James McAndrews and Samira Rajan

The Timing and Funding of Fedwire Funds Transfers

- The dollar value of payments made over the Fedwire Funds Transfer service reaches its highest level between 4 p.m. and 5 p.m. each day.
- This peak in payment activity likely reflects efforts by banks to synchronize their outgoing payments with the large payment inflows they expect to receive in the late afternoon.
- By using the incoming transfers to fund outgoing payments, banks avoid the more costly alternatives of drawing down their account balances at the Federal Reserve or using overdraft credit.
- To support the banks' funding strategy, policymakers might establish formal "synchronization periods" and encourage banks to concentrate payments during these periods.
- The resulting increase in payment coordination could further reduce financing costs and minimize the number and duration of overdrafts.

The timing of payments across the Fedwire Funds Transfer service exhibits a regular pattern over the course of the day, with payment activity peaking in the late afternoon.[1] This pattern can be explained, in part, by the fact that banks derive benefits from coordinating the timing of their payment activity. Many payments made by banks during the day are offsetting. By synchronizing payments, banks can take advantage of incoming funds to make outgoing payments. The afternoon peak in activity reflects, to some extent, banks' coordination of payment timing in an attempt to tap this funding source.

A full explanation of the timing of funds transfers recognizes two factors that affect banks' intraday liquidity management. First, the timing of banks' payment activity reflects underlying customer demand. For example, settlement of financial transactions customarily takes place in the late afternoon, which tends to cause a demand for payments late in the day. Second, such timing also reflects a bank's response to customer demand for prompt payment. When responding to this demand, banks incur costs that take up expensive liquidity resources—either deposits at, or overdrafts from, the Federal Reserve System.

The liquidity cost of making a payment varies with the amount of coordination involved in payment timing. During periods of heavy payment traffic, a bank can, to a greater extent, fund an outgoing payment with incoming payments. Conversely, during off-peak times, a bank must rely more on account balances or overdrafts to fund payments, which increases the cost of making

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a payment. As a result, banks are induced to time their payments to coincide with an activity peak, thereby reinforcing the peak. Such behavior can lead to the observed aggregate patterns during periods of light as well as heavy payment activity.

In this article, we measure banks' alternative funding sources for Fedwire funds transfers throughout the day, using a data set that includes all banks' Fedwire funds transfers and Federal Reserve System deposits. This approach allows us to gauge the importance of incoming payments as a source of funding. We find that incoming payments used by banks to offset outgoing payments that are entered within the same minute account for 25 percent of the value of these transfers during normal activity periods and as much as 40 percent during peak periods.

This level of payment coordination is impressive. However, economic analyses suggest that activity coordination by subjects in similar environments typically falls short of the level that would allow the subjects to benefit fully from such coordination.[2] Accordingly, with many thousands of banks participating in Fedwire, there is reason to believe that the banks would prefer even greater coordination of payment activity. Furthermore, greater synchronization of payments would lead to a decrease in daylight overdrafts extended by the central bank. With these considerations in mind, we also examine a policy that might allow banks to coordinate their payment activity even more effectively: the creation of activity periods that would serve as "focal times" for entering payments.

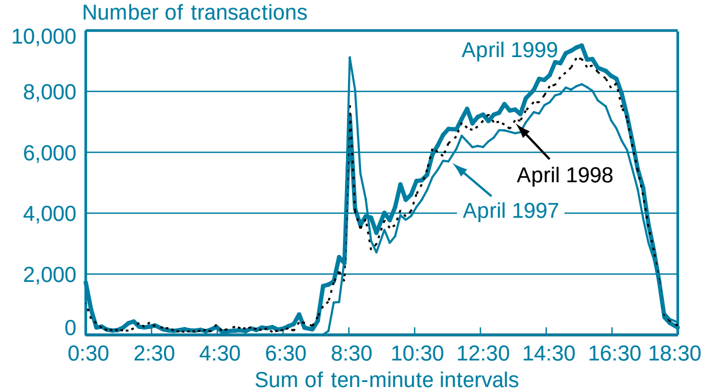
Our study proceeds as follows. In the next section, we review the intraday pattern of Fedwire funds transfers. We then offer possible explanations for this pattern by examining a model of payment timing. Next, we measure the different sources of Fedwire funding during the day. Finally, we discuss the implications of our findings for various policy issues, including the expansion of the operating hours of the Fedwire Funds Transfer service and the facilitation of payment coordination.

The Timing of Fedwire Payments

Fedwire is a real-time gross settlement (RTGS) system, in which payment requests are processed and settled by the Federal Reserve System as soon as they are initiated by banks. The number of funds transfers sent per minute varies over the course of the day in a fairly predictable pattern. The average minute-by-minute patterns of the number of transfers for April 1997, 1998, and 1999 appear in Chart 1.[3] We see that a flurry of payments occurs at 8:30 a.m., which used to be the opening time for the Fedwire Funds Transfer service. After this flurry, the number of transfers sent per minute falls to a much lower level around 9:30 a.m. From that trough, the number of transfers grows fairly steadily throughout the day, reaching a peak from 2:30 to 4:30 in the afternoon. Transaction volume declines rapidly after 4:30 p.m. and approaches zero transfers per minute at the close of the service at 6:30 p.m.

Chart 1

Average Daily Fedwire Funds Transactions by Time of Day



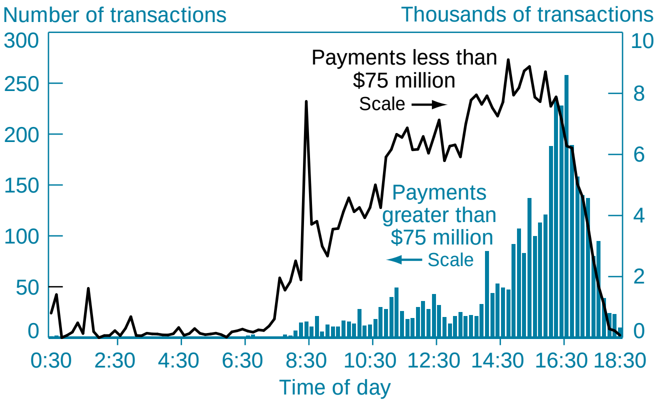
Source: Federal Reserve Bank of New York.

