.082)	(0.869)	(1.148)	(1.214)	(1.114)	(1.158)
DCV	-11,678***	-4,357***	-2,139***	-672.5**	260.8	1,221***	1,554***	1,354***	1,723***
	(463.0)	(321.5)	(352.6)	(270.9)	(201.7)	(253.3)	(253.3)	(216.3)	(285.6)
EOM	-276.7	-153.0	160.3	312.6*	288.1**	622.5***	724.5***	495.9***	508.2***
	(256.8)	(164.8)	(277.6)	(173.6)	(115.5)	(159.4)	(183.2)	(186.4)	(174.0)
t	-0.170	0.230	1.584***	-0.262	-0.383*	-0.710**	-0.550*	-0.216	-0.875***
	(0.367)	(0.269)	(0.412)	(0.305)	(0.208)	(0.280)	(0.286)	(0.251)	(0.272)
Constant	6,624***	16,313***	22,051***	27,537***	27,934***	29,919***	32,661***	34,159***	36,757***
	(945.0)	(757.5)	(1,179)	(742.8)	(491.0)	(658.4)	(732.6)	(671.0)	(728.9)
Observations	1,787	1,787	1,787	1,787	1,787	1,787	1,787	1,787	1,787
Adjusted R-squared	0.874	0.557	0.394	0.224	0.172	0.250	0.427	0.514	0.479

Source: Authors´s calculations. Notes: Ordinary least squares (OLS) regressions with Newey-West standard errors reported in parentheses, using the non-transformed data. Percentile denotes the time in seconds at which the i-th percentile (where i equals 10, 20, …, 90) of the daily total payment value is submitted on day t. RR2020 is a dummy variable equal to 1 from April 22, 2020 to September 10, 2024, during which the reserve requirement ratio for checking and saving accounts decreased from 11% to 8% and for CDs with maturities under 18 months decreased from 4.5% to 3.5%; RR2024 is a dummy variable equal to 1 from September 11, 2024, when the reserve requirement ratio for checking and saving accounts decreased from 8% to 7% and for CDs with maturities under 18 months decreased from 3.5% to 2.5%; payments is the daily payments value settled in the system on day t; transactions are the number of daily payments on day t; members are the number of active entities in the payment system on day t; Repos/Reserves is the ratio between daily repos and available reserves on day t; HHI is a measure of payment concentration across active institutions on day t; DCV is a dummy variable equal to 1 from April 1, 2024, when a new Central Securities Depository (DCV) was adopted; EOM is a dummy variable equal to 1 at the end of each month; t is the time trend.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$