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Changes in the Timing Distribution of Fedwire Funds Transfers

- The Federal Reserve's Fedwire funds transfer service has long displayed a concentrated peak of activity in the late afternoon.
- Sending large payments late in the day can heighten operational risk by increasing the potential magnitude of liquidity dislocation and risk if operational disruptions occur.
- A study of the distribution of Fedwire payments finds that the peak of the timing distribution has become more concentrated, has shifted to later in the day, and has been divided into two peaks.
- These trends are likely explained by a higher value of payments transferred, the settlement patterns of private settlement institutions, and increased industry concentration.
- The study uncovers no specific evidence of heightened operational risk associated with late activity, but it points to a high level of interaction between Fedwire and private settlement institutions.

1. Introduction

The Federal Reserve's Fedwire funds transfer service is the biggest large-value payments system in the United States in terms of participants, value, volume, and use by other settlement systems. Although Fedwire funds activity has long been concentrated in the late afternoon, recently there has been a noticeable shift to later in the day. The value of funds activity after 17:00 has increased from 20 percent in 1998 to more than 30 percent in 2005 (Board of Governors of the Federal Reserve System 2006). In 2006, the Federal Reserve commented on the risk posed by this change:

> "From an operational risk perspective, delaying the sending of large payments until late in the day increases the potential magnitude of liquidity dislocation and risk in the financial industry if late-in-the-day operational disruptions should occur. An increase in such risk is particularly troublesome in an era of heightened concern about operational disruptions from a range of sources" (Board of Governors of the Federal Reserve System 2006).

There is a complex set of trade-offs between risks and costs in large-value payments systems (Bank for International Settlements 2005). Theory suggests that the concentration of late-afternoon Fedwire activity is the result of coordination among banks to reduce liquidity costs, delay costs, and credit risks. As these costs and risks change over time, we would

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expect the timing of payment activity to be affected. In this article, we seek to quantify how the changing environment in which Fedwire operates has affected the timing of payment value transferred within the system.

We observe several trends in payment timing from 1998 to 2006. After 2000, the peak in payment activity shifts to later in the day. Indeed, post-2000, a greater concentration of payments occurs after 17:00. At the same time, however, several factors have been associated with increased payment activity early in the day, such as the creation of the Continuous Linked Settlement (CLS) Bank, an institution that settles U.S. dollar payments early in the morning; changes to the Clearing House Interbank Payments System's (CHIPS) settlement practices; and expanded Fedwire operating hours. Despite these developments, we find that the distribution of payment activity across the day still peaks more in the late afternoon.

Payments made through Fedwire are distributed throughout the operating day, so no single statistic fully captures the changes in timing that we observe. To analyze the timing of payments on Fedwire, we measure the times at which each percentile of value transferred on a particular day was completed. In addition, we use regression analysis to examine factors associated with the intraday timing of each percentile of value transferred by Fedwire over time. Explanatory variables here include changes in the Federal Reserve's Payments System Risk Policy and the activity of settlement systems. We measure the effects of multiple explanatory variables on the whole time distribution of payments to understand more fully why parts of the Fedwire timing distribution have changed.

We seek to quantify how the changing environment in which Fedwire operates has affected the timing of payment value transferred within the system.

Our study focuses on two notable changes that have affected the higher percentiles of value transferred on Fedwire: the 60th-90th percentiles. First, the most concentrated period of value transfer on Fedwire has moved to later in the day, from 16:48 to 17:11; second, the concentration of Fedwire value transferred has increased. Together, these changes have resulted in greater percentages of value transferred after 17:00.[1] Our analysis suggests that these changes are explained largely by the change in the timing of CHIPS end-of-day settlement activity, growth in the volume and value of Fedwire payments, and growth in the pattern of industry concentration (a measure of the amount of Fedwire value submitted by different system participants).

Our study proceeds as follows. The next section reviews the literature on models of banks' payment timing decisions.[2] Section 3 considers how Fedwire payments are currently distributed across the time of day and how the distribution has changed over time. In Section 4, we use regression analysis to examine which factors have been most relevant in explaining these trends. Section 5 focuses on the influence that settlement institutions have on the timing of Fedwire payments. We conclude with a brief summary of our observations and offer suggestions for further research.

2. Literature Review

Banks seek to minimize the costs associated with sending payments. The existing models of banks' payment-sending behavior generally focus on four factors: the cost of liquidity, the cost of delay, uncertainty (both strategic and structural) and settlement risk, and the instruction arrival process.

The cost to banks of settling a payment is a function of the cost of liquidity used to send the payment and the cost associated with delaying it. The cost of liquidity is the cost a bank faces when using account balances (usually modeled as being held at the central bank) in a payments system. This cost is often zero as long as the bank has a positive balance in its account and nonzero if the bank needs to borrow money to settle the payment. In Fedwire, the Federal Reserve provides intraday (daylight) credit in the form of overdrafts for which banks are charged a marginal fee, if the bank is eligible for daylight credit and has exceeded the amount of credit that falls within a deductible amount (Board of Governors of the Federal Reserve System 2004). Many other payments systems provide collateralized intraday liquidity at zero marginal cost after the bank posts collateral. An additional source of liquidity in payments systems is the overnight money market for federal funds and repos. The cost of delay is the compensation a bank must pay a customer for a delayed payment or the reputational damage and loss of future business a bank suffers from delaying customer payment requests (Angelini 1998).

Angelini (1998, 2000) considers the behavior of banks vis-à-vis liquidity and delay costs in a real-time gross settlement (RTGS) payments system. He shows that the equilibrium in an RTGS system involves excessive delay of payments, as banks do not fully internalize the benefits to other banks from the receipt

[1] We measure this peak as the median daily time of the top ten minutes of Fedwire value.

[2] For simplicity of exposition, we use the term *banks* to refer to direct participants in the payments system, although these participants may not necessarily be banks.

of funds. Bech and Garratt (2003) find that RTGS systems can be characterized by multiple equilibria, with the relative costs of liquidity and delay determining whether the system has an early or late equilibrium. Additionally, whether intraday liquidity is provided as priced or collateralized credit influences the type of "game" and the associated equilibria that would result. Other papers that consider how changes in liquidity prices affect payment timing are Bech (2008) and Mills and Nesmith (2008). Green (2005) discusses the welfare implications of these models and questions whether there are social costs to delay.

An observed late-day distribution of payments could occur either because banks delay payments or because banks receive payment instructions late in the day.

Kahn, McAndrews, and Roberds (2003), Mills and Nesmith (2008), and Bech (2008) focus on settlement risk in payments systems. Settlement risk is the uncertainty to which banks are subject when they face the choice of submitting or delaying a payment. Participant A may expect an offsetting payment from Participant B to occur later in the day. However, uncertainty about whether Participant B might either default or delay sending payment until the next day can result in Participant A's decision to delay delivery of its payment to the RTGS system.

An important but often overlooked assumption of these models is the time at which customers submit payment instructions to their bank. It is only after a bank receives an instruction from its customer (including the bank itself) that the bank decides whether to send settlement instructions to the payments system or delay settlement. An observed late-day distribution of payments could occur either because banks delay payments or because banks receive payment instructions late in the day. For example, after CLS Bank began operations, banks had a new stream of payments to submit at a particular time of day, which can cause significant changes in the overall value time distribution of payments.

A factor that has not been discussed in the literature but may influence payment timing decisions is the industrial structure of banks that participate in the payments system. Industrial structure can differ for a number of reasons, many of which may be exogenous to banks' activities in the payments system. Such differences can result in varying costs of liquidity. In addition, the number of banks in a payments system—whether 10 or 1,000—can influence the likelihood of successful coordination of payments.

A number of studies provide empirical evidence on liquidity costs. McAndrews and Rajan (2000) document the payment and value timing distributions on the Fedwire funds service. McAndrews and Potter (2002) show the effects of the terrorist attacks of September 11, 2001, on the timing of payments over Fedwire. Mills and Nesmith (2008) find that the charging of overdraft fees on Fedwire in 1994 sped up the settlement of payments on the securities service but did not change the timing of payments on the funds service. Heller, Nellen, and Strum (2000) show that the introduction of intraday credit to banks in the Swiss Interbank Clearing system dramatically shifted the value time distribution of payments to earlier in the day. McAndrews (2006) finds that high-payment-value days lead to later value-weighted average payment value settlement times on Fedwire, consistent with a model of higher shadow prices of liquidity on high-payment-value days. Becher, Galbiati, and Tudela (2008), examining the timing of sterling payments on the Clearing House Automated Payment System (CHAPS), find that CHAPS has a less pronounced late-in-the-day peak than the Fedwire funds service does. The divergent patterns in Fedwire and CHAPS are broadly consistent with the models of Bech and Garratt (2003) and Bech (2008), but they also likely reflect the imposition and maintenance of throughput guidelines by CHAPS participants; the guidelines govern the percentage of value to be submitted at different times during the day. Finally, several papers use simulations to examine the trade-off between liquidity costs and delays in theoretical payments systems, including Koponen and Soramäki (2005) and Leinonen and Soramäki (2005).

3. Descriptive Analysis

Here we analyze payment and value time distributions on the Fedwire funds service. We focus on the number and value of payments transferred during a minute and contrast the time series of these variables in 1998 and 2006. Our work is purely descriptive; in the next section, we conduct regression analysis exploring the reasons behind the changes observed.

For our examination, we remove all payments to or from the settlement institutions: CHIPS, CLS Bank, and the Depository Trust Company (DTC). This allows us to focus on the non-settlement institutions' funds transfers on Fedwire, as these are subject to the strategic decisions of the sending party. Notably, this approach excludes the early-morning activity of CHIPS and CLS Bank.

3.1 General Pattern in the Timing of Payments

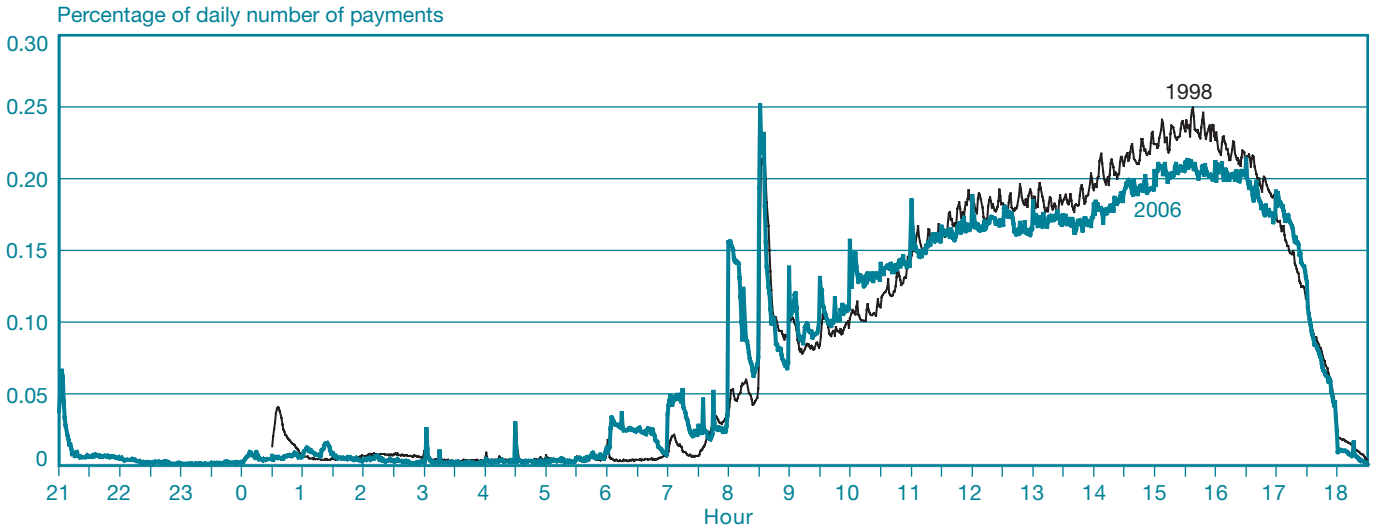
Charts 1 and 2, respectively, present the probability distribution functions for the percentage of the daily number of transfers and the percentage of daily value settled. Each point on Chart 1 (Chart 2) represents the average number (value) of payments transferred during that minute expressed as a percentage of the total number (value) of payments transferred that day. The charts show that the timing of Fedwire payments exhibits a general pattern that remained essentially stable between 1998 and 2006, whereby both the number and value of payments peaked in the late afternoon. We start by describing this general pattern.

Chart 1 shows that relatively few payments are sent before 08:00, with the notable exception of the period following the opening of Fedwire (00:30 in 1998 and 21:00 in 2006), when many banks submit their CHIPS prefunding payments (recall that funds transfers to or from CHIPS and to or from CLS Bank are excluded from our measure of funds transfers in these charts). In the ten-minute period beginning at 08:30, there is a large spike in payment activity in 1998 and in 2006. The spike partially results from increases in bank balances attributable to the Federal Reserve Bank of New York's making principal and interest payments on behalf of the U.S. Treasury and government-sponsored enterprises (GSEs) as well as customer activity associated with the opening of the Fedwire securities service. After 08:30, payment volume initially declines, then steadily rises to a plateau between 15:00 and 16:00, when it reaches a level of activity similar to that of the 08:30 period. After 16:00, payment volume drops sharply until the close of Fedwire.

The value of payments settled also peaks in the late afternoon, but the peak is both sharper and later than that of the volume of payments (Chart 2). Like volume, value settled is low during the early-morning hours and it rises to its peak around the time DTC and CHIPS close. Note that while payment volume is falling after 16:00, payment value is rising. This is the result of the concentration of large-value payments late in the day. Finally, although discernible, the peaks around the opening of Fedwire and at 08:30 are proportionally much lower for the value of payments than for the volume of payments.

The timing of Fedwire payments exhibits a general pattern that remained essentially stable between 1998 and 2006, whereby both the number and value of payments peaked in the late afternoon.