The very largest payments are even more concentrated late in the day. The patterns of payments above the ninety-ninth percentile and those below it are shown in Chart 2. The chart indicates that for much of the day, there is a fairly low level of the largest-value payments. After a sharp increase following 4:30 p.m., once the Clearing House Interbank Payments System (CHIPS) has closed, the number of such payments falls considerably after 5:30 p.m.[4] Because the largest-value payments constitute in dollar terms the bulk of the value transferred by the Funds Transfer service, the patterns of these payments strongly influence the patterns of value exchanged per minute throughout the day. Chart 3 confirms that the value exchanged is more heavily concentrated in the period around 4:30 p.m. than is the number of funds transfers. Hence, in terms of the number of transfers, the dollar value of payments, and the number of largest-value payments, we can place the peak period for the Fedwire Funds Transfer service at 2:30 to 5:30 p.m., with the peak in value transfer occurring between 4 and 5 p.m.

Chart 2

Distribution of Fedwire Funds Transactions by Size of Payment

March 18, 1999

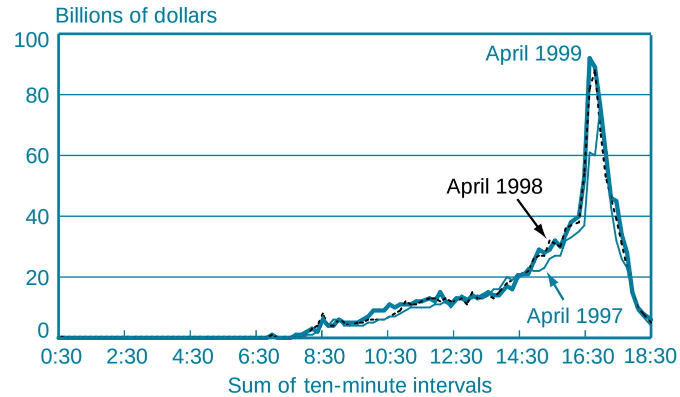


Source: Federal Reserve Bank of New York.

Note: $75 million is the ninety-ninth percentile for payment size on March 18, 1999.

Chart 3

Value of Average Daily Fedwire Funds Transactions by Time of Day



Source: Federal Reserve Bank of New York.

Durability of Payment Patterns

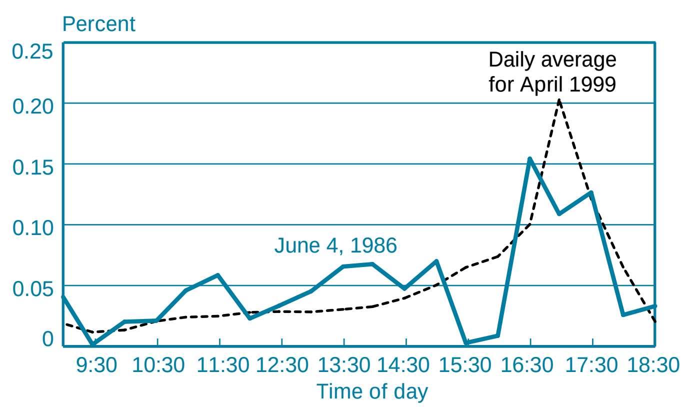
The Fedwire Funds Transfer service expanded its hours of operation from ten to eighteen hours in December 1997, so that it is now open from 12:30 a.m. until 6:30 p.m. eastern time. The change was made mainly to accommodate potential earlier settlement of foreign exchange trades. However, neither the timing of activity peaks nor the timing of any other payment patterns has been significantly affected by the lengthening of the Fedwire day.

The primary difference in payment patterns before and after December 1997 is the decrease in the number of payments made at 8:30 a.m.: there has been a decline equal to about 0.5 percent of the number of payments made between 8:30 and 9:30 a.m. Yet the percentage of funds transfers made between 12:30 a.m. and 8:30 a.m. remains roughly 1 percent, so some of the activity that took place at the 8:30 a.m. opening now takes place prior to that time. Overall, there has been a slight increase in the share of the value of payments completed by noon: for the period April-November 1998, 13.75 percent of the value was completed by that time, compared with 13.30 percent for the same period in 1997.

Some evidence suggests that the afternoon peak is higher today than it was prior to the implementation of the pricing of daylight overdrafts in 1987. Richards (1995), for example, notes that the share of value transferred by noon dropped about 5 percent in the year following the imposition of overdraft fees. In addition, a report by the Federal Reserve Bank of New York (1987) of large-value funds transfers during a single day in 1986 shows a less concentrated pattern of payment activity during the day. Using data from the report, we compare the percentage of the day's payments completed during various times of the day in 1986—prior to the imposition of overdraft fees—with the timing of payments in 1999 (Chart 4). We see that a larger share of the day's payments

Chart 4

Percentage of Dollar Volume Completed over Fedwire Funds Transfer Service



Source: Federal Reserve Bank of New York.

Notes: Data for 1986 payments include transfers in excess of $1 million. April 1999 data include transfers in excess of $1 million in 1986 dollars.

was completed earlier in the day in 1986 than in 1999 (although after 5:30 p.m., payments were made more quickly in 1999). At the same time, it is clear that in 1986 there was a substantial concentration of payments in the late afternoon. In short, the evidence confirms that payment traffic has long been characterized by a late afternoon peak.

Liquidity Externalities and the Coordination of Payments

Why are payments, especially the largest ones, concentrated in the late afternoon? As noted, this phenomenon may result from the timing of payment requests by customers and from the payments generated by the banks' own financial activity, which may be concentrated at the end of the day so that banks can settle financial market trades. In addition, banks themselves may time the submission of payments to coincide with the incoming payments that they expect to receive late in the day.[5] To explain this latter possibility, we first describe the funding sources for a bank's payments.

Sources of Payment Funding

Banks face a budget constraint when making payments: those made in a real-time gross settlement system run by a central bank typically are made by transfer of deposit account balances held at the central bank. Although a bank may have other assets, RTGS systems generally require that funds be in an account in the system at payment time, so that the systems do not have to rely on other forms of bank assets.[6] Account balances, then, serve as one source of funds by which a bank can make payments. However, account balances at central banks usually pay low interest rates, which creates an incentive for banks to minimize the amount of funds on account there.[7]

In the Fedwire Funds Transfer service, as in many other RTGS systems, banks transfer their account balances to make payments. Of course, one could reasonably ask, what if a bank's account balance falls to zero? For banks that are allowed to incur daylight overdrafts, that form of credit from the central bank is an additional source of funds that can be used for payments.[8] Finally, if a bank receives a payment from another system participant, that payment replenishes its account balance and allows the bank to make outgoing payments. A recent report on RTGS systems described these funding sources as: "(a) balances maintained on account with the central bank, (b) incoming transfers from other banks, [and] (c) credit extensions from the central bank."[9]

Before we discuss liquidity externalities in an RTGS system, we should look more closely at these three sources of funding. In particular, we consider incoming transfers from other banks. As noted earlier, when a bank exhausts its account balances at a particular time, it can make additional payments (without borrowing) if it receives incoming transfers from other banks. But because banks receive incoming payments and make outgoing payments throughout the day, it is important to examine the extent to which banks use incoming payments to fund the outgoing ones. We adopt the view that incoming payments arriving *at roughly the same time* as offsetting outgoing payments serve as a source of funding for the outgoing payments. Conversely, we also adopt the view that incoming transfers that "sit" in the receiver's account for a long period of time do not fund specific payments. If incoming payments sit in such an account, then we consider payments made long after the bank has received funds as being made by the transfer of balances maintained at the central bank.

Coordination of Payment Timing

It may be surprising to learn that the synchronous receipt of incoming transfers is a legitimate source of funding for a bank. This possibility exists whenever banks exchange payments throughout the day. For example, assume that Bank A owes Bank B $100, Bank B owes Bank C $75, and Bank C owes Bank A $50. If these payments took place at different times (in this sequence), Bank A's balance, for example, would fall by $100 in the first period and then would rise by $50 in the third. However, if these payments took place simultaneously, Bank A, which owes $100, would see its deposit balance fall by only $50 because it would receive a $50 payment from Bank C. In this way, the receipt of the incoming transfer from Bank C allows Bank A to "fund" its $100 payment—half with its own deposit balance and half with incoming funds. Although the end-of-day balance for all of the banks would be the same in either scenario, the uncoordinated timing of payments requires the banks either to incur larger overdrafts for a longer period or to maintain higher levels of

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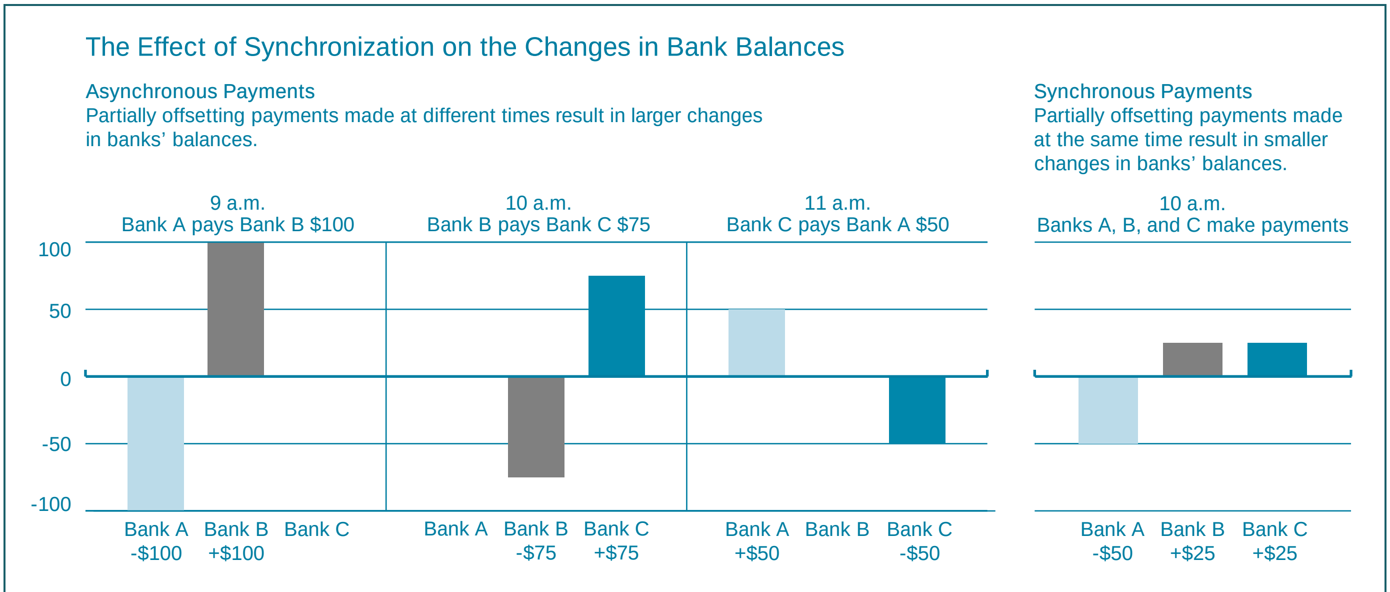


deposits to avoid overdrafts, relative to the synchronous timing of payment. If Banks A, B, and C could all coordinate the timing of their payments, each would have a lower funding cost than it would have had it been the first bank to pay. The exhibit presents the effect of synchronization on the change in the balances of the banks as they make these payments.

It is important to note that, in this regard, what is true for banks is also true for their customers. Banks impose limits on their customers' overdrafts and charge fees for the use of overdraft credit. Customers, like banks, try to seek the lowest cost funding for their payments. The timing of payments among bank customers therefore can lead to similar benefits for them. In particular, as customers receive payments, they can send payments using the incoming funds to avoid (or to limit the size of) overdrafts. In this way, payment coordination can reduce the customer's costs of making payments. We saw in Chart 4 that a noticeable peak existed in Fedwire payments prior to the imposition of overdraft fees by the Federal Reserve System. That pattern likely reflects, to some extent, the coordination of customer payments as well as the underlying timing of other late-in-the-day customer demand, such as for making settlement payments in the financial markets.

Although the exhibit illustrates the benefit of coordinating payment timing, the difficulty of achieving such a synchronized pattern is considerable because the timing of payments in some respects resembles a coordination game.[10] Banks can benefit by entering payments simultaneously to Fedwire, but they typically do not know when their counterparties might send offsetting payments. Hence, there is the potential for miscoordination. For instance, one bank enters a payment expecting to receive, but in fact does not get, an offsetting payment. Or two banks each delay sending their payments, as one expects the other to send its payment first. In these examples, coordination could be achieved simply by establishing conventions, such as sending payments regularly at a particular time, day after day. The 4:30 p.m. peak in payment activity might represent such a convention. When banks repeatedly send payments to one another day after day, the repetition in payment patterns can in some cases lead to successful coordination among a bank and its counterparties.