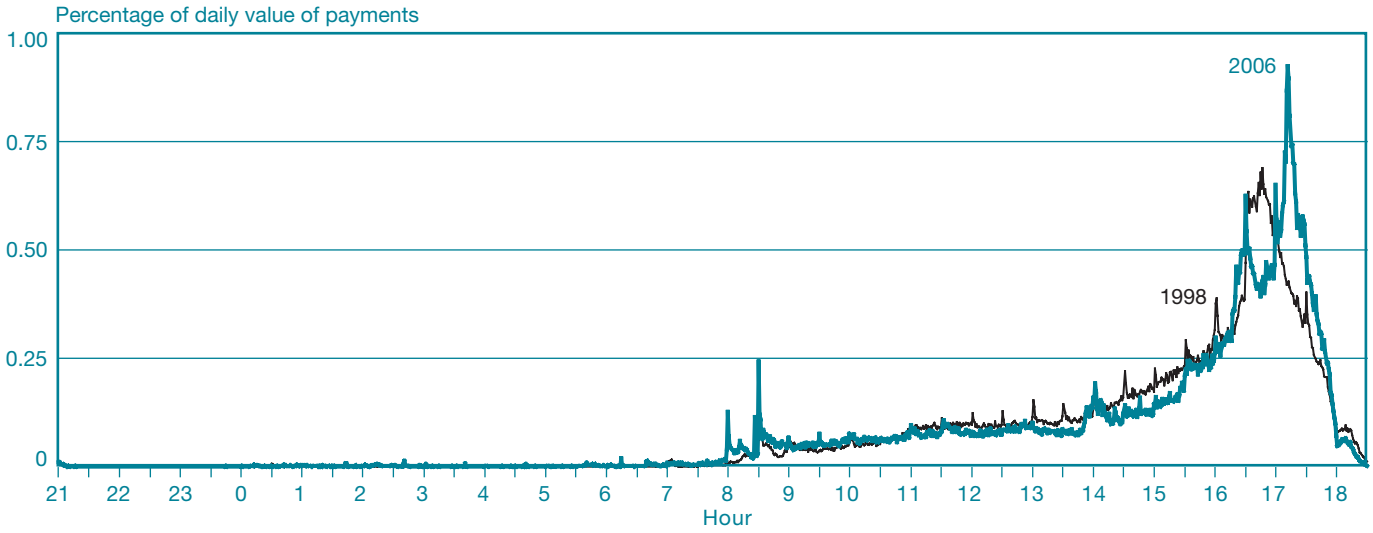
Chart 1
Fedwire Funds Payment Time Distribution, 1998 and 2006



Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: The chart shows the mean daily percentage of total payments settled in each minute. Values exclude payments associated with CHIPS, CLS Bank, DTC, and principal and interest payment funding.

Chart 2
Fedwire Funds Value Time Distribution, 1998 and 2006



Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: The chart shows the mean daily percentage of total payments settled in each minute. Values exclude payments associated with CHIPS, CLS Bank, DTC, and principal and interest payment funding.

3.2 Changes in the Distribution of Value

A comparison of Charts 1 and 2 indicates that the value time distribution has changed much more than the volume time distribution. Therefore, we now focus on the evolution of the value time distribution. Table 1 presents the times at which the deciles of payment value settled on average in 1998 and 2006. The earliest and latest deciles—10, 20, and 100—settled earlier in 2006 than in 1998. The remaining deciles—30-90—moved to later-day settlement. Additionally, there is decreased variability in the settlement time of deciles 40-100, implying much more regularity in the later part of the value time distribution.

Table 1
Percentiles of Value Time Distribution

	1998		2006		
Percentile	Mean	Standard Deviation	Mean	Standard Deviation	Difference (Minutes)
10	11:15:21	00:09:34	10:37:37	00:15:22	-37.7
20	12:58:33	00:14:09	12:44:10	00:18:02	-14.4
30	14:24:21	00:15:41	14:33:51	00:17:60	9.5
40	15:19:59	00:14:58	15:38:09	00:13:25	18.2
50	15:59:29	00:14:33	16:15:04	00:10:44	15.6
60	16:28:18	00:12:09	16:37:29	00:08:22	9.2
70	16:46:05	00:10:46	16:58:58	00:07:09	12.9
80	17:02:47	00:10:43	17:14:06	00:04:20	11.3
90	17:26:25	00:11:27	17:30:12	00:03:53	3.8
100	18:37:28	00:23:05	18:31:14	00:07:15	-6.2

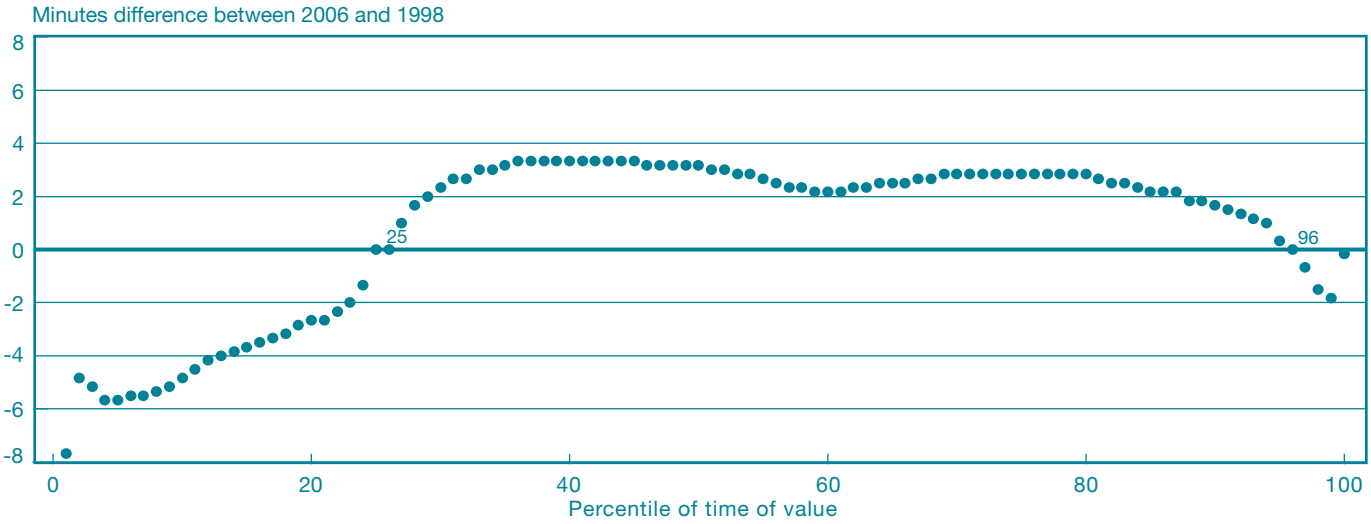
Sources: Federal Reserve Bank of New York; authors' calculations.

To understand the significance of these value shifts, we calculate the time at which each percentile of daily value settles for each day in 1998 and 2006. Then, for each percentile, we compare the distributions of the samples collected in 1998 and 2006 nonparametrically using the Mann-Whitney two-sample statistic. Our results appear in Chart 3. As the x-axis indicates, each of the 100 points corresponds to a percentile, moving left to right from percentile 1 to percentile 100. The y-axis corresponds to the number of minutes that must be added to or subtracted from the 2006 sample until the Mann-Whitney test is insignificant at the 5 percent level. For instance, the first point at the bottom of Chart 3 indicates that the first percentile in 2006 settled significantly earlier than the first percentile in 1998 by at least 7 minutes and 30 seconds. However, a point on the origin line indicates that the corresponding percentile cannot be distinguished statistically between the two samples.

Percentiles 1-24 are located below the origin axis, indicating that the lower percentiles of value were transferred earlier in the day in 2006 relative to 1998. Percentiles 27-95 lay above the origin line, indicating that most of the value distribution shifted to later in the day between 1998 and 2006. However, the points

Chart 3

Mann-Whitney U Test on Percentiles of Value Time, 1998 to 2006



Sources: Federal Reserve Bank of New York; authors' calculations.

Note: Minutes are subtracted from/added to each percentile until a Mann-Whitney rank-sum test is insignificant at the 5 percent level.

corresponding to the last percentiles, 96-99, are located below the origin line. It appears that the last percentiles of value were transferred later in the day in 1998. This result may be explained by a decline in the number and length of extensions since 1998.

The probability density function of the value time distributions in 1998 and 2006 is presented in Chart 2. Observe first that the supports of the 1998 and 2006 distributions in the chart have different lower bounds. Indeed, Fedwire operating hours were expanded when the opening hour was moved from 00:30 to 21:00 on May 17, 2004. Chart 2 shows that the change in the opening hour did not dramatically affect the distribution of value settled prior to 07:00. After 07:00, the two distributions intersect several times, suggesting no clear pattern to how the timing of payments changed between 1998 and 2006. We identify five distinctive features from our analysis of Chart 2:

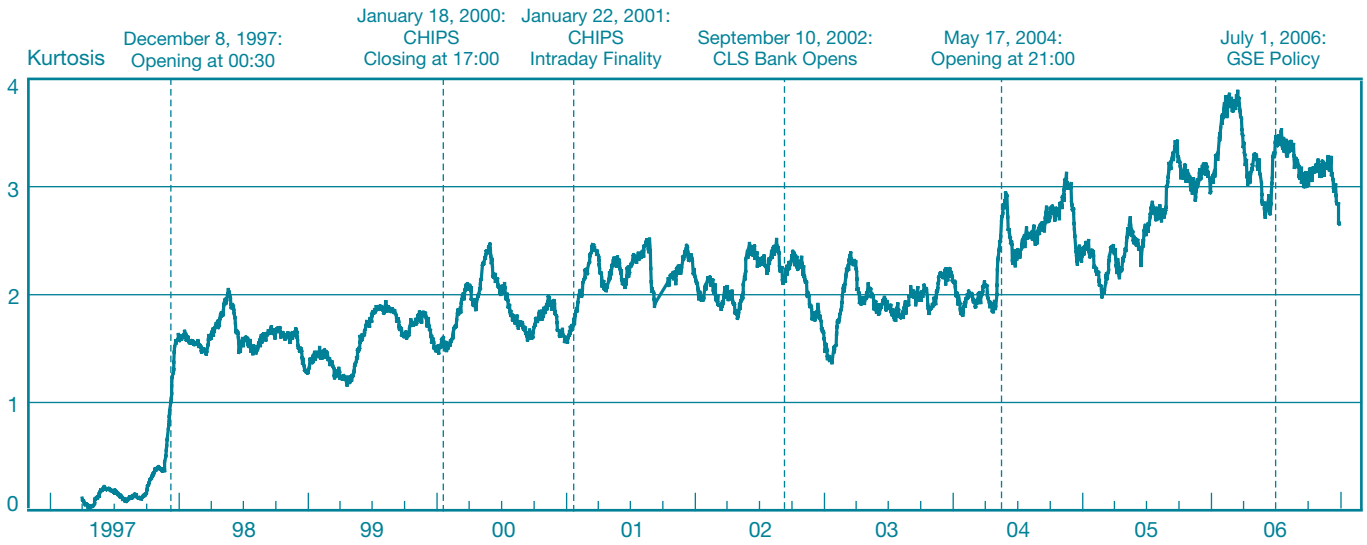
The highest peak of the distribution shifts to a later time, from around 16:48 in 1998 to around 17:11 in 2006.

1. The distribution of value settled becomes more concentrated. In particular, observe that the magnitude of the highest peak is greater in 2006 than in 1998. To confirm this observation, we plot in Chart 4 the evolution of the kurtosis of the payment value distribution. The chart shows a clear positive time trend between 1998 and 2006. If we interpret the kurtosis as a measure of peakedness, Chart 4 confirms that the distribution of value settled has become more concentrated over time. This result is important from a policy perspective, as it reflects a greater coordination in the timing of payments among Fedwire participants. A by-product of the greater coordination of payment activity, the amount of value transferred on Fedwire that is offsetting within a ten-minute period rose significantly, from 56 percent in 1998 to 58 percent in 2006. As the amount of offsetting payments rises, banks enjoy greater economy in the use of liquidity.
2. The highest peak of the distribution shifts to a later time, from around 16:48 in 1998 to around 17:11 in 2006. In other words, the minute during which most of the daily value is transferred is now twenty-three minutes closer to closing time. Chart 5 shows the distribution of value settled by time for each year between 1998 and 2006. It is clear from the chart that the highest peak moved to a later time between 1999 and 2000, and it was not a gradual move. The mean daily time of the top ten contiguous minutes of Fedwire funds value moved twenty minutes later, from 16:48 to 17:08, and the median daily time moved twenty-three minutes later, from 16:48 to 17:11, supporting the presence of a significant shift toward a later time in the peak of the distribution.[3]

[3] This difference is statistically significant at the 1 percent level for the Mann-Whitney two-sample statistic.

Chart 4

Kurtosis of Fedwire Funds Value Time Distribution

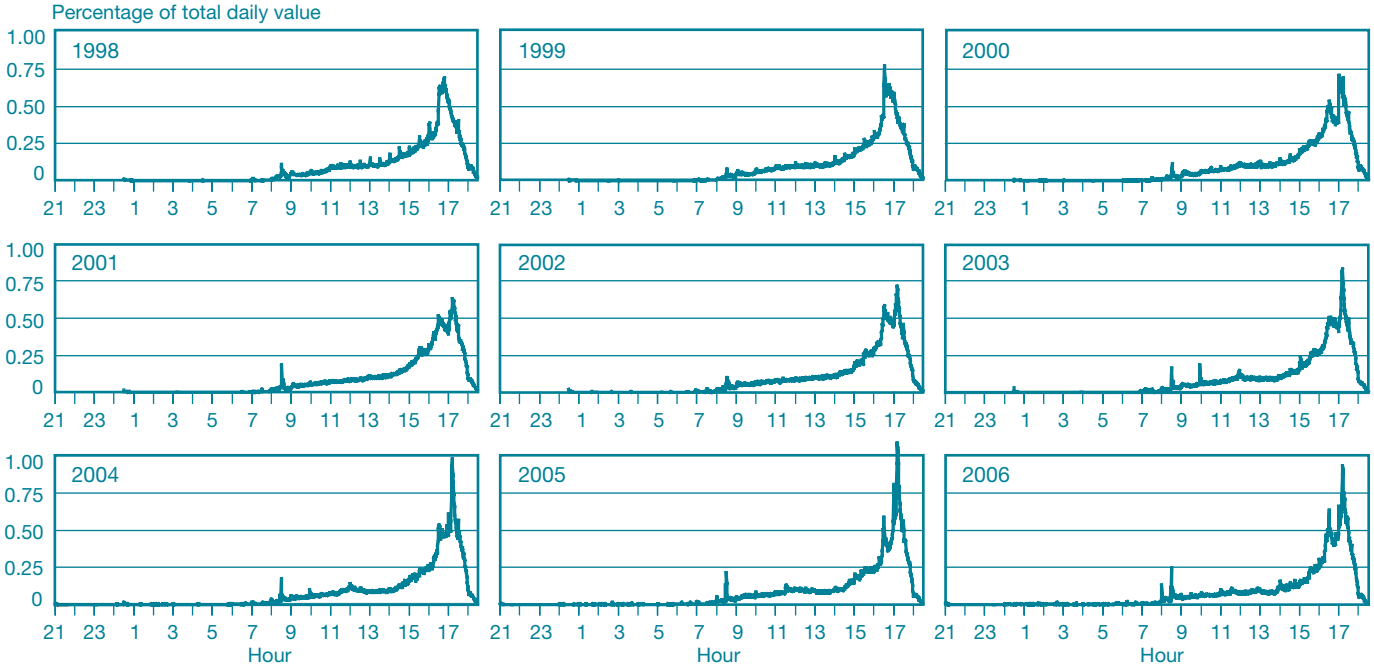


Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: Kurtosis is the excess kurtosis. A twenty-one-day centered moving average is used. Values exclude payments associated with CHIPS, CLS Bank, DTC, and principal and interest payment funding. GSE is government-sponsored enterprise.

Chart 5

Fedwire Funds Value Time Distribution by Year



Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: The panels show the mean daily percentage of total payment value settled in each minute. Values exclude payments associated with CHIPS, CLS Bank, DTC, and principal and interest payment funding.

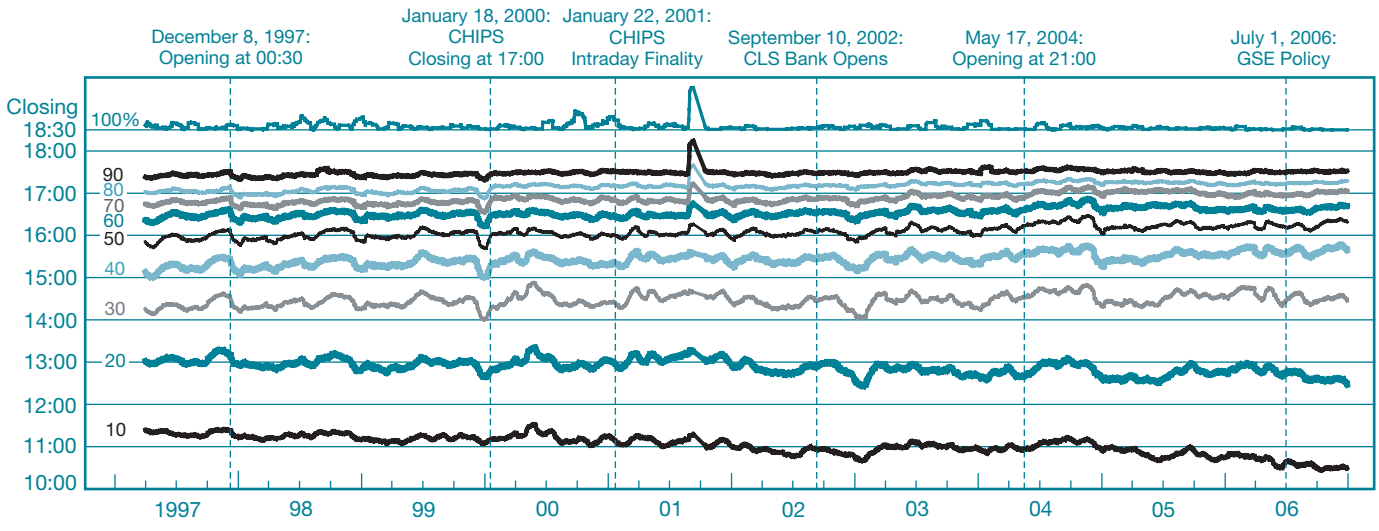
3. At the time of highest activity (between 16:00 and 17:30), the 2006 distribution exhibits three distinct peaks: two of comparable magnitude at precisely 16:30 and 17:00 and the third (the sharpest) at around 17:11. By comparison, the 1998 distribution possesses only two peaks: the sharpest at around 16:45 and a slightly smaller peak at 16:30. An analysis of the distribution of value settled for each year between 1998 and 2006 indicates that: 1) the 16:30 peak is present every year throughout the sample period; 2) as documented above, the highest peak moved from 16:48 to 17:11 between 1999 and 2000; and 3) the emergence of the 17:00 peak can be traced to 2004.
4. The 1998 distribution of value settled exhibits regular clock effects. Indeed, as indicated by the equidistant spikes in the 1998 probability distribution in Chart 2, there seems to be a flurry of activity every half-hour on the half-hour between 11:30 and 16:30. In contrast, these clock effects are not as discernible in the 2006 distribution. An analysis of the distribution of value settled for each year between 1998 and 2006 indicates that the clock effects gradually dissipate until they virtually disappear in 2002. We have not been able to identify what causes these clock effects and why they have faded away over time. In particular, it is unclear whether the effects are attributable to technological factors, the behavior of Fedwire participants, or institutional constraints.
5. The 2006 distribution exhibits a higher amount of activity at precisely 08:00 and 08:30. An analysis of the distribution of value settled for each year between 1998 and 2006 indicates that the 08:30 peak increased gradually over time, while the 08:00 peak is present only in 2006. The 08:00 peak is likely associated with the Federal Reserve's July 2006 change to its Payments System Risk Policy regarding GSEs, while the 08:30 peak is likely associated with the increased importance of the securities markets and the opening of the Fedwire securities service at 08:30.

We conclude this section with an analysis of Chart 6, in which the deciles of daily value settled are presented as a time series spanning the period from September 1997 to February 2007. The chart identifies several discrete events that may have affected the timing of Fedwire payments: changes in operating hours, changes in CHIPS operations, changes in CLS Bank operations, and changes in the Federal Reserve's Payments System Risk Policy regarding GSEs. Chart 6 provides a slightly different perspective on how the timing of payments evolved over time. Five points in particular are worth noting:

1. The deciles exhibit different trends. The first two deciles show a negative trend while the deciles between 40 percent and 90 percent indicate a slightly positive trend. These results are consistent with the dual shift we identified earlier when comparing the value of payments in 2006 and 1998. Indeed, we found that in 2006 the value settled moved toward earlier payments at the beginning of the day and toward later payments later in the day.

Chart 6

Deciles of Fedwire Funds Value Time Distribution



Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: A twenty-one-day centered moving average is used. Values exclude payments associated with CHIPS, CLS Bank, DTC, and principal and interest payment funding. GSE is government-sponsored enterprise.

2. The first four deciles are not grouped together as much as the five deciles between 50 percent and 90 percent are. This observation is consistent with the shape of the payment value time distribution in Chart 2, which is highly concentrated toward the end of the day.
3. After 2004, the 100th percentile rarely exceeds the 18:30 closing time, indicating that extensions of Fedwire operating hours occur less frequently.
4. The deciles exhibit various peaks and valleys. The reasons for some of these peaks and valleys are clear, such as September 11, 2001, which led to later payments. Others are not as obvious.
5. The events documented in Chart 6 do not have a clear effect on the evolution of the times at which the various deciles of payment value settle. In particular, it is difficult to conclude unambiguously from the chart whether trends in the percentiles of value can be imputed directly to any one of these events. In the next section, we conduct a regression analysis to disentangle the effects of various factors on the timing of payments.

4. Regression Analysis

4.1 Model and Data

Our regression analysis identifies the factors that affected the distribution, or at least part of the distribution, of payment values. After experimenting with different specifications, we settled upon an easily interpretable yet robust model consisting of 100 linear regressions, each estimated separately for a given percentile of value.[4] To address possible serial correlation and heteroskedasticity problems, we relied on the approach developed by Newey and West (1987) to correct the estimated standard errors.[5] Finally, we conducted various diagnostic tests and compared the results of several alternative specifications to ensure that our results are robust.

Our sample consists of daily observations for virtually every business day between March 1998 and November 2006.[6] In a given regression, the dependent variable is defined as the time at which the corresponding percentile of value settled on a specific day, which we measure in the number of seconds since the day's Fedwire opening. The same set of explanatory variables is used in each of the 100 regressions. A formal definition of these variables as well as their sources can be found in Appendix A. Drawing on the literature we reviewed earlier, we include a number of potentially relevant variables in our analysis, which we organize into five categories: value and volume, Federal Reserve policies and operations, settlement system activities, other control variables, and calendar effects. Summary statistics for the independent variables are presented in Table 2.

Our regression analysis identifies the factors that affected the distribution, or at least part of the distribution, of payment values.

Value and Volume

The value as well as the number, or volume, of payments transferred over Fedwire may play a role in determining when Fedwire participants submit payments. To account for these effects, we disaggregate the nonsettlement daily value of Fedwire funds into four mutually exclusive groups. More specifically, we differentiate: 1) the total value transferred by banks on behalf of their customers, 2) the total value of deliveries of federal funds purchases and sales, 3) the total value of federal funds returns (of the prior day's deliveries), and 4) the value of all other interbank transfers, thereby consisting of payments not included in the groups made on behalf of customers or as part of a federal funds purchase, sale, or return. All else equal, and controlling in particular for the number of Fedwire payments, we observe that a higher value of transfers should result in a higher demand for daylight credit, which would lead to a higher shadow cost of liquidity. As a result, one may anticipate that higher values of payments lead to later settlement of payments.

[4] We recognize that there may be better specifications as well as more efficient inference techniques for analyzing the Fedwire value time distribution. In particular, since we do not estimate the joint distribution of all percentiles, we are not able to compare statistically point estimates across neighboring percentiles. Instead, we contrast only how a variable of interest affects different parts of the distribution, such as the low percentiles (corresponding to the morning) and the high percentiles (corresponding to the late afternoon). Observe, however, that: 1) our specification does not imply that the times at which the percentiles of value settle are independent and 2) if we can assume that our system of regression equations has the structure of a Seemingly Unrelated Regressions (SURE) model, then there is no loss of efficiency in estimating the regressions separately rather than jointly by GLS, since the explanatory variables are the same in each percentile regression.

[5] Note that we also estimated the model with lagged (up to ten lags) dependent variables. The results remain virtually unchanged and the differences are strongly insignificant.

[6] We are missing data for the following dates: April 1, 1997; December 22-24, 1997; March 1-3, 1999; April 20-22, 1999; October 14-15, 1999; October 18, 1999; and November 9, 1999.

Table 2

Summary Statistics of Independent Variables

Variable	Mean	Median	Standard Deviation	Minimum	Maximum
Target federal funds rate (percent)	3.61	4.00	1.88	1.00	6.50
Operating hour extension (minutes)	00:04:05	00:00:00	00:19:06	00:00:00	05:16:00
Interbank payment value (billions of dollars)	487.08	476.19	75.40	148.79	865.82
Customer payment value (billions of dollars)	610.25	585.75	144.39	152.27	1334.25
Federal funds deliveries (billions of dollars)	250.83	257.65	65.70	0.92	472.64
Federal funds returns (billions of dollars)	250.09	257.84	64.21	0.92	432.61
Payments greater than or equal to $10 million	0.908	0.909	0.011	0.853	0.934
Number of payments (thousands)	465.237	453.817	79.101	186.895	904.726
Federal funds deviation	-0.01	0.00	0.13	-1.56	1.81
HHI of Fedwire value	529.8	516.5	107.0	220.2	795.3

Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: Payments greater than or equal to $10 million is defined as the fraction of daily value from payments greater than or equal to $10 million, excluding CHIPS, CLS Bank, DTC, and principal and interest funding payments. HHI is the Herfindahl-Hirschmann Index, a measure of the concentration of payment activity among banks.

As the size of payments varies greatly, we also include in the regressions the share of daily value consisting of individual payments in excess of $10 million in value. We chose $10 million as a threshold because it is quite close to the top 1 percent of individual payments when ranked by value. We hypothesize that a large proportion of high-value payments would cause a greater need for daylight credit, resulting in higher shadow costs of liquidity and later payments.

Finally, we control for the number of payments.[7] After we hold the values of payments constant, an increase in volume results in smaller individual payments on average. Therefore, one may expect that higher volume would be associated with faster Fedwire settlement, as smaller individual payments are less likely to require drawing in daylight credit. An alternative hypothesis is that a higher volume of transfers places higher operational demands on banks to check the credit lines of customers and other processes associated with submission of payments to Fedwire, and it could therefore result in later settlement.

Federal Reserve Policies and Operations

The Federal Reserve Banks offer many Fedwire participants access to daylight overdrafts for a fee and subject to upper limits, as described in the Federal Reserve's Payments System Risk Policy. These upper limits on the amount of daylight overdrafts that can be extended to a bank participant are called net debit caps. We include as a dummy variable the date of the liberalization of net debit caps that occurred on February 21, 2002, which allowed foreign banking organizations to modify the net debit cap calculation for U.S. branches and agencies of foreign banks (we call that variable the Foreign Capital Equivalency Policy). That change resulted in a one-time increase of approximately 10 percent in the aggregate net debit caps of Fedwire participants. We argue that this change in policy lowered the costs of liquidity for these banks and should result in earlier settlement of payments. Because the policy change was applied primarily to foreign banks—many of which participate in CHIPS and CLS Bank, which have early-in-the-day activity—we expect this faster settlement to affect mainly the lowest percentiles of Fedwire activity.

Another change in the Payments System Risk Policy, which occurred on July 20, 2006, restricted GSEs and certain international organizations from incurring daylight overdrafts. In general, this change represents a restriction of access to daylight credit, and we would expect it to correspond to an increase in liquidity costs. Thus, we hypothesize that this change, which we capture with a dummy variable, would result in slower payment settlement. Not all GSEs are exactly comparable, however. In particular, a distinctive feature of Fannie Mae and Freddie Mac is their payment of principal and interest on the 15th and the 25th of each month (or on dates close to the 15th and 25th when they fall on weekends or banking holidays). We therefore include an additional dummy variable to measure whether the change in policy affects the

[7] Note that although the value and volume variables drift during the sample period, we find no evidence suggesting that they may be nonstationary. More specifically, after conducting a series of Dickey-Fuller tests (with ten lags) and Phillips-Perron unit-root tests, we rejected the nonstationary hypothesis at the 1 percent significance level.

timing of Fedwire payments differently on these specific dates. We do not have an unambiguous prediction about the effect of this policy change on the timing distribution. On the one hand, the change may generate more delays, as they represent a restriction on access to liquidity; on the other hand, it may accelerate Fedwire payments, because GSEs must have funds delivered to them prior to releasing their principal and interest payments.

We include a dummy variable for all dates after the Federal Reserve extended, in May 2004, the opening hours of Fedwire to 21:30. We contend that this change may increase the submission of early-morning payments to Fedwire. Occasionally, the Federal Reserve Banks decide to extend the hours of Fedwire operation because of significant operational problems of a participant or the system. As such, we include a variable that measures the duration of the extension in minutes. We hypothesize that extensions may increase settlement risk and uncertainty and are associated with later payments—especially for the final few percentiles of payment value—and therefore they slow the settlement of the later percentiles of funds transfers. Finally, we include the target fed funds rate as a variable to control for any effect that monetary policy decisions might have on the timing of payments.

Settlement System Activities

Every day, most financial institutions are active simultaneously in a number of markets and payments systems—in particular, in the settlement systems CLS Bank, CHIPS, and DTC. (See Appendix B for a description of these systems.) This activity may affect the liquidity available to these participants at a given time during the day, which in turn may influence the time at which Fedwire participants decide to submit payments. To control for the influence of settlement system activity on the timing of Fedwire payments, we include a dummy variable for the dates after which CLS Bank began operation. Because CLS Bank operates early in the day in the United States, we reason that it may quicken the settlement of Fedwire payments submitted in the morning.

We also include variables measuring the times at which CHIPS and DTC conduct their late-afternoon settlements.[8] We hypothesize that the times of these settlement systems are associated with decreased uncertainty and with rapid redistribution of balances in various banks' accounts after these settlements are complete. Because of these effects, these times can also act as focal points for the settlement of other Fedwire payments (we discuss these points in more detail below). We conjecture that the time of these settlements will positively influence the timing of Fedwire payments: as their times move, so will the timing of Fedwire payments.

In addition to time variables associated with CHIPS, DTC, and CLS Bank, we include the value of U.S. dollar settlements conducted each day through CLS Bank, the values of the initial and final prefunding values in CHIPS, and the net-net settlement values in DTC. In our view, an increase in values settled through the settlement systems would increase demand for daylight credit, increasing its shadow cost, and result in later settlement times.