Synchronization of payments . . . allows banks to tap incoming transfers from other banks as a key source of funding.

By concentrating payments in a short period, banks can work to resolve the coordination problem. They can then delay sending customer requests during the day, provided that the delay is not too costly, if they anticipate that other banks will make their payments later in the day (either because of customer requests or because other banks are also anticipating that their counterparties will send payments later in the day). As more and more banks behave in this manner, a peak period of payment activity will emerge during which banks receive payments more frequently than they do at other times. With these incoming payments, each receiving bank will see its Fedwire balance increase, enabling it to make its own payments and in turn replenishing the balances of the banks to which it sends funds. Synchronization of payments thus allows banks to tap incoming transfers from other banks as a key source of funding.

It is possible, however, that the amount of synchronization is less than ideal. The Fedwire Funds Transfer service has many thousands of participating banks, and each day their payment flows are at least slightly different from the previous day's flows. In this environment, a bank may be unaware of incoming funds that may be arriving from a bank with which it rarely exchanges payments. The two banks therefore might not coordinate the timing of their payments as successfully as they might have if they had full information or if they exchanged payments regularly. Furthermore, economic analyses of similar environments suggest that the participants rarely can coordinate well enough to take advantage of the full benefits of coordination, even with full information. Often, the participants coordinate less fully than they would prefer. Repetition of the situation tends to increase the amount of coordination achieved, while the inclusion of more participants tends to decrease the amount. Although none of these analyses has been repeated as frequently as the number of times in which a day's Fedwire payments occur, none has involved as many participants as there are Fedwire banks. Therefore, the amount of payment coordination among banks is conceivably less than desirable.

Measurement of the Different Payment Funding Sources during the Day

We now consider what practical application these observations hold for the Fedwire Funds Transfer service. To accomplish this, we begin by choosing appropriate measures of the different funding sources. Then, using Federal Reserve System data, we can assess the degree to which banks participating in Fedwire use these sources to make payments and we can track that usage at different times of the day. Our goal is to confirm that during the peak activity period, banks fund a larger share of their payments with incoming transfers from other banks than they do at any other time of the day.

We measure the sources of funding available to banks as follows, beginning with the extension of daylight funds overdrafts. To assess fees for banks' use of daylight credit, the Federal Reserve measures overdrafts using the Daylight Overdraft Reporting and Pricing System.[11] Only those overdrafts outstanding at fifty-nine seconds after the minute are included in the overdraft fee calculations (Box A describes the calculation of daylight overdraft charges). We adopt a similar method for measuring overdrafts as a funding source for bank payments: we measure the extension of daylight funds overdrafts in terms of the amount by which a bank's balance falls below zero (or below its negative balance of the previous minute) at the end of a minute, measured on a minute-by-minute basis throughout the day for all banks.[12] In other words, this source of funding measures the amount by which a bank's payments during a minute cause its account balance to fall into (or further into) a negative position.

Our measure of incoming transfers of other banks depends on the time of receipt of the transfer. If the incoming transfer quickly offsets an outgoing one, we consider the incoming transfer to be a source of funding for the outgoing payment. More specifically, our measure of this source of funding is the value of incoming payments that offset outgoing payments within a minute. We adopt this definition because of its relationship to the Federal Reserve's method of measuring overdrafts when assessing fees. As described above, our measure of payments made by overdrafts is based on the amount of overdrafts outstanding at the end of the minute. For that reason, we choose to measure incoming payments that offset outgoing payments made *within the same minute* as those that fund outgoing payments. Those incoming payments either prevent the extension of an overdraft that will be included in the bank's fee calculation or prevent a reduction in the bank's maintained account balance (exact definitions of the variables appear in the appendix).[13] In other words, this source of funding is the value of the payments a bank makes during a minute that, because of funds received during that minute, do not reduce its account balance.

> *It is possible . . . that the amount of [payment] synchronization is less than ideal. A bank may be unaware of incoming funds that may be arriving from a bank with which it rarely exchanges payments.*

After accounting for the payments made by the extension of overdraft credit from the Federal Reserve System and those made by the receipt of incoming transfers from other banks, we assign the remaining payments to banks' maintained account balances at the Federal Reserve. In other words, this source of

Box A

Calculation of Daylight Overdraft Charges[a]

As of April 14, 1994, each depository institution using the Fedwire Funds Transfer and Book-Entry Securities services is charged a fee based on the level of daylight overdrafts it incurs. A daylight overdraft is a negative account balance that occurs during the operating day.

Before describing the calculation of these fees, we note that all daylight overdrafts incurred by a depository institution are subject to a net debit cap. The cap represents the maximum dollar amount of uncollateralized daylight overdrafts that an institution can incur.[b] There are several categories that institutions may fall into that govern the amount of the cap, and the Federal Reserve System monitors their account balances to ensure that cap violations do not occur frequently.

The Federal Reserve follows three steps when calculating an institution's daylight overdraft fee on a particular day:

- First, the average per-minute overdraft incurred by the institution on that day is computed. To do this, the Federal Reserve uses the Daylight Overdraft Reporting and Pricing System to record all negative end-of-minute balances (fifty-nine seconds after the minute). These negative balances are added for the institution for all the minutes of the day in which it has had an overdraft (positive end-of-minute balances are not used to offset negative balances). This sum is divided by the number of minutes in a standard Fedwire day to arrive at the average daily overdraft. Since the expanded operating hours began, a standard Fedwire day runs from 12:30 a.m. to 6:30 p.m. eastern time, for a total of 1,081 minutes.
- Second, the average daily overdraft is multiplied by the fee that the Federal Reserve imposes on daylight overdrafts. Currently, this effective rate equals 15 basis points—or 18/24—an annualized rate of 36 basis points. This effective rate is the annualized rate multiplied by the fraction of the day during which Fedwire operates. To determine the effective daily rate, the Federal Reserve multiplies this number by 1/360. The fee multiplied by the average daily overdraft yields the gross overdraft charge.
- Third, institutions have a deductible, which is a level of overdrafts that they can incur without having to pay a fee. It allows an institution some flexibility in its liquidity management. The deductible is equal to 10 percent of the institution's qualifying capital for daylight overdrafts. The value of the deductible is subtracted from the gross overdraft charge to yield the daily charge to an institution. To determine the value of the deductible, the Federal Reserve multiplies the deductible by a daily effective rate, as in the calculation in the previous bullet. However, there is one difference in the calculations: although the annual rate by which the threshold is valued is also 36 basis points, the fraction of the day is multiplied by 10/24, rather than by 18/24.