[Our analysis includes] variables measuring the times at which CHIPS and DTC conduct their late-afternoon settlements . . . . These times can also act as focal points for the settlement of other Fedwire payments.

Other Control Variables

We include both a constant and a time trend in our regression. The time trend is meant to control for trends, such as technological change, other than those captured by other covariates (for example, the volume and values of payments). In addition, we include the Herfindahl-Hirschmann Index (HHI) of payment market shares, a measure of the concentration of payment activity among banks. We expect this variable to control for industry mergers and other changes in the pattern of payments between banks. As discussed earlier, industrial structure can affect payment timing in a number of ways not fully examined in the literature. A more concentrated industrial structure might be able to coordinate payments more easily, but at either an earlier or later time of day. A more concentrated structure could result in more payment value being transferred by the larger bank that is more likely to have exceeded its deductible portion of the overdraft fee schedule, and therefore is more likely to economize liquidity actively. As a result, a greater concentration in industrial structure in the payment market could lead to later settlement. Finally, we include the interest rate spread between the effective federal funds rate and the target federal funds rate. We reason that when this spread is high, the net demand for end-of-day

[8] CLS Bank settles at multiple times in the early morning; because CLS Bank operates so early and its settlement time is so diffuse and therefore difficult to characterize, we do not include a settlement time variable for it.

balances is relatively high, which we would expect to be associated with later payment timing.

Calendar Effects

There are many predictable differences in payment activity across the days of the week and over the year. For example, Mondays predictably have higher volume than Fridays on average; days at the beginning of the month are likewise expected to be high value. To control for these effects on the timing of Fedwire payments, we include a number of dummy variables for various calendar effects. Included are dummies for the days of the week, the days preceding and following holidays, the first of the month, the last day of the quarter, the last day of the year and, separately, the last five days of the year. In addition, we include dummies for days on which the New York Stock Exchange is closed and, separately, days on which it closes early. Dummies are also included for each of the final five days of the reserve maintenance period (the day-of-week dummy captures both the effect of the day of the week and the effect of the first five days of the reserve maintenance period); we include that variable in case the reserve maintenance period influences payment activity. Finally, we include a separate dummy for the two-week period including and following September 11, 2001. During that period, Fedwire operating hours were regularly extended and were expected to experience later activity than normal.

Before analyzing our regression results, we emphasize one point. The variables described above may be expected to affect some parts, but not necessarily all, of the timing distribution. For instance, CLS Bank value may be considered likely to affect the payment distribution early in the day, but it may not necessarily have a lasting effect on the final percentiles of the distribution. Conversely, CHIPS final payout value may be considered likely to affect only the upper tail of the value distribution.

Results

To streamline our analysis, we present our estimation results graphically in Charts 7-11. We start by providing information about the interpretation of each chart. The x-axes of each chart display two scales. The bottom scale represents the percentile of value, or equivalently the regression number, moving from 1 to 100. The top scale represents the average time in 2006 at which the corresponding percentile settled during the day. The afternoon peak of the Fedwire value time distribution is evident when comparing these two scales. 12:00, which is fifteen hours after the opening of Fedwire, is only the 15th percentile of value time. By comparison, the hour between 16:00 and 17:00 includes more than twenty percentiles. Each chart corresponds to an explanatory variable; for instance, Chart 7.1 corresponds to interbank payment value. Each chart plots twenty points indicating the point estimate of the coefficient for that variable in the corresponding linear regression. As indicated in the chart notes, the color of the point identifies the level of statistical significance of the point estimate. On each side of a point estimate, we add a band representing the 95 percent confidence interval for this point estimate. Finally, we plot in Chart 12 the adjusted R^2 for each regression.

In terms of interpretation, a parameter significantly greater (lower) than zero in a regression for a given percentile indicates that the marginal effect of the corresponding explanatory variable delays (accelerates) the time at which that percentile settles.

In these charts, the results of multiple percentiles are shown on the same scale. This gives a full sense of each variable's effect on the timing of payments across the entire day. However, as we mentioned, comparisons between percentiles could be misleading and may overstate the economic effect of variables in the middle percentiles. Delaying a payment by the same amount of time becomes more costly as the end of the day approaches, when there is less time left to settle all remaining payments. For example, five minutes of delay at 17:30, when there is only one hour of the business day left, can be considered a larger economic effect than five minutes of delay at 12:00.

Value and Volume

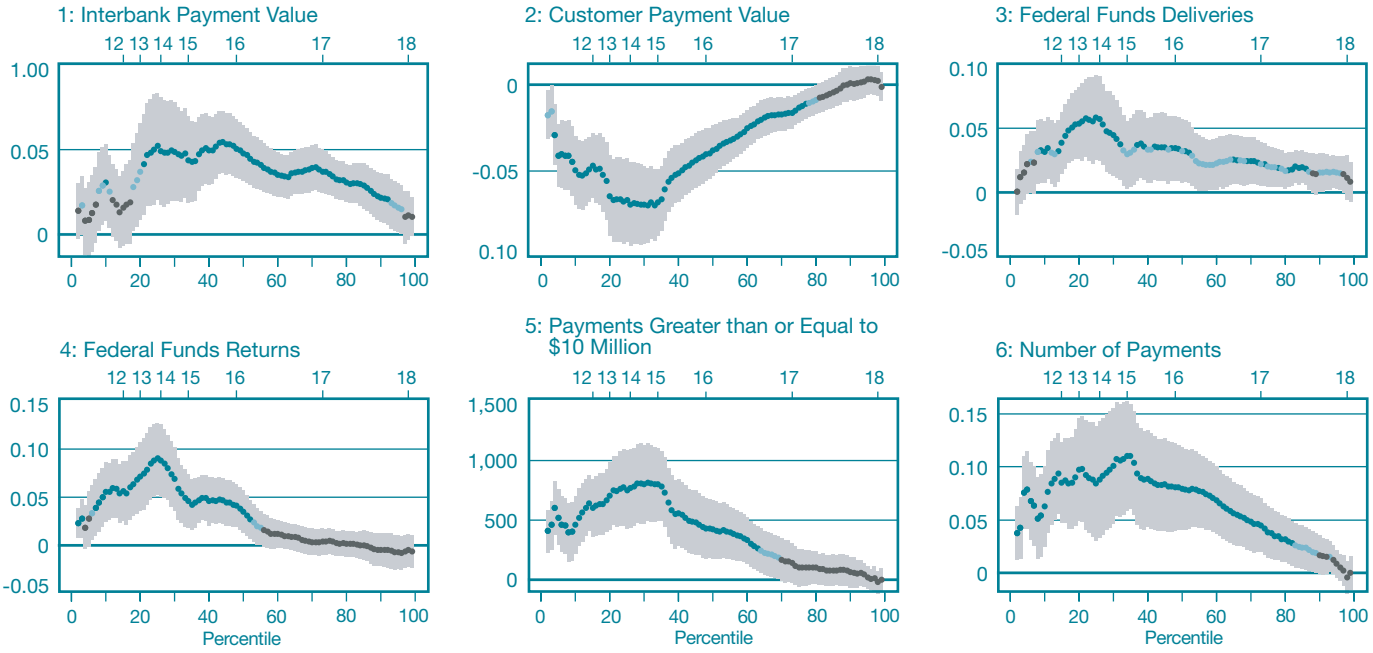
The parameters associated with the value of interbank payments settled over Fedwire are significant and greater than zero for virtually all percentiles (Chart 7.1). In other words, it appears that more interbank transfers over Fedwire tend to slow down the settlement of payments generally throughout the day. This result is consistent with the argument that banks have an incentive to delay their interbank payments, which are of high average value and may incur little delay cost because no customer may be demanding early settlement because of the cost of daylight credit.

In contrast, the parameters corresponding to the total value transferred by banks on behalf of their customers over Fedwire are negative and significant for all percentiles below 85 percent, that is, for payments submitted before 17:45 on average in 2006 (Chart 7.2). Fedwire payments therefore seem to settle earlier, when the value of transactions transferred by banks' customers is high. This result may be explained by the fact that, compared

Chart 7

Regressions of Fedwire Funds Value Time Percentiles

Value and Volume



Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: The upper x-axis displays the mean 2006 time for selected percentiles. The y-axis displays the value of the coefficient. The band represents the 95 percent confidence interval for the point estimates. We use independent ordinary least squares regressions with Newey-West standard errors (maximum lag = 10) for the 2nd to 99th percentiles of value. The color of the point indicates the significance of the coefficient: blue = 1 percent, light blue = 5 percent, dark gray = insignificant. There are 2,200 observations for each regression.

with interbank transfers, banks face a higher delay cost when acting on customers' requests for payments. In particular, banks may be asked by their customers to execute their transfers by a certain time.

The results suggest that both forms of federal funds activity tend to delay the timing of Fedwire payments. Indeed, the significant parameters in Charts 7.3 and 7.4 are systematically greater than zero. Observe, however, that federal funds returns appear to have a slightly larger effect earlier in the day, while the effect of federal funds deliveries persists throughout the day. These results may be considered surprising since both types of activities tend to occur later in the day. We conjecture that federal funds purchases and sales also capture the demand for overnight credit. This would therefore explain why higher federal funds deliveries are associated with delayed Fedwire payments throughout the day. Likewise, it is possible that banks expecting a return of federal funds may tend to delay their Fedwire payments in the morning until their accounts have been credited.

All else equal, an increase in the number of Fedwire transfers results in delayed payments for most of the day.

We now turn to the effect of the number of Fedwire payments transferred in a day. Virtually all parameters in Chart 7.6 are positive and significant for percentiles up to 80 percent, or equivalently for payments transferred before 17:45 on average in 2006. In other words, all else equal, an increase in the number of Fedwire transfers results in delayed payments for most of the day. This result seems to contradict our hypothesis that a greater number of transfers may expedite Fedwire payments, as it implies lower average size payments once we control for the total value transferred. Instead, the result possibly points toward greater operational costs, whereby banks must delay payments because it takes more time to process a greater number of payments.

The size of individual payments, however, is not completely neutral. Indeed, we find that the fraction of individual payments exceeding $10 million affects the timing of payments for percentiles up to 65 percent (Chart 7.5). In other words, large individual transfers delay payments submitted before 16:45 on average in 2006. This result does not unambiguously support our view that large individual payments lead to delayed settlement because they increase the likelihood of daylight overdrafts. We argue that our finding of no such delays after 16:45 may be explained by the fact that opportunities for multilateral netting are greater at the peak of Fedwire activity. As a result, banks may be less likely to delay large individual payments at the end of the day, as the risk of daylight overdraft decreases.

Federal Reserve Policies and Operations

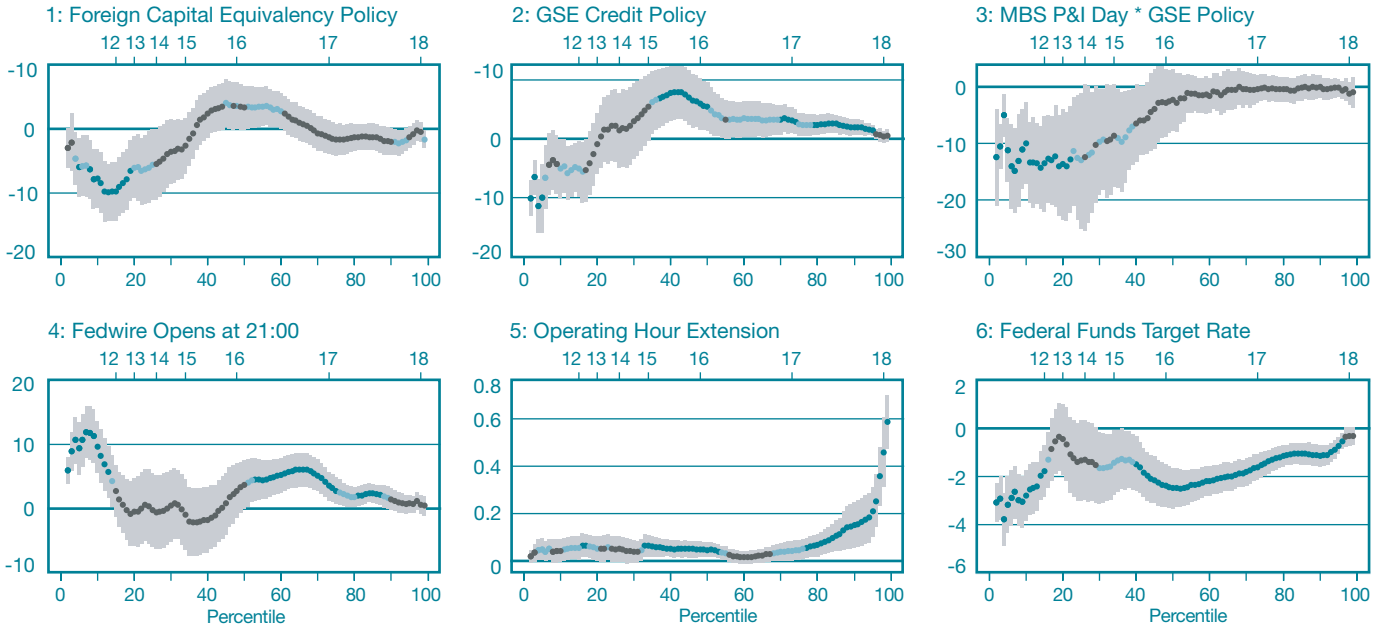
The July 1, 2006, modifications to the Federal Reserve's Payments System Risk Policy with regard to GSEs seem to have contributed to the delays in payments submitted after 15:00 on average in 2006 (Chart 8.2). Indeed, most estimated parameters for percentiles above 35 percent are significant and greater than zero. This result is therefore consistent with our hypothesis that the removal of access to intraday credit by GSEs and international organizations resulted in a shift toward later Fedwire payments. It is also consistent with the observation that the Federal Home Loan Banks decided to delay settlement of their principal and interest payments from 08:30 to approximately 14:00 after the implementation of the policy (but the delay effects persist throughout most of the remainder of the day).

As Fannie Mae and Freddie Mac are somewhat distinct from other GSEs, we also test whether the change in the Payments System Risk Policy had a specific effect on the 15th and 25th of the month, dates on which these two institutions make their principal and interest payments. Controlling for these specific dates over our entire sample period (see our discussion below) as well as for the policy change for all days following its implementation, we find that the timing of Fedwire payments shifted to earlier in the morning, but remained unchanged in the afternoon. Indeed, only the percentiles below 20 percent

Chart 8

Regressions of Fedwire Funds Value Time Percentiles

Federal Reserve Policies and Operations



Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: The upper x-axis displays the mean 2006 time for selected percentiles. The y-axis displays the value of the coefficient. The band represents the 95 percent confidence interval for the point estimates. We use independent ordinary least squares regressions with Newey-West standard errors (maximum lag = 10) for the 2nd to 99th percentiles of value. The color of the point indicates the significance of the coefficient: blue = 1 percent, light blue = 5 percent, dark gray = insignificant. There are 2,200 observations for each regression. GSE is government-sponsored enterprise; MBS is mortgage-backed securities; P&I is principal and interest.

are significant and negative (Chart 8.3). This result may be explained by a combination of two factors. First, compared with other GSEs, Fannie Mae and Freddie Mac did not delay markedly their payments of principal and interest after July 1, 2006. Second, after the policy change, these two GSEs found ways to have funds delivered to them earlier in the morning than they did prior to the change, in order to avoid having to draw on daylight overdrafts.

In another significant change to the Payments System Risk Policy, the February 21, 2002, Foreign Capital Equivalency Policy change increased the net debit cap of foreign banking organizations. We hypothesize that because foreign banking organizations conduct a larger percentage of their payments in the early Fedwire operating hours (from 21:00 to 08:00), which overlap with the operating hours of European and Asian markets, this change would affect the low percentiles of the Fedwire value time distribution. Chart 8.1 shows that the estimated parameters for percentiles below 20 percent are significant and negative, indicating that the change in Federal Reserve policies accelerated the submission of Fedwire payments in the morning. This result is therefore consistent with our prediction that the increase in net debit caps benefited mostly foreign banks submitting payments early in the morning, partly because of their active participation in CHIPS and CLS Bank.

We also find that the parameters associated with the duration of occasional extensions of Fedwire opening hours are significant and positive for most percentiles throughout the day. Observe also that the magnitude of the effect is significantly larger as the official closing time nears (that is, after 17:30). In other words, and in line with intuition, the duration of an extension is in general positively correlated with delays in the timing of payments, and it is particularly powerful for explaining delays at the end of the day.[9]

Finally, and somewhat surprisingly, our regression results in Chart 8.4 suggest that payments submitted in the morning were settled significantly later, not sooner, after Fedwire extended its opening hours from 00:30 to 21:00.

Settlement System Activities

We find no evidence supporting the hypothesis that the opening of CLS Bank had an effect on the timing of payments submitted through Fedwire (again, recall that payments to and from CLS Bank itself are removed from our measures). Indeed, all but a small number of estimated parameters associated with either the dummy variable capturing the opening date of CLS Bank (Chart 9.8) or the variable capturing the value of payments exchanged over CLS Bank (Chart 9.7) are insignificant. Therefore, the conjecture that the creation of CLS Bank may have helped speed up other Fedwire payments because it settles early in the day turned out to be unfounded.

In contrast, the other two settlement systems—CHIPS and DTC—appear to play major roles in shaping the value time distribution of Fedwire funds transfers, especially toward the end of the day. In particular, we identify significant delays in Fedwire payments submitted late in the afternoon (between 16:15 and 17:15 on average in 2006) on days DTC settles later.

CHIPS and DTC appear to play major roles in shaping the value time distribution of Fedwire funds transfers, especially toward the end of the day.

Indeed, the point estimates in Chart 9.6 are significantly greater than zero in the regressions conducted for the percentiles 55 percent to 85 percent. As we discuss in the next section, this result is particularly relevant, as DTC settlement typically occurs near the time of highest Fedwire activity.

Likewise, we find that the time of CHIPS settlement plays a significant role in explaining the upper tail of the value time distribution of Fedwire payments. Indeed, the estimations reported in Chart 9.1 suggest a strong positive effect, highly concentrated around the 75th percentile, which is very close to the time at which the highest peak of Fedwire activity occurs in 2006 (Chart 2). As we explore in greater detail in the next section, the emergence of the after-17:00 peak in Fedwire value transferred coincides with the change in CHIPS settlement time. In other words, the end-of-day shift in the timing of payments toward a later time may be traced in large part to the change in the timing of CHIPS settlement. Our regression results suggest that the January 2000 change in the timing of CHIPS settlement led to later settlement of the 65th-95th percentiles of Fedwire value.

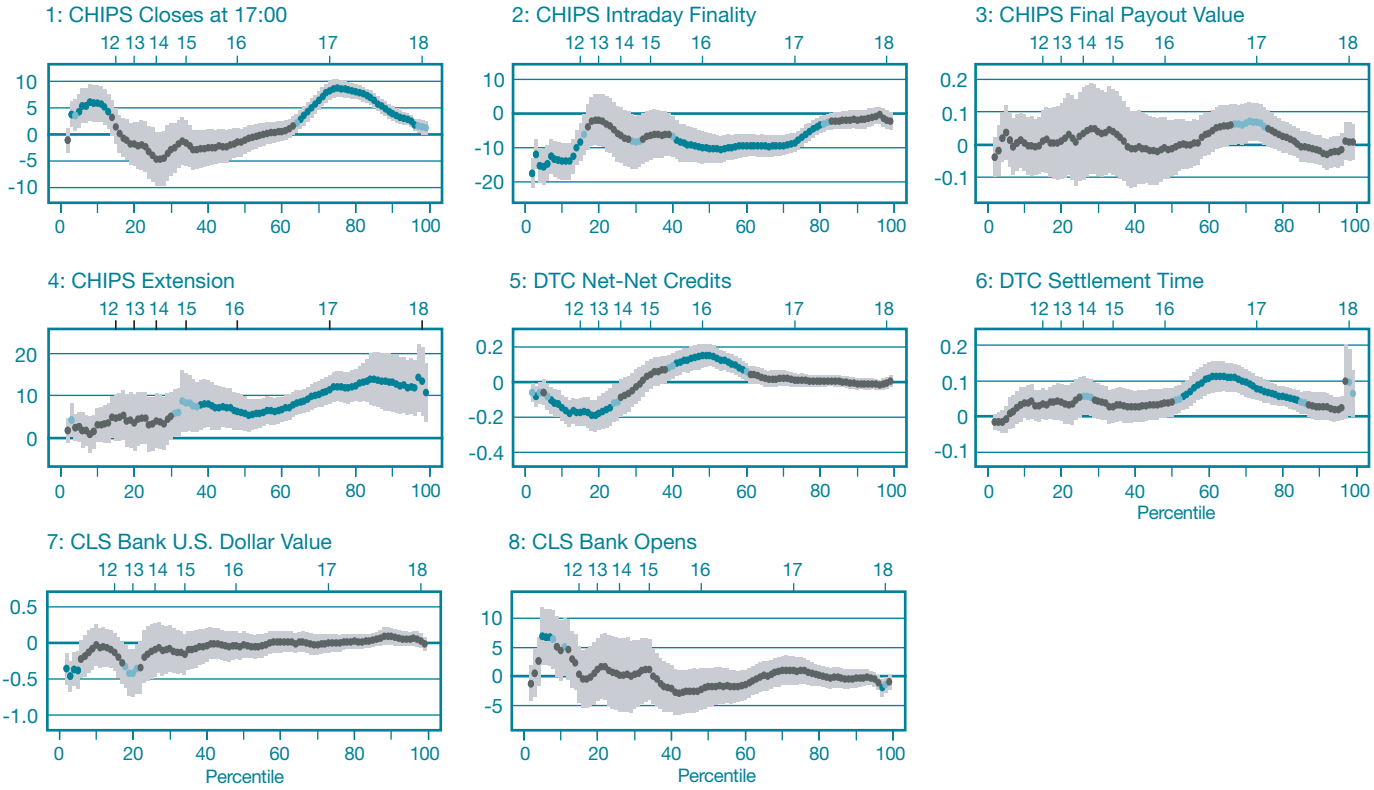
In contrast with the effects of the change in CHIPS settlement time, the change in the CHIPS settlement mechanism (to provide intraday finality of payments made via CHIPS) quickened the settlement of Fedwire payments throughout most of the day. Most of the estimated parameters in Chart 9.2 are significant and negative. This result may point to a consequence that the new CHIPS settlement mechanism has on customers: It may enable banks to credit their customers for payments made on CHIPS earlier in the day than was the practice before January 22, 2001. As a result of this earlier

[9] We find no indication that the occasional extensions of Fedwire operations may be endogenous. In other words, this variable may be considered as capturing only technical failure in Fedwire operations.

Chart 9

Regressions of Fedwire Funds Value Time Percentiles

Settlement Institutions



Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: The upper x-axis displays the mean 2006 time for selected percentiles. The y-axis displays the value of the coefficient. The band represents the 95 percent confidence interval for the point estimates. We use independent ordinary least squares regressions with Newey-West standard errors (maximum lag = 10) for the 2nd to 99th percentiles of value. The color of the point indicates the significance of the coefficient: blue = 1 percent, light blue = 5 percent, dark gray = insignificant. There are 2,200 observations for each regression.

redistribution of liquidity, banks' customers may now be able to submit other payments over Fedwire earlier.

Less clear is the influence of the variables capturing CHIPS and DTC values on the timing of Fedwire payments. For instance, we find that large CHIPS final payouts slow Fedwire payments at the end of the day (Chart 9.3). This result is not consistent with the hypothesis that, by releasing funds after it settles, CHIPS may accelerate payments made through Fedwire. Instead, it could suggest that CHIPS participants that have to make payments to settle their positions may experience a temporary liquidity squeeze that leads them to delay their Fedwire payments. Alternatively, it may reflect some greater uncertainties in banks' positions on days of high CHIPS settlements that cause increased delays of Fedwire payments.

The effect of DTC net-net credits is complicated. Chart 9.5 shows that larger DTC net-net credits appear to: 1) expedite Fedwire payments submitted in the morning (before 13:30), 2) slow mid-afternoon Fedwire payments (between 15:30 and 16:30), and 3) have no effect on payments submitted at the end of the day (after 16:30). We have no explanation for the first result. The second result may be explained by the fact that, as the level of activity on DTC increases throughout the day, liquidity available to other banks to make Fedwire payments is removed. Finally, the third result suggests that at the end of the day, the timing of Fedwire payments is affected only by the time at which DTC settles, not by the value of DTC net-net credits.

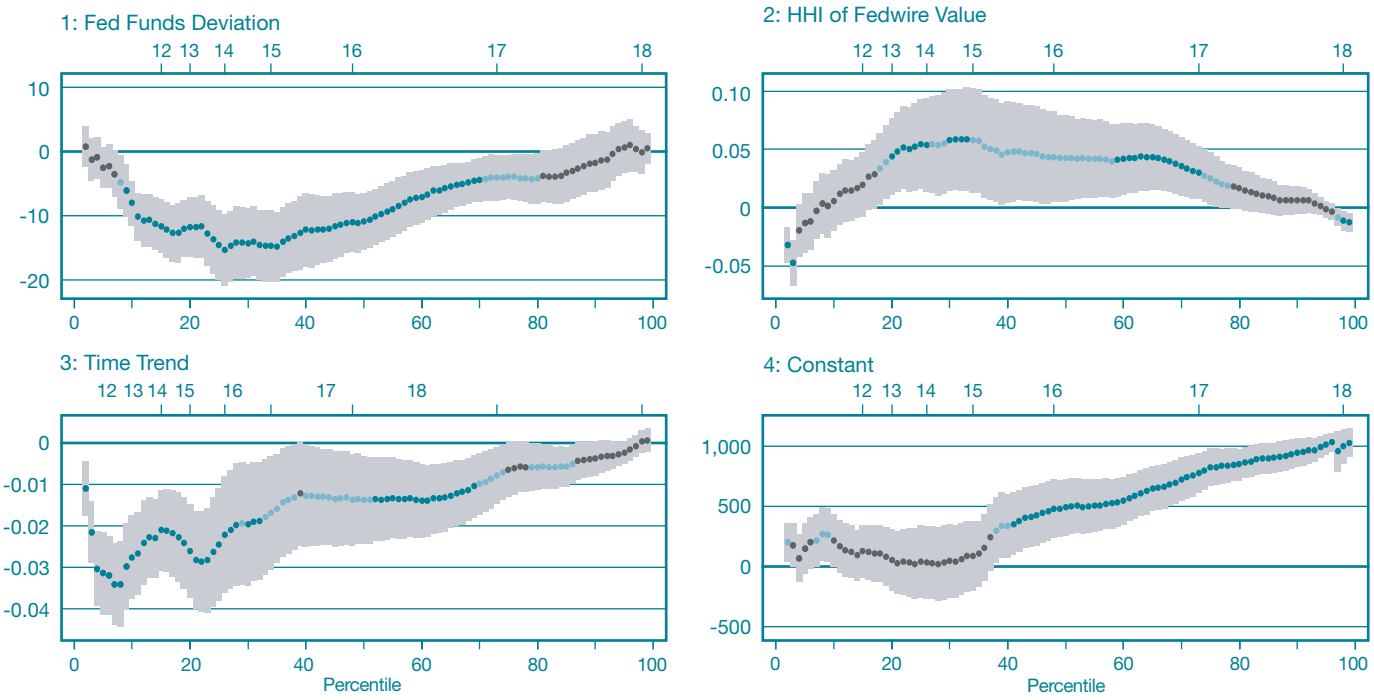
Other Control Variables

We find that a higher degree of industry concentration, as measured by the HHI, slows the transfer of Fedwire payments submitted after 12:00 up until the time of highest Fedwire activity. Indeed, most of the estimated parameters below the 75th percentile in Chart 10.2 are positive and significant. One

Chart 10

Regressions of Fedwire Funds Value Time Percentiles

Other Control Variables



Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: The upper x-axis displays the mean 2006 time for selected percentiles. The y-axis displays the value of the coefficient. The band represents the 95 percent confidence interval for the point estimates. We use independent ordinary least squares regressions with Newey-West standard errors (maximum lag = 10) for the 2nd to 99th percentiles of value. The color of the point indicates the significance of the coefficient: blue = 1 percent, light blue = 5 percent, dark gray = insignificant. There are 2,200 observations for each regression. HHI is the Herfindahl-Hirschmann Index, a measure of the concentration of payment activity among banks.

hypothesis is that an increase in industry concentration helps improve coordination and thereby facilitates the transfer of payments around a single point in time. Our finding that increased concentration in payment market shares tends to slow the settlement of payments might still be consistent with increased coordination, but it reflects the fact that coordination occurs around a later time of day, possibly at the peak of Fedwire activity.

An alternative hypothesis is that the increased concentration results in greater economization of liquidity by banks. The largest banks are more likely to pay positive overdraft fees and therefore face a positive marginal cost of liquidity. As payment shares move from banks with a zero marginal cost of liquidity to those with a positive marginal cost, we would expect settlement to occur later in the day. The nature of the increase in concentration is consistent with this hypothesis; the payment value market share of the top four banks has increased by 13 percentage points, while the share of banks ranked 5th through 50th has declined by 2 percentage points over the period. This shows that payment activity has moved from relatively small banks (market shares ranked below 50th), which face low marginal overdraft costs, to the largest banks (top four), which regularly face a higher positive fee for the use of their marginal daylight overdrafts.

The federal funds rate deviation shifts most of the distribution of Fedwire payments earlier (Chart 10.1). This result does not support the hypothesis that a positive deviation reflects a higher than anticipated demand for intraday liquidity by Fedwire participants and therefore would be associated with later Fedwire payments. Instead, we conjecture that the effect of federal funds deviations could be explained by Fedwire participants having an incentive to purchase federal funds early if they are trading at a higher than anticipated price.