After ascertaining each of the above parameters, the Federal Reserve multiplies the average per-minute overdraft by the effective daily rate charged for overdrafts. The value of the institution's deductible is then subtracted from this gross daily charge to arrive at the daily overdraft charge assessed.

The Federal Reserve calculates this daily overdraft charge for each day and totals the charges over a two-week reserve maintenance period. If the sum of the daily overdraft charges incurred during these two weeks is less than $25, the fee is waived.

[a]This section is based on Board of Governors of the Federal Reserve System (1998).

[b]An institution may choose to increase its capacity for daylight overdrafts by pledging collateral, but this collateral is applied to overdrafts related to book-entry securities only. Overdrafts related to funds transfers may not be collateralized.

funding is the value of all payments made during a minute that result in a reduced, but positive, balance in a bank's account. The sum of all these sources of funding equals the sum of payments sent in each minute.

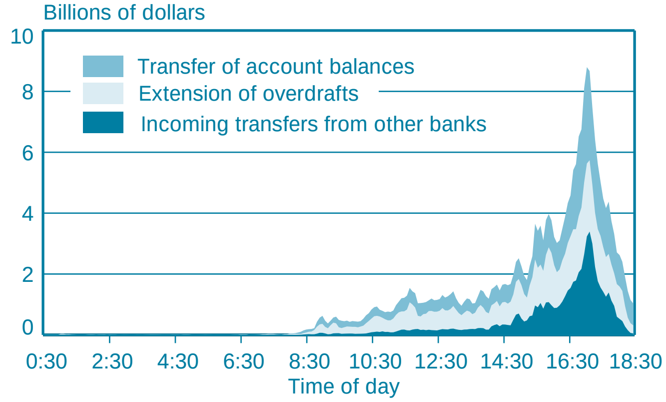
Our measures of the different sources of intraday funds are shown in Chart 5, which depicts the average amounts of each funding source for all Fedwire funds transfers for March 18, April 5, May 13, and June 17, 1999.[14] The outside line of the chart indicates the gross payments made by minute of the day. The interior lines denote the amount of payments made with the three possible sources of funding. It is clear that the utilization of each source varies over the day. In particular, we see a considerable increase in the funding of payments by incoming payments of other banks (arriving in the same minute) during the late afternoon peak. This effect was anticipated by our model (and by our discussion), which suggests that banks coordinate payment timing during the peak afternoon period to take advantage of this funding source.

The shares of the various sources of funding throughout the day are depicted in Chart 6. Early in the day, nearly all

Chart 5

Contributions of Funding Sources of Fedwire Funds Transfers

Average of Four Days

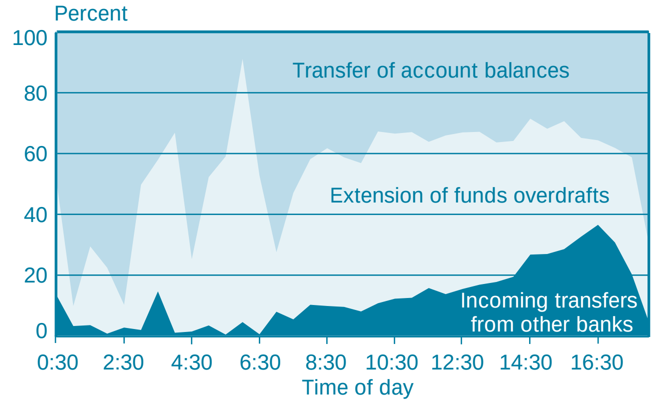


Source: Federal Reserve Bank of New York.

Chart 6

Shares of Funding Sources of Fedwire Funds Transfers

Average of Four Days over Half-Hour Intervals



Source: Federal Reserve Bank of New York.

Note: Because few payments are made between 12:30 and 8:30 a.m., the variation in the shares of funding sources during that period of the day is driven by a small number of payments.

payments are made by the transfer of maintained balances or by the use of funds overdrafts extended by the Federal Reserve. As the day progresses, these sources continue to predominate. Finally, as the afternoon payment peak gets under way, incoming payments from other banks that offset outgoing payments within the minute become an important component of payment funding. When payments are highly concentrated, as they are between 4:30 and 5:30 p.m., this (inexpensive) source of funding is the most available and the most utilized. For example, between 4:30 and 5:30 p.m., 16 percent more payment value is funded by incoming payments within the minute than is funded between 2:30 and 4:30 p.m. Overall, 35.6 percent of funds transfers are funded by the movements of maintained balances, 39.0 percent are funded by the extension of funds overdrafts, and 25.4 percent are funded by incoming payments within the minute.

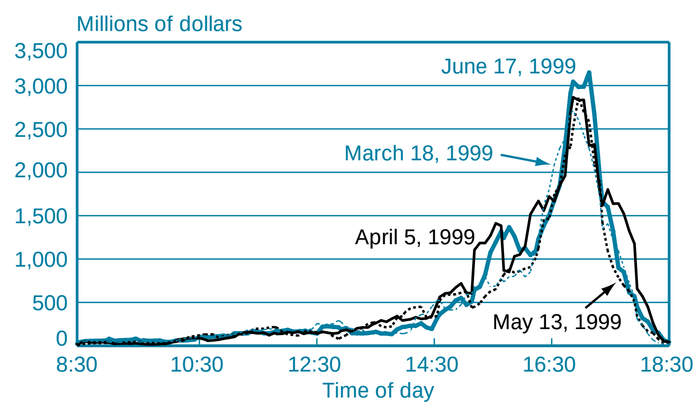
Chart 7 displays the value of the incoming payments that offset outgoing payments within the minute across the four sample days, illustrating both the pattern of funding and the stability of that pattern across the sample days. The correlation between the series in Chart 7 averages .907, indicating that payment activity is highly predictable.

Of course, our measure of the payments funded by incoming funds might be considered conservative. For example, a bank that receives an incoming payment three or five minutes after making a large payment may still be satisfied that the payment was accomplished with less expense than it would have been if an offsetting payment had not arrived until hours later. To gauge how a longer period might affect our measure of funding, we compare the amounts of incoming payments that offset outgoing payments within a fifteen-minute period and within a one-minute period (Chart 8). Again, we see a strong pattern: during the peak period, offsetting payments are matched (in time) more effectively than at any other time during the day. This pattern leads to lower payment costs during the peak period, which in turn reinforces the payment pattern.

Chart 7

Value of Payments Matched by Incoming Transfers

Thirty-Minute Moving Average

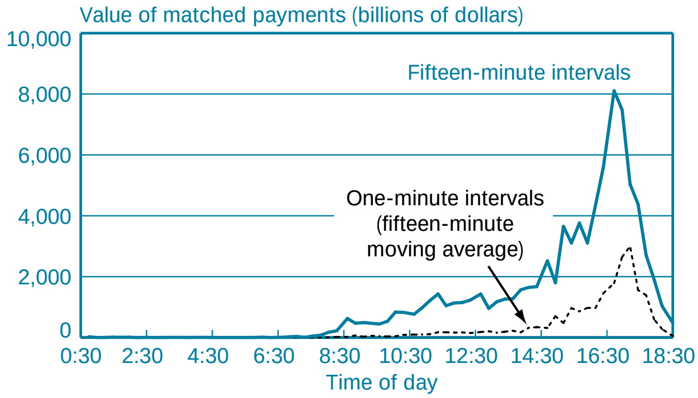


Source: Federal Reserve Bank of New York.

Chart 8

Payments Funded by Incoming Transfers Compared at Different Intervals

Average of Four Days



Source: Federal Reserve Bank of New York.

Sensitivity of the Offsetting of Incoming and Outgoing Payments to the Concentration of Payments

The calculation of an elasticity measure offers another way to examine the sensitivity of the value of incoming payments as a funding source to the concentration of payments. Box B displays a fitted relationship between the percentage of payments within a minute that are matched by incoming payments and the percentage of the day's payments that occur in that minute. We find that a quadratic equation fits the data better than a linear relationship does. Using the fitted relationship, we see that the elasticity of the percentage of payments made by incoming payments that offset outgoing payments within the minute to the concentration of payments at the median minute of activity across the four sample days is 0.25. The elasticity initially rises as the concentration of payments rises, and averages approximately 0.55 between 4:30 and 5:30 p.m. This elasticity implies that if 1 percent of payments were transferred from minutes of median payment

Box B

Sensitivity of Funding by Incoming Payments to Payment Concentration

Variables

$Incoming\ \ payments_t$: The percentage of the value of minute t's payments that are offset by incoming payments.

$Amount\ \ of\ \ payments_t$: The percentage of the value of the day's payments that are conducted in minute t.

Fitted Equation

$$Incoming\ \ payments_t = constant + bAmount\ \ of\ \ payments_t + c(Amount\ \ of\ \ payments_t)^2 + \varepsilon .$$

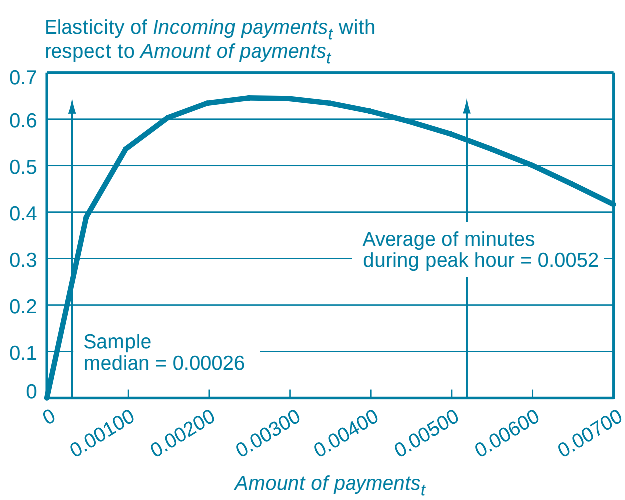
The parameters $constant$, b, and c are to be estimated using the four days of activity used in the construction of Charts 6-8 in the text, and ε is an error term. The estimated equation is given by:

$$Incoming\ \ payments_t = \underset{(.001)}{.0564} + \underset{(1.78)}{76.85} Amount\ \ of\ \ payments_t - \underset{176.1.}{3743.11}(Amount\ \ of\ \ payments_t)^2$$

The standard errors of the parameter estimates are in parentheses. All of the estimated parameters are significant at the 1 percent level. The F value for the equation is 1415 and the adjusted R^2 is .39.

The fitted equation is increasing for all levels of $Amount\ \ of\ \ payments_t$ between [0, .01026]. The average of $Amount\ \ of\ \ payments_t$ during the peak hour between 4:30 and 5:30 p.m. is .00521. In fewer than twenty minutes out of the 4,324 observations does $Amount\ \ of\ \ payments_t$ exceed .01026.

This equation suggests that there is a strongly positive relationship between the degree to which payments offset within a minute, and the concentration of payments within that minute, throughout most of the range of the sample. This equation leads to an elasticity of $Incoming\ \ payments_t$ with respect to $Amount\ \ of\ \ payments_t$ equal to 0.55 during the peak period of payment activity. The elasticity is positive in the concentration of payments over the sample, as shown in the chart below.



volume to minutes of the hour from 4:30 to 5:30 p.m., there would be a net gain of approximately 0.30 percent in the proportion of payments funded by the matching of offsetting payments. That is, while 0.25 percent of the matching of offsetting payments would be lost from the median minutes of payment activity, 0.55 percent would be gained during the peak hour, for a net increase of 0.30 percent.

It is important to recognize that this relationship is fitted "within-sample"—that is, it is not a forecast of what would happen should more concentration of payments occur. Instead, it records statistically the relationship between the concentration, or synchronization, of payments, and the amount of funding by incoming payments that accompanies that synchronization in the sample days. Within the sample, the positive relationship between concentration of payments and the matching of offsetting payments suggests that by synchronizing payments, one has an effective way to tap this source of funding.