Finally, the time trend is found to be significantly lower than zero for most percentiles during the day (Chart 10.3). Before we interpret this result, recall that in the descriptive analysis we identified a dual adjustment process between 1998 and 2006,

with a trend toward earlier payments for low percentiles and a trend toward later payments for higher percentiles. The estimated time trend therefore appears to capture part of the first effect, but it is not consistent with the second. In other words, the move toward later Fedwire payments at the end of the day is explained in our regressions by explanatory variables other than the exogenous time trend. In addition, observe that the influence of the time trend on the timing of Fedwire transfers provides some support for the hypothesis that technological improvements, such as in queuing mechanisms used at various banks, may have contributed to accelerating transfers over Fedwire.

Calendar Effects

We now comment briefly on some of the major calendar effects. We find that compared with Thursdays, the timing of payments on Mondays (especially in the morning) and Tuesdays is delayed (Charts 11.5 and 11.6), but for the most part the timing is not significantly different on Wednesdays and Fridays, except for a marked end-of-week effect at the close of Fedwire on Fridays (Charts 11.7 and 11.8). Controlling for the days of the week, we find that the timing of Fedwire payments is virtually identical during the second week of the maintenance period (Charts 11.9-11.12), except for the Monday of the second week (Chart 11.11), when payments settle earlier.

Chart 11.1 indicates that Fedwire payments tend to settle earlier when Fannie Mae and Freddie Mac make principal and interest payments (on the 15th and 25th of the month). This effect was anticipated, because these payments are typically issued around 08:30, and therefore they provide Fedwire participants with an influx of liquidity early in the morning.

In addition, we find that, all else equal, Fedwire payments settle earlier: 1) on days when the New York Stock Exchange is either closed or closes early (Charts 11.2 and 11.3), 2) on the days preceding and following a holiday (Charts 11.14 and 11.15), 3) on the last days of each quarter (Chart 11.17), and 4) on the last five days of the year (Chart 11.18). In contrast, Fedwire payments tended to be submitted later on the first of the month (Chart 11.16) and during the week following September 11, 2001 (Chart 11.4).

Finally, observe that the adjusted R^2s are generally high (Chart 12), indicating that our regression models are able to capture a large part of the daily variations in the percentiles of Fedwire value. Note also that the adjusted R^2s tend to be closer to 1 for higher percentiles. This result is consistent with the fact that low percentiles, corresponding to payments settled in the morning, are in general more volatile from one day to the next.

4.2 Economic Significance

To put our regression results into a more general perspective, we conduct two exercises. First, we measure which variables can explain a later-than-normal settlement of Fedwire value on a given day in 2006. The second exercise measures the approximate economic contribution of various factors in explaining the shift in late-day payments between 1998 and 2006. To start, both exercises confine our attention to those variables that largely explain the variation in the timing of payments submitted after 17:00. This may be considered particularly relevant in light of the Board of Governors of the Federal Reserve System's 2006 consultation paper, which points out that the recent shift of the Fedwire activity peak to closer to the end of the day raises some concerns in terms of operational problems. Understanding the factors affecting the submission of Fedwire payments at the end of the day is therefore of particular interest when analyzing potential economic costs and benefits of alternative policy options.

Understanding the factors affecting the submission of Fedwire payments at the end of the day is . . . of particular interest when analyzing potential economic costs and benefits of alternative policy options.

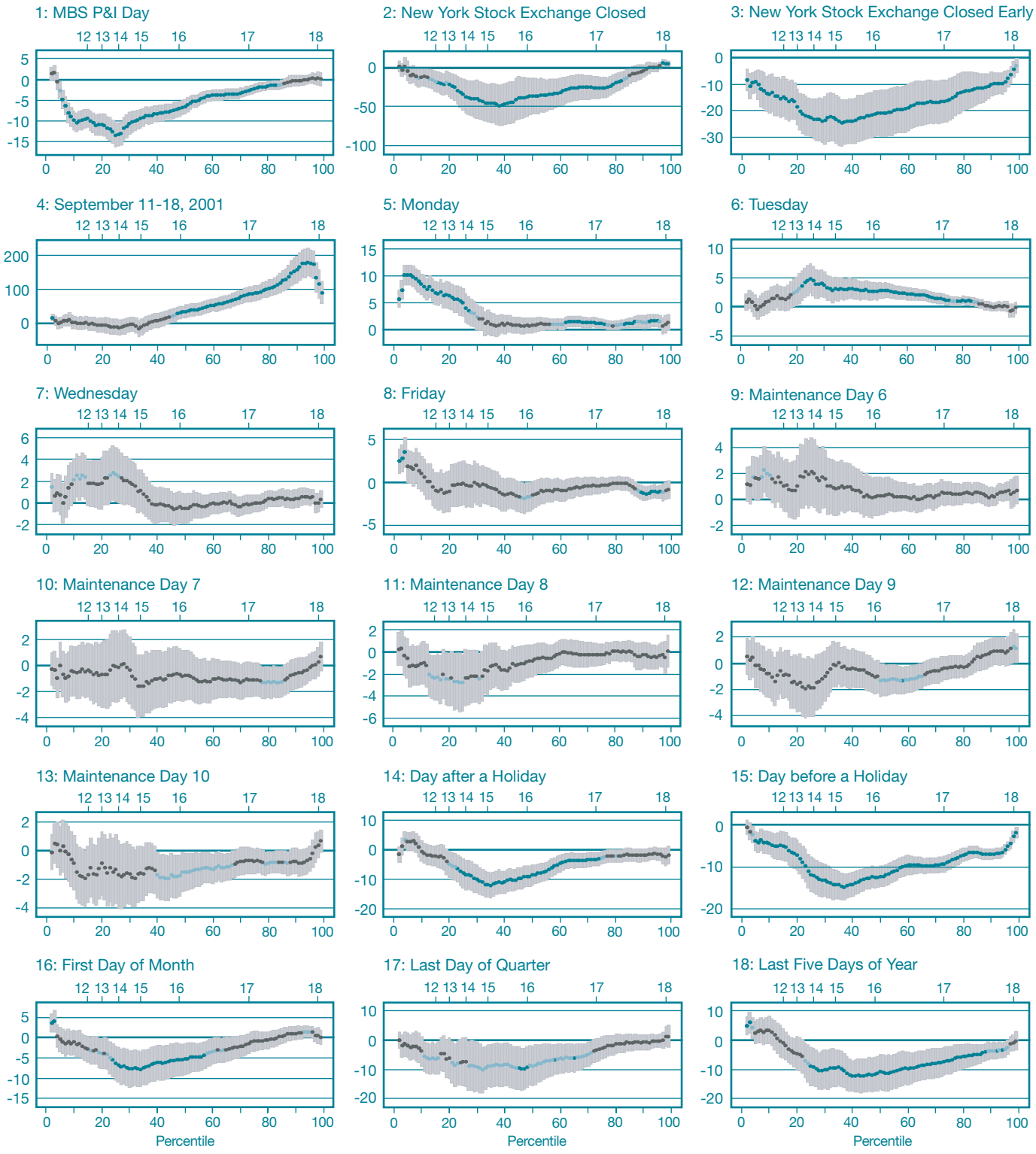
In our first exercise, we take out the effect of long-run growth in most continuous variables, such as volume and value, by removing the trend of each of the continuous covariates (those that vary in number or in value over time). Next, we measure a small day-to-day variation in the level of the variable—namely, a one standard deviation of this adjusted variable. We also consider a typical day by setting all calendar effects equal to zero and without an extension of Fedwire operation. Finally, we ignore the effect of past specific events, such as the May 17, 2004, extension of Fedwire operating hours and the creation of CLS Bank, as these events are not expected to repeat in the variation of activity on Fedwire from one day to the next. We then measure the economic significance of all of our variables in explaining the timing of payments made on Fedwire after 17:00 by multiplying the estimated coefficient by the one-standard-deviation change in the variable.

Surprisingly, we find that only three variables appear to play a significant economic role in explaining the timing of Fedwire

Chart 11

Regressions of the Fedwire Funds Value Time Percentiles

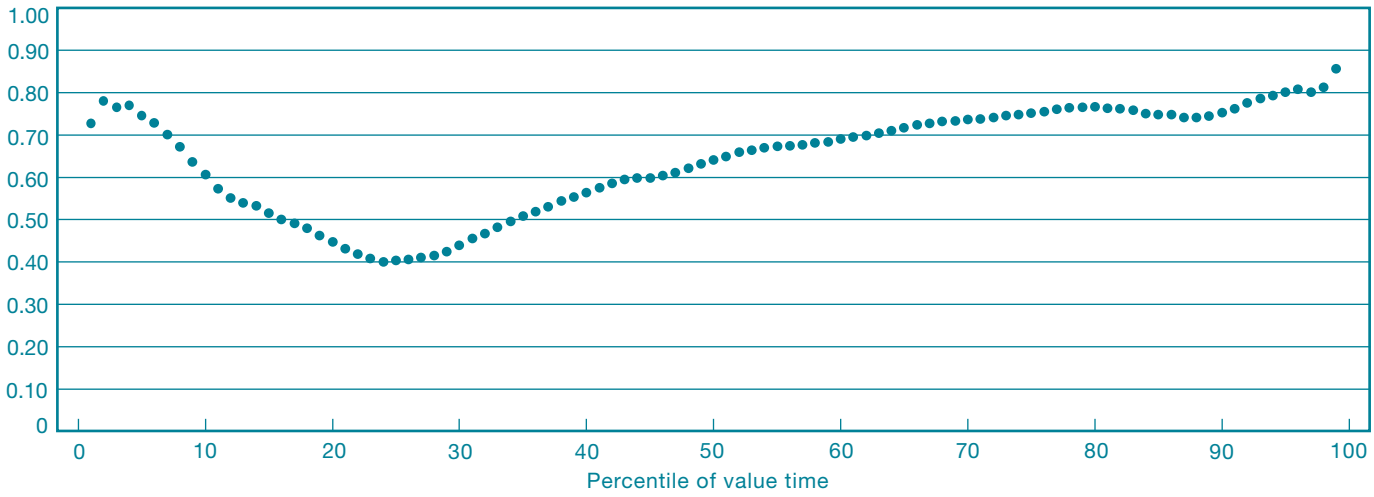
Calendar Effects



Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: The upper x-axis displays the mean 2006 time for selected percentiles. The y-axis displays the value of the coefficient. The band represents the 95 percent confidence interval for the point estimates. We use independent ordinary least squares regressions with Newey-West standard errors (maximum lag = 10) for the 2nd to 99th percentiles of value. The color of the point indicates the significance of the coefficient: blue = 1 percent, light blue = 5 percent, dark gray = insignificant. There are 2,200 observations for each regression. MBS is mortgage-backed securities; P&I is principal and interest.

Chart 12
Adjusted R^2 of Regressions



Source: Authors' calculations.

payments submitted after 17:00 from one day to the next. In particular, a typical day-to-day variation in either the value of interbank payments or in the number of daily Fedwire transfers each delays payments submitted after 17:00 by roughly three minutes on average. In addition, we find that an extension of CHIPS operating hours delays virtually all payments submitted after 17:00 by ten minutes on average. We note that although large in magnitude, this effect does not necessarily constitute a major risk, as CHIPS extensions are rare in practice, especially since CHIPS changed its settlement mechanism (for instance, CHIPS extended its hours of operation only once between January 2005 and December 2006). Nevertheless, this effect does illustrate how significantly the operations of settlement

[Our result] suggests that very few variables have an influence on payments submitted after 17:00 on a day-to-day basis.

institutions are interconnected. To summarize, this first exercise indicates that although numerous factors contribute to the shift in the time of highest Fedwire activity between 16:30 and 17:00, their effects appear to be confined to that period and do not spill over near Fedwire's closing time. This result should be reassuring, as it suggests that very few variables have an influence on payments submitted after 17:00 on a day-to-day basis.

Our second exercise evaluates the economically significant factors that contributed to the shift in the after-17:00 value time distribution of Fedwire payments between 1998 and 2006. Note, however, that our regression model is not perfectly suited to disentangle the respective contribution of each explanatory variable from the changes in the timing distribution observed during this period. Because most of the covariates varied jointly between 1998 and 2006, our model cannot pin down precisely the contribution of each explanatory variable to the shift in the timing of payments. The results presented here should therefore be interpreted as orders of magnitudes rather than exact measurements. Again, we are more interested in the end-of-day changes and we therefore focus on the changes in the 75th percentile, which roughly corresponds to the time of highest Fedwire activity in 2006.

Our model predicts that compared with 1998, the 75th percentile should have shifted fourteen and a half minutes later in 2006. This shift is slightly more than the thirteen minutes we actually observe in the data, but it is within two standard deviations. If we consider the effect of the time trend as being exogenous, we find the following:

1. When combined, the increase in the number and value of Fedwire payments between 1998 and 2006 accounted for slightly more than 40 percent of this shift in the 75th percentile toward a later time.[10]
2. The change in CHIPS closing time on January 18, 2000, if considered an exogenous event, contributed more than 30 percent by itself. This effect, however, is partially offset by the modification in the CHIPS settlement mechanism, which moved the 75th percentile earlier. As a result, the aggregate contribution of CHIPS to the later settlement

[10] In this measure, we include all variations between 1998 and 2006 in the values of interbank payments, customer payments, and federal fund deliveries and returns. We also include the increase in the share of individual payments greater than $10 million.

of the 75th percentile may be estimated at around 10 percent.