Discussion

The realization that the concentration of payments occurring late in the day may reflect the resolution of a coordination problem suggests that the pattern is stable and durable. With regard to the recently extended early morning hours of the Fedwire Funds Transfer service, one of the difficulties faced in encouraging more payments to be made during these hours is how to raise the expectations of banks that many other banks will also enter payments then. This is a chicken-and-egg problem: until many payments are actually made early in the morning, any individual early payment will rely more on overdrafts or account balances and therefore will be more expensive, at the margin, than if it was made later in the day.[15] This general situation is likely to be faced by new systems planning to operate at that time, such as the one proposed by CLS Bank or the new CHIPS system, which would require that Fedwire payments be made during the early morning hours. For example, CLS Bank proposes settling matched foreign exchange trades at the same time across different currencies (see Roscoe [1998] or Board of Governors of the Federal Reserve System [1999] for a description). Similarly, the new CHIPS system plans to fund an intraday matching system partially with funds sent to a special account early in the morning (see Nelson [1998] for a description). Participants in such arrangements may have to hold additional account balances or utilize more overdraft funding to make their early morning payments than would be necessary if their payments were designed to take place during the peak in activity.

The bunching of payments in the afternoon is in accord with our theoretical model: banks are induced to coordinate payments to take advantage of potentially offsetting funds. The coordination of payment activity—the synchronization of payments—reflects banks' expectations that, as a larger number of payments are entered, more of them will be offsetting and more may, in part, be funding the settlement of other payments. This effect results in a greater use of incoming payments to fund outgoing payments, which in turn would tend to lessen the reliance on account balances or overdrafts to make payments. It saves costs for the banks involved and may help to explain the strong peak in payment activity.

The decreased reliance on other sources of payment funding, including overdrafts from the Federal Reserve, that accompanies synchronization of payments not only can lower costs for commercial banks, but can also reduce the risk of exposure by the Federal Reserve. As banks synchronize their payments more closely, the duration of overdrafts outstanding would be reduced (and the amount of overdrafts would likely fall as well). This relationship is clear if one imagines the extreme case of all payments being made at the same time: overdrafts would be at a minimum level in that the simultaneous entry of all payments would make maximum use of offsetting payments.[16] The reduction in the duration, and possibly the amount, of overdrafts that accompanies the increased concentration of payment timing would therefore reduce the risk of failure to which the Federal Reserve is exposed during the extension of an overdraft loan to a bank.

As we have noted, the degree of payment synchronization might be less than the ideal amount that banks would choose if they could coordinate their payment activity successfully. If that is so, a greater effort to coordinate payment timing may result in a greater share of the day's payments being funded by the synchronized matching and offsetting of payments. As our model suggests, this could be an underutilized source of payment funding. If greater synchronization could be achieved, payments could be made at lower cost and the risk of exposure by the Federal Reserve could be lessened.

Encouraging Payment Synchronization

If the amount of payment coordination is less than ideal, policies that encourage greater coordination of payment timing might be useful. Of course, such policies should not be coercive, but should instead provide more opportunities for banks to coordinate payment timing.

To overcome a lack of payment coordination by banks, the central bank could attempt to guide their expectations by creating a short period—a focal time—in which banks could expect that incoming payments would be entered by other banks. An example of such a policy might be the establishment of two ten- or twenty-minute "synchronization periods." During these periods, only overdrafts outstanding at the end of the period would be entered into a bank's overdraft fee calculation. Banks would not be charged for any overdrafts that they incurred within the synchronization periods and repaid prior to the end of the periods.[17] For example, these periods might operate late in the morning and then early in the afternoon peak.[18] This policy could increase banks' expectations that many payments, including incoming ones, would be entered during the synchronization periods. If the policy was successful, a greater percentage of the day's payments would be made within short periods and therefore would be offsetting within the periods. Less reliance would then be placed on other sources of funding, including the extension of overdrafts. In particular, the average duration of overdrafts would decline and overall overdrafts, including those made within the synchronization periods, would fall.

Potential Problems . . . and Solutions

A policy such as the one just described could conceivably pose some problems—yet those problems are not without solutions:

- *The high degree of payment bunching at the end of the day might increase uncertainty, and could be deleterious to the smooth functioning of the federal funds market near the end of the day.* The act of timing the synchronization periods in the late morning or early in the afternoon peak could mitigate any problems of delayed resolution of uncertainty. Moreover, as long as the delay in anticipation of the periods results in earlier payments on average, the periods would help the participants to overcome the problem of payment delay.
- *If the synchronization period is too short, the successful coordination of so many payments could impose a greater burden on the system's equipment.* This problem represents a resource cost, in terms of computers as well as telecommunications links, of handling a large number of payments in a short period of time. A solution to this problem may be to increase the length of the synchronization periods, or perhaps to employ a peak-load pricing system that would accurately recover the additional costs incurred by the banks that utilize these periods.
- *The central bank would be extending overdrafts during the synchronization periods but not assessing fees on them*. Such overdrafts would be made for a slightly different purpose and they would not last as long as overdrafts extended at other times of the day. In addition, one could view the intrasynchronization-period overdrafts as a cost of achieving the coordination that may lower the overall level and duration of daylight overdrafts. Nonetheless, firm overdraft caps would be necessary to prevent banks from borrowing excessively during the synchronization periods. In addition, overdrafts that exceed some threshold could be required to be collateralized. In this way, if large overdrafts accumulated at any time during the day, the central bank's risk exposure would be securely capped.
- *Depending on the durability of the existing pattern of payments, the synchronization periods might be relatively ineffective, attracting few additional payments*. The cost of implementing the synchronization periods is low. Moreover, we would expect that any increase in the amount of payment coordination would require some time to achieve, as banks adjust to the changing opportunities provided by the periods and the behavior of their counterparties.

Conclusion

Our review of the timing of Fedwire funds transfers suggests that it is reasonable to expect the observed peak in payment activity. It is likely that some payment requests are coordinated to be entered during a peak period of activity late in the afternoon. This pattern is consistent with the outcome of a coordination game among the banks (and among their customers): as banks synchronize their payments more closely, their need for account balances or explicit overdrafts to make payments diminishes. This activity makes payments sent during the peak less expensive, at the margin, than payments sent at other times of the day.

By measuring the funding sources of payments made in the Fedwire Funds Transfer service, we found that approximately 25 percent of a day's payments are funded by incoming payments that offset payments made by banks within the same minute. This source of funding is more readily available during the late-afternoon activity peak, when large-value payments are more closely synchronized; such activity accounts for approximately 40 percent of payment funding at that time.

Payment synchronization benefits banks through the reduced costs of making synchronized payments, but it also has other benefits, as it tends to reduce the amount and duration of overdrafts from the Federal Reserve System. The extension of an overdraft creates a slight risk for the Federal Reserve: should a borrowing bank fail while an overdraft is outstanding, the Federal Reserve would have to seek repayment in bankruptcy court. For this reason, the Federal Reserve has adopted policies to reduce overdrafts (see Board of Governors of the Federal Reserve System [1998] for details). The synchronization of payments is another potential tool for the Federal Reserve to reduce both overdrafts and their duration.

However, the synchronization process, in its current form, may be less than ideal for the Fedwire system's participants. With that in mind, and with the goal of reducing the extent and duration of overdrafts, we considered a policy initiative that could assist banks in synchronizing their payments. The initiative would create synchronization periods in the late morning and early in the current activity peak. During these periods, banks could run intrasynchronization-period overdrafts and not face any charges for them. Banks could be encouraged to enter more payments during these periods, which would lead to reduced payment funding costs and a decreased reliance on overdraft funding during the day.

Finally, many countries recently have adopted real-time gross settlement systems for large-value payments.[19] RTGS systems offer many advantages in managing risk and in linking payment flows with securities markets and other payment systems in a timely fashion. It is important, therefore, to understand better the economic incentives and behavior of participants in an RTGS system. We have focused on the issue of how the cost of liquidity in an RTGS system is affected by the timing of a bank's payment activity, but many other issues remain to be investigated. With better availability of data—and with a range of system designs now operating across countries—the potential for further research into these systems is greater than ever.

Appendix: Definition of Variables

Dollar value of payments made by Bank i to Bank j in minute t:

p_{ij}^{t} .

Funds balance of Bank i at the end of minute t:

$$B_i^t = B_i^0 - \sum_{s=0}^{t} (p_{ij}^{s}) + \sum_{s=0}^{t} (p_{ji}^{s}),$$

where B_i^0 is the balance in the bank's account at the Federal Reserve at the start of the day.

Extension of daylight funds overdrafts:

$$D_t = \sum_i \{min\{|B_i^t - 0|, |B_i^t - B_i^{t-1}|\} \\ :B_i^t < 0 \ and \ B_i^t < B_i^{t-1}\}.$$

Dollar value of payments funded by offsetting incoming payments within the minute:

$$I_t = GrossPayments\left[1 - \left\{1 \Big/ \left(\tfrac{1}{2}\left(\sum_i \left|\sum_j p_{ij}^t - \sum_j p_{ji}^t\right|\right)\right)\right\}\right].$$

We decompose the funding of gross payments in minute t into the following sources:

$$GrossPayments = D_t + I_t + Allotherpayments.$$

The last category, $Allotherpayments$, consists of those payments funded by the transfer of balances maintained in banks' accounts (for more than a minute) at the Federal Reserve.

Endnotes

1. Fedwire is a large-value payment system owned and operated by the Federal Reserve System. Two services are associated with Fedwire: the Funds Transfer service and the Book-Entry Securities service. In this article, we focus on the Funds Transfer service, which allows a depository institution to transfer funds from an account held at a Federal Reserve Bank to the account of any other Fedwire Funds Transfer service participant.

2. See van Huyck, Battalio, and Beil (1990) for an example of such an analysis.

3. Throughout this article, the dates chosen for the various calculations were governed by the availability of data at the time the calculations were performed. Here, April data are used because April was the most recent full month for which data were available.

4. CHIPS, operated by CHIPCo, is a large-value deferred netting system that settles at 4:30 p.m. Banks face constraints within CHIPS on their net debit positions and may be uncertain as to whether a particular payment can be settled over CHIPS. If a payment does not satisfy the constraints during the operating hours of CHIPS, banks tend to send the payment over Fedwire when CHIPS closes.

5. Angelini (1998) and Kobayakawa (1997) consider alternative models of payment timing in a real-time gross settlement system.

6. Of course, a bank can sell other assets and add to its account balances at the central bank.

7. Reserve balances at the Federal Reserve are charged a zero interest rate and are determined by reserve requirements on the amount of certain deposits at the participating bank. Participating banks receive earning credits on their required clearing balances at the Federal Reserve; these credits are not transferable to third parties.

8. Banks using the Fedwire Funds Transfer service must stay within their "debit cap," which limits the amount by which they can overdraft their account. Some banks have a zero debit cap, which means that they cannot overdraft their accounts at all.

9. Bank for International Settlements (1997). The report included a fourth category: "(d) borrowing from other banks through the money markets," which we include as part of (a).

10. A coordination game is a social situation in which there are gains to the participants from coordinating their actions—such as everyone in the United States driving on the right-hand side of the road or adhering to a uniform calendar of holidays. A model of a payment timing decision that results in a coordination game is available from James McAndrews.

11. See Board of Governors of the Federal Reserve System (1998) for a description of the measurement of overdrafts for assessing overdraft fees.

12. Note that we are measuring only funds-related overdrafts. Daylight overdrafts created in a transaction involving book-entry securities are not considered. See Box A for details.

13. To calculate the amount of offsetting payments, we use an intraminute "netting ratio," which is the ratio of gross payments sent in a given period to the net change in balances required to make those payments within the period. In our earlier example, only $50 had to be transferred from Bank A to settle all $225 worth of payments. There, the netting ratio is (225/50) = 4.5, indicating the dollar's worth of payments being made per dollar of deposit funds. A high netting ratio indicates that there is a high degree of offset among the payments being made during the period. We then measure the amount of offsetting payments as $(gross\ payments)*(1-(1/netting\ ratio))$. See the appendix for a more complete explanation.

14. The days represent a sample from a set of days for which we have collected bank balance and overdraft data. For each month between March and June 1999, two days were randomly chosen as days for which data were collected.

15. Stehm (1998) points out this issue when reviewing early morning payment activity.

16. We performed a simulation of a multibank payment system with a random distribution of payments across banks. Moving from a situation in which banks spread payments evenly across several periods to a situation in which payments are all made at the same time, the overdrafts of the system fall, and are of reduced duration as payments are concentrated in fewer periods.

17. This policy can be interpreted as a special case of time-varying pricing for overdrafts. That is, banks would not be charged for overdrafts incurred during a synchronization period but would be assessed fees for overdrafts at other times, including the overdrafts outstanding at the close of the synchronization period.

18. Our analysis suggests that attempts to alter the timing of the afternoon peak drastically would not be very effective. Placing the synchronization periods at these particular times—in the late morning or early in the afternoon peak—would encourage banks to send more payments then.

19. See Bank for International Settlements (1997).

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