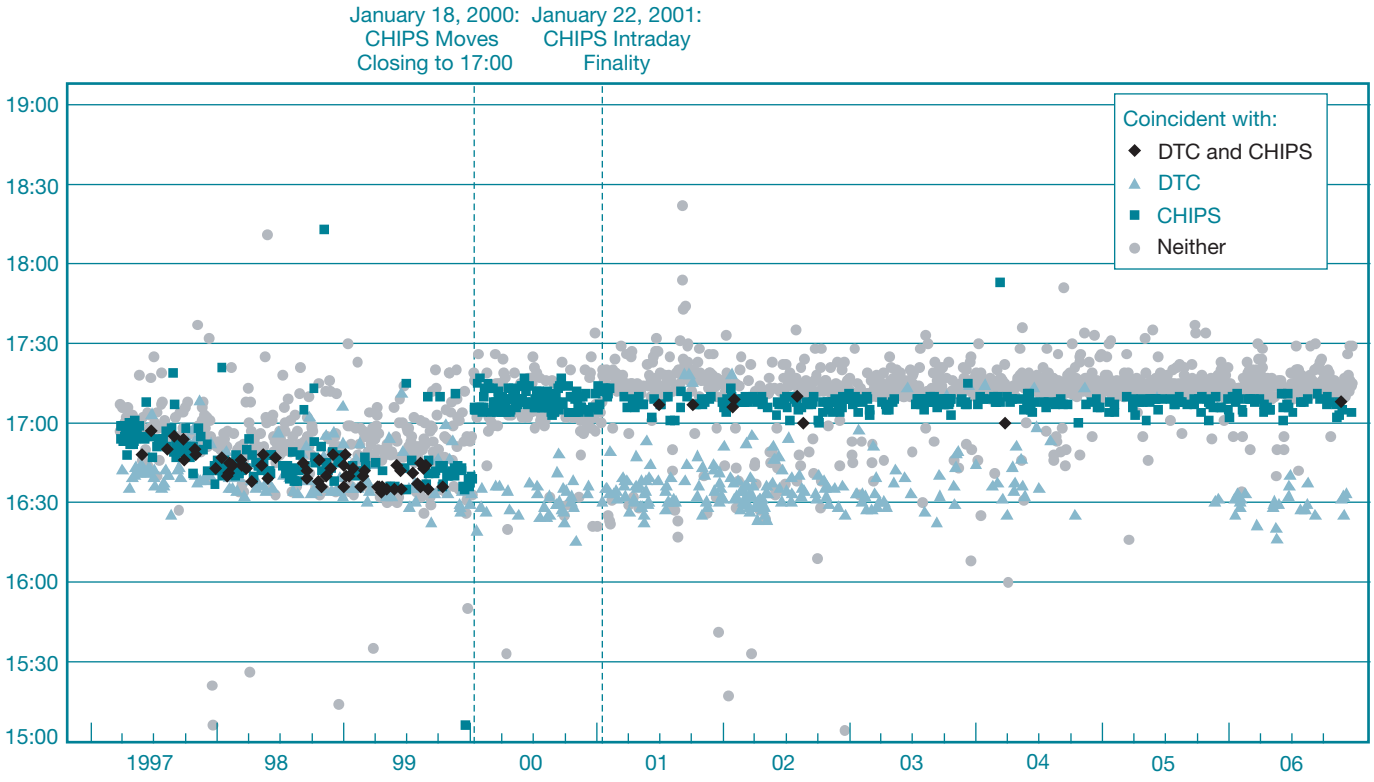
3. Finally, the last major contributor to the shift of the 75th percentile toward a later time is the higher concentration of payment activity among banks. We find that between 1998 and 2006, the increase in the HHI accounted for close to 30 percent of the shift.

5. Influence of CHIPS and DTC on Settlement Time

Our regression analysis points to a few specific variables as highly explanatory of the shift to later settlement of the 70th-90th percentiles of Fedwire activity. In this section, we present other evidence of the influence of the settlement institutions—CHIPS and DTC—on the value time distribution of Fedwire activity. Specifically, we consider the time at which the peak in Fedwire value transfer occurs. Recall Chart 2, which shows that the peak in Fedwire value transfer occurred before 17:00 in 1998 and after 17:00 in 2006.

To illustrate the dependency of the Fedwire value time distribution on the behavior of CHIPS settlement timing, we measure the timing of the peak of Fedwire activity as the midpoint of the ten contiguous minutes of highest value transferred during the day. Chart 13 displays the time of the peak ten minutes of value transferred on Fedwire from 1997 through 2006. Each point represents the time at which the midpoint of the top ten contiguous minutes of Fedwire value settled on each day between 1997 and 2006. We see that prior to January 18, 2000, there was a peak at approximately the same time daily (although that time varied from day to day). Its time trended downward from around 17:00 in 1997 to around 16:48 in early January 2000. After January 18, 2000, however, a distinctly new pattern emerged. Peaks tended to occur at two specific times: 16:30 and 17:11, with the most common peak at 17:11. This is consistent with the observation in Chart 5 that the value time distribution of Fedwire changed from a single-peak distribution to a dual-peak distribution in 2000.

Chart 13
Time of Peak Ten Minutes of Fedwire Funds Value

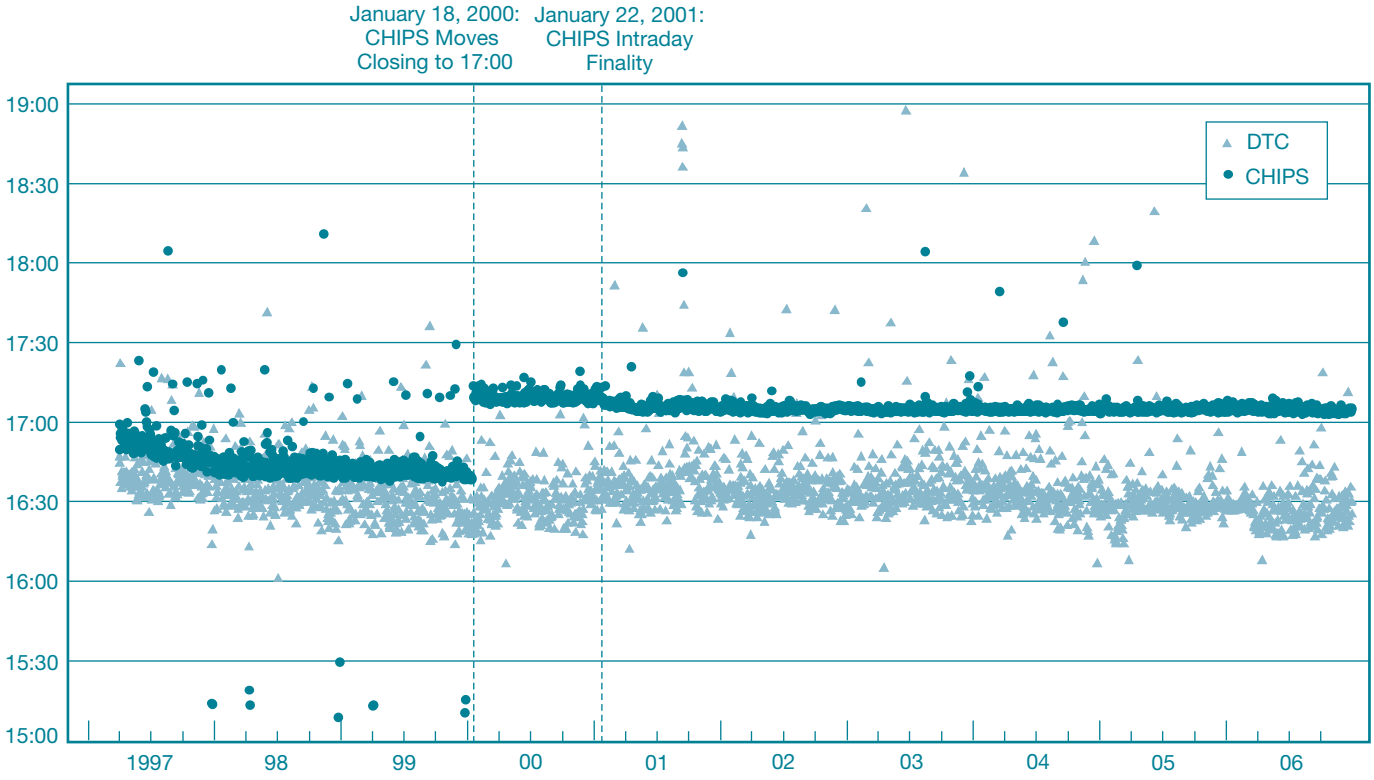


Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: Seven days settling after 19:00 were excluded. Values exclude payments associated with CHIPS, CLS Bank, DTC, and principal and interest payment funding.

Chart 14

End-of-Day Settlement Times of CHIPS and DTC



Sources: Federal Reserve Bank of New York; authors' calculations.

Note: Seven days settling after 18:30 were excluded.

The regression analysis suggests a reason for why the shift occurred. Prior to January 18, 2000, CHIPS effected its final settlement at approximately 16:40; on January 18, 2000 (and thereafter), it moved its settlement of final payouts to approximately 17:10, while the value-weighted time of DTC's settlement remained roughly constant over the period. Examination of Charts 13 and 14 suggests that prior to January 18, 2000, Fedwire's peak of settlement activity occurred simultaneously with the roughly coincident settlement times of CHIPS and DTC. After January 18, 2000, when CHIPS moved to a later settlement time, two peaks of settlement activity emerged on Fedwire. One coincided with DTC settlement time at 16:30, and the other moved more closely to CHIPS settlement time after 17:00. The distinct change in pattern, so closely matching the timing pattern of CHIPS and DTC, as well as the evidence from the regression analysis, points to the timing of the settlement institutions' late-in-the-day settlement as being highly explanatory in the timing shifts of Fedwire's peak and late-day activity over the 1998-2006 period.

Why should Fedwire's peak activity in value transfer coincide so closely with the final payouts of the major settlement institutions? We advance four hypotheses, which are not necessarily mutually exclusive: the bank liquidity cascade, the customer credit cascade, the resolution of uncertainty, and the role played by settlement times as focal points.

First, we advance our bank liquidity cascade hypothesis. Consider the activities of DTC. As we discuss in Appendix B, DTC accumulates balances in its account and releases them back to the banking system during its final payout procedures. That outflow of balances from DTC and the resulting inflow to banks can trigger a cascade of payments made by the receivers of DTC payouts, which triggers further payments made by the receivers of those payments, and so on. The cascade of payments can occur if banks are withholding payments because they face internal constraints attributable to a cost of liquidity or some other limit on their willingness to submit payments earlier. Beyeler et al. (2006) provide a model and simulation of a similar process.

A second reason for such a release of payments is the related customer credit cascade hypothesis. Not only do banks face constraints in making timely payments, but so do their customers. Those customers, or the depositors of banks, also receive funds following payouts on a major settlement system, which provides funds to their accounts. If those depositors had been withholding payments because they could not easily obtain credit to send payments, the inflow of settlement system payments could provide the needed funding for them to execute their withheld payments; the release of those depositor payments could result in the release of payments by the receivers of their payments, and so on.

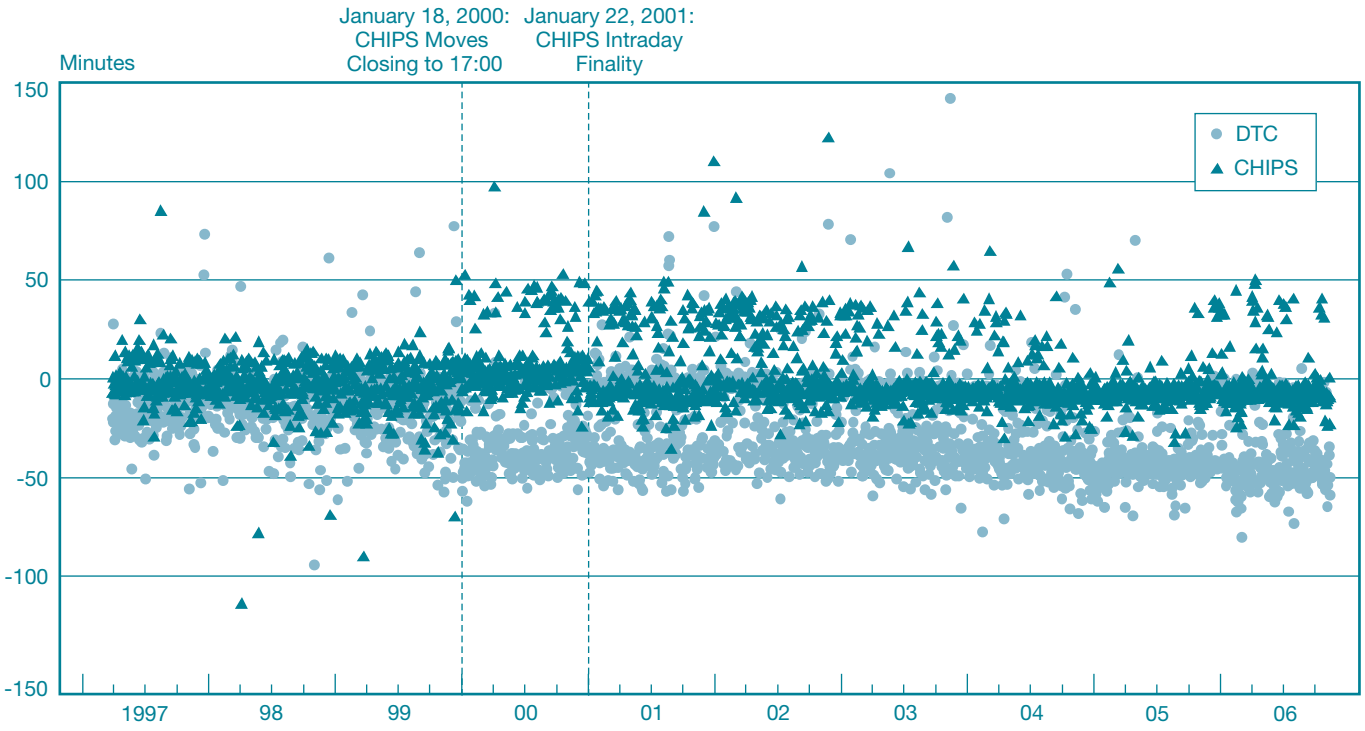
The resolution-of-uncertainty hypothesis is a third reason why banks might release payments after a major settlement system's final payouts. Prior to settling at a major settlement institution, banks could be uncertain of the exact amount of their payout from the system (or their obligation to the system), and there could be some uncertainty about whether all parties in the settlement system will perform as expected. After the uncertainty is resolved, banks might evaluate more precisely the effect of releasing payments, arranging for the purchase or sale of federal funds, and making any other adjustments.

Finally, banks, according to the focal point hypothesis, might coordinate their payment submissions with a settlement institution. Banks might choose to release payments after the final payouts of a major settlement institution because they believe that other banks will do so at the same time. If many banks choose to release payments at the same time, each bank has a higher likelihood of receiving payments during that peak of payment activity; therefore, it is more likely that the banks will have a lower cost of funding their outgoing payments at that time (by incurring fewer daylight overdrafts and avoiding any constraints, such as bumping up against a net debit cap). This same phenomenon could hold true for depositors—a hypothesis discussed in McAndrews and Rajan (2000).

While our analysis cannot clearly distinguish between the alternative hypotheses, it is instructive to consider what the data might imply about the relative weight of the various hypotheses as explanations for the changes observed after January 18, 2000. Chart 15 shows the difference in the settlement times of CHIPS and DTC and the time of the top ten minutes of Fedwire value transferred. A band of five minutes on either side of 0 on the y-axis represents the time of settlement of the top ten minutes of Fedwire value. A circle represents the time of DTC settlement and a triangle the time

Chart 15

Difference between Peak Ten Minutes and Settlement Times of CHIPS and DTC



Sources: Federal Reserve Bank of New York; authors' calculations.

Note: Values exclude payments associated with CHIPS, CLS Bank, DTC, and principal and interest payment funding.

of CHIPS settlement. When a point falls within the five-minute band on either side of 0, the settlements of Fedwire and that system coincide. The clearest pattern that Chart 15 displays is that prior to January 18, 2000, the three systems—CHIPS, DTC, and Fedwire—settled roughly simultaneously; after that date, CHIPS and DTC settlement times diverged. The time of Fedwire peak settlement tends to bounce between the time of DTC settlement and a time immediately subsequent to CHIPS settlement. This is because, prior to January 18, 2000, it was fairly common to have all three systems settle roughly simultaneously, so it is difficult to distinguish among the various hypotheses. These same patterns are visible in Chart 13.

After January 18, 2000, we see two tendencies. First, on days on which the 16:30 peak is the time of the highest value transferred on Fedwire, DTC settlement often falls within the ten minutes of highest value transferred on Fedwire. Second, when the 17:11 peak is the time of highest value transferred on Fedwire, it is usually (and increasingly over time) the case that CHIPS settlement precedes and falls outside the highest ten minutes of Fedwire value transferred.

CHIPS is the last major institution to settle; at that point in the processing day, most uncertainty about bank balances is expected to be resolved and banks might reason that it is a good time to send payments after CHIPS has settled.

These tendencies might suggest that DTC settlement kicks off a liquidity and customer credit cascade, an observation supported by the quickness of value transfer on Fedwire following DTC settlement. This observation is also consistent with the fact that DTC's account balances grow over the day and are then released with DTC settlement to other banks, which effectively increases the short-term supply of liquidity in the rest of the banking system. However, the fact that the peak of activity follows CHIPS settlement with only some delay might suggest that the cause of the activity is more closely associated with resolution of uncertainty than with a liquidity or credit cascade. This explanation is also consistent with the fact that CHIPS settlement is mainly a redistribution of balances among banks, rather than a net release of liquidity back to banks. The focal point hypothesis might also offer a good explanation for the peak that occurs after CHIPS settlement. CHIPS is the last major institution to settle; at that point in the processing day, most uncertainty about bank balances is expected to be resolved and banks might reason that it is a good time to send payments after CHIPS has settled.

6. Conclusion

In its report on large-value payments systems, the Committee on Payment and Settlement Systems noted that the timing of payment submission is a market practice of major importance (Bank for International Settlements 2005). It is not uncommon for stable behavioral conventions to arise around the time when participants submit certain types of payments for settlement. Such conventions can arise endogenously among direct participants, and non-RTGS payments can be an important "exogenous" factor affecting a bank's RTGS liquidity.

Our examination of payment time distribution trends in the Fedwire funds service from 1998 to 2006 finds that the lower percentiles of timing have moved to earlier in the operating day. In addition, the very last percentiles transferred have also moved to earlier over the study period, as extensions of the Fedwire operating day have become more rare. We also observe that while more value settles earlier in the morning and the later percentiles of value settle later in the afternoon, the distribution of value transferred has become more peaked. A greater percentage of value was transferred during the peak of activity in 2006 than in the early part of our sample.

We considered a host of factors affecting changes in the distribution of Fedwire timing. Federal Reserve policies and operations were found to affect settlement times in notable ways. Changes to the Federal Reserve's Payments System Risk Policy in 2002, which expanded net debit caps significantly, quickened Fedwire settlement in the morning and early afternoon, while 2006 policy changes, which lowered extensions of daylight credit overall, tended to slow settlement throughout the afternoon. Both changes are consistent with banks economizing on liquidity costs in their submission of payments. Changes in the values and volumes transferred over Fedwire have increased over the period, as has the proportion of large individual payments. Taken together, these changes explain a large share of the later settlement of payments (after 17:00) over the period. However, we find that a larger value of customer payments tends to quicken Fedwire settlement, possibly because of the higher delay costs of customer payments—another influence noted in the economic literature.

There were numerous changes in settlement institutions over the period. The introduction of CLS Bank operation and the values transferred by CLS Bank appear to have had little effect on the value time distribution on Fedwire. Changes in CHIPS operations had countervailing effects, with a 2000 move toward later settlement time by CHIPS clearly contributing to a later peak in Fedwire activity. The move by CHIPS to intraday finality in 2001, though, tended to speed settlement of the 40th-80th percentiles of Fedwire value. Increased values transferred by CHIPS tended to delay settlement on Fedwire

for the 50th-80th percentiles, while on DTC heightened values quickened early settlement and delayed mid-afternoon settlement. A payment market that has grown more concentrated had a significant influence on the later settlement of Fedwire value. These results reflect the various calendar effects and activity in other financial markets included in our regression analysis.

A major contributor to the later settlement of Fedwire payments was the change in CHIPS settlement time from roughly 16:45 to 17:10 on January 18, 2000. The time of the midpoint of the highest ten minutes of Fedwire value transferred moved in a remarkably coincident fashion from 16:48 to 17:11 on that date. This pattern persisted, with the Fedwire value time distribution displaying two main peaks: one remaining at 16:30, nearly coincident with DTC settlement, and one at 17:11, shortly after the time of CHIPS final payouts. Over time, these new peaks of activity have been stable.

Our results also suggest that changes in the value of interbank payments and in the number of daily Fedwire transfers can explain most of the daily variation in the time of value transferred on Fedwire after 17:00. The rare case of an extension of CHIPS operating hours delays virtually all payments submitted after 17:00, a clear illustration of the interdependence between Fedwire and CHIPS.

In addition, we estimate that increases in the number and value of Fedwire payments between 1998 and 2006 contributed slightly more than 40 percent to the long-run change in the 75th percentile of the value time distribution of payments. Of this amount, the aggregate contribution of CHIPS may be estimated at around 10 percent, and the increase in industry concentration accounted for close to 30 percent.

The clear interdependence between payment timing on Fedwire and CHIPS reinforces the points made in the Committee on Payment and Settlement Systems' report on large-value payments systems (Bank for International Settlements 2005). The role of settlement institutions that utilize Fedwire for pay-ins and payouts is a major factor determining system activity. This article has reviewed a number of hypotheses on the possible channels through which settlement systems affect Fedwire activity. Further research on these channels would indeed provide a better understanding of the factors that affect the timing distribution of payments in large-value systems.

Also deserving of further research is the effect of increased industry concentration on the timing of payments, a topic that has not been explored in the theoretical literature. Furthermore, researchers could benefit from conducting similar studies of other payments systems to ascertain the effects of daylight credit policies, system operations, settlement systems, industrial structure, and other determinants of payment timing. Their results could shed light on the robustness of our results.

Appendix A: Data

Our data source is Federal Reserve Bank of New York records of every Fedwire funds service transaction. Unless otherwise stated, data are used to construct the variables below associated with Fedwire funds activity. We have data on all Fedwire funds transfers between April 1997 and December 2006, except for April 1, 1997; December 22-24, 1997; March 1-3, 1999; April 20-22, 1999; October 14-15, 1999; October 18, 1999; and November 9, 1999.

Variables

ith percentile of value time is the time at which *i* percent of the total daily value has settled. We exclude payments to or from CHIPS, CLS Bank, and DTC. We also exclude payments associated with interest and redemption payments of government-sponsored enterprises and international institutions after the Federal Reserve's Payments System Risk Policy change on July 1, 2006. These payments related to P&I (principal and interest) are Fedwire funds payments between two different accounts of the securities issuer, that is, payments from the general account to the funding account and from the funding account to the distribution account.

Foreign Capital Equivalency Policy is a binary variable equal to 1 on and after February 21, 2002, when the Federal Reserve changed the criteria for determining U.S. capital equivalency for foreign banks. This policy change increased the sum of the net debit caps of all Fedwire funds participants by $123 billion, or 12 percent (see Board of Governors of the Federal Reserve System [2001]).

GSE credit policy is a binary variable equal to 1 on and after July 1, 2006. The Federal Reserve changed its Payments System Risk Policy to require GSEs and international organizations to fully fund interest and redemption payments on securities before the funds are sent, and it removed the provision of free intraday credit to these issuers (Board of Governors of the Federal Reserve System 2004; McAndrews 2006).

MBS P&I day, pre-GSE policy is a binary variable equal to 1 on the 15th and 25th of the month, or the first business day thereafter, before the change in GSE credit policy on July 1, 2006. On these days, Fannie Mae and Freddie Mac make interest and redemption payments on mortgage-backed securities (MBSs). These are generally the largest interest and redemption payment days of the month.

MBS P&I day, post-GSE policy is a binary variable equal to 1 on the 15th and 25th of the month, or the first business day thereafter, after the change in GSE credit policy on July 1, 2006.

Fedwire opens at 21:00 is a binary variable equal to 1 for all days on or after May 17, 2005. On that date, the Federal Reserve extended the operating hours of the Fedwire funds service from 18 hours to 21.5 hours by moving the opening time from 00:30 to 21:00 (Board of Governors of the Federal Reserve System 2003).

Operating hour extension is the number of minutes that the Fedwire funds service remains open after 18:30. The Federal Reserve will occasionally extend Fedwire's operating hours at the request of a participant having operational difficulties or if the system is experiencing operational problems (Bank for International Settlements 2005).

Fed funds target rate — Source: <http://www.ny.frb.org/markets/omo/dmm/fedfunds.cfm>.

Interbank payment value is the sum of the payment values of all Fedwire funds transfers that are not fed funds deliveries, fed funds returns, customer payments, or settlement payments for CHIPS, CLS Bank, or DTC, or that are not principal and interest redemptions.

Customer payment value is the sum of the payment values of all Fedwire funds transfers with a business function code of customer payment.

Fed funds deliveries is the total value of new fed funds loans. These loans were identified from Fedwire funds transactions, as in Furfine (1999).

Fed funds returns is the total value of the returns of the fed funds loans. It is equal to the value of fed funds deliveries for the previous business day plus the interest on those loans. These loans were identified from Fedwire funds transactions, as in Furfine (1999).

Payments ≥ $10 mn. is the fraction of daily value from payments greater than or equal to $10 million. This excludes all CHIPS, CLS Bank, DTC, and P&I funding payments. The

threshold value of $10 million is the value used in a survey of bank intraday liquidity management conducted by the Payments Risk Committee and the Wholesale Customer Advisory Group (2007).

Number of payments is the daily number of Fedwire funds payments, including interbank, customer, and fed funds transactions, but excluding all CHIPS, CLS Bank, DTC, and P&I funding payments.

CHIPS settlement at 17:00 — CHIPS settlement time is a binary variable equal to 1 for all days on or after January 18, 2000. On that date, the time at which end-of-day CHIPS payouts occurred moved from approximately 16:45 to 17:10.

CHIPS intraday finality is a binary variable set to 1 for all dates on or after January 22, 2001. This is the date when CHIPS moved from an end-of-day multilateral net debit system to a mixed-payments system with intraday finality.

CHIPS final payout value is the value of the end-of-day payouts sent by CHIPS over Fedwire to CHIPS participants with a net credit position.

CHIPS extension is a binary variable for a later-than-normal CHIPS final payout time. This is defined as a CHIPS final payout occurring after 17:00 for days before January 18, 2000, and after 17:15 otherwise.

DTC settlement time is the value-weighted mean time of Fedwire funds payments sent by DTC after 16:00.

DTC net-net credit value is the sum of all Fedwire funds payments sent by DTC after 16:00.

CLS Bank opens is a binary variable equal to 1 for all days on or after September 10, 2002, when CLS Bank International began settling U.S. dollar transactions.

CLS Bank USD value is the daily sum of payments sent by CLS Bank over Fedwire. It is equivalent to the value of all U.S. dollar legs settled by CLS Bank.

Sep. 11-18, 2001, is a binary variable equal to 1 for those dates. This is the period in which the Fedwire payments system was disrupted by the terrorist attacks on September 11 (McAndrews and Potter 2002).

NYSE closures and NYSE early closures — Source: <http://www.nyse.com/pdfs/closings.pdf>.

Reserve maintenance cycle days are binary variables for the days in a reserve maintenance cycle. The maintenance cycle is a two-week period starting on a Thursday (see Federal Reserve Banks [2006] for the starting and ending dates of maintenance cycles). We include dummies for all days of the week with Thursdays—the first day of the reserve maintenance cycle—as the excluded group. To disentangle the effect of the maintenance cycle above from any day-of-week effects, we include binary variables for maintenance days in the second week of the maintenance cycles, that is, days 6-10.

HHI of Fedwire value is the Herfindahl-Hirschmann Index of the value of Fedwire funds payments sent by master accounts.

Fed funds deviation is the difference between the effective fed funds rate and the target fed funds rate. Source: <http://www.ny.frb.org/markets/omo/dmm/fedfunds.cfm>.

CHIPS

CHIPS is a private, large-value U.S. dollar payments system owned and operated by the Clearing House Payments Company (Federal Reserve Bank of New York 2002; Bank for International Settlements 2003b, 2005). As of April 2007, CHIPS had 45 members and settled 329,000 transactions valued at $1.7 trillion per day.[11] From its opening in 1970 until 2001, CHIPS operated as an end-of-day multilateral net debit settlement system: After CHIPS closed at 04:30 (05:00 after January 18, 2000), participants with negative net positions would send payments to CHIPS over Fedwire to cover their positions; CHIPS would then send payments to those participants with net positive positions.

On January 22, 2001, CHIPS adopted intraday payment finality with a continuous offsetting algorithm to optimize liquidity. All CHIPS participants must fund their accounts with a Fedwire transfer to CHIPS between the opening of Fedwire and 09:00 before they can send or receive payments. These balances, totaling about $3 billion, are used to settle payments during CHIPS operating hours. At the close of CHIPS at 17:00, any unsettled payments are multilaterally netted. These net positions are settled over Fedwire via transfers to and from CHIPS.

CLS Bank

CLS Bank is a payment-versus-payment settlement system that settles foreign exchange transactions in fifteen currencies (CLS Bank 2007; Miller and Northcott 2002; Bank for International Settlements 2003a, 2005). CLS Bank is operated by CLS Bank International, a bank-owned Edge Act corporation incorporated in the United States. CLS Bank was founded in response to concerns raised by the G-10 central banks about settlement risk in foreign exchange transactions (Bank for International Settlements 1993). CLS Bank began operation in September 2002; as of December 2006, it had 57 members and settled an average of 290,000 transactions valued at $3.3 trillion per day.[12]

CLS Bank uses a payment-versus-payment method in which funds to settle trades are exchanged simultaneously in different currencies. In order to accomplish simultaneous transfers, CLS Bank is open during the five-hour settlement window—01:00 to 06:00 EST—when real-time gross settlement systems in Europe, the Americas, and Asia are open.

DTC

DTC is a securities settlement system that settles the majority of U.S. corporate securities and commercial paper transactions. It is a wholly owned subsidiary of Depository Trust & Clearing Corporation (Bank for International Settlements 2003a, 2005). DTC has 407 participants and 86 settling banks. On average, it settles 800,000 transactions valued at $896 billion per day (Payments Risk Committee and Wholesale Customer Advisory Group 2007).

DTC participants fund their accounts through Fedwire transfers (via a settlement bank for many) to the DTC Federal Reserve account. Money market instruments represent 62 percent of DTC value. The ability of paying agents to accept maturing securities is limited by the agents' net debit cap. To remove the debit cap constraint, agents will make progress payments to their accounts via Fedwire transfers to DTC. The majority of this activity occurs between 12:00 and 14:00. At 16:00, the DTC settlement process begins. Banks with net debits send the net amount to DTC over the net settlement system at 16:35. At 16:40, DTC sends Fedwire funds transfers to participants with net credits (Payments Risk Committee and Wholesale Customer Advisory Group 2007).

[11] Source: CHIPS (<http://www.chips.org/about/pages/001221.php>).

[12] Source: CLS Bank International (<http://www.cls-group.com/news/article.cfm?objectid=78EA8ED8-EC63-6345-C60967F0ECA7E5C3>).

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