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The U.S. dollar clearing and settlement system received little attention during the recent financial crisis, mainly because it performed reliably, processing record volumes and values of trades made in stressed financial markets. This article shows how Federal Reserve policy measures aimed at providing liquidity and stability to the financial system during and after the crisis had a major impact on settlement liquidity and thus on the efficiency of clearing and settlement system activity. The measures led to a substantial decrease in daylight overdrafts extended by the Federal Reserve and a quickening of settlement relative to the precrisis period. The decrease in daylight overdrafts reduced credit risk for the Federal Reserve and the earlier time at which payments settled suggests important efficiency gains as well as diminished operational risks. Interestingly, both improvements were the focus of the revisions to the Federal Reserve's Payment System Risk policy, adopted in late 2008 and implemented in March 2011. To a large extent, the desired outcome had been achieved ahead of the policy change. The authors explain that as the amount of reserves available to the banking system and the opportunity cost of holding such reserves are at the center of any framework for implementing monetary policy, the recent experience offers important lessons for policy going forward.

27 The Microstructure of the TIPS Market

Michael J. Fleming and Neel Krishnan

The potential advantages from the introduction of Treasury inflation-protected securities (TIPS) in 1997 have not been fully realized, mainly because TIPS are less liquid than nominal Treasury securities. The lack of liquidity is thought to adversely affect TIPS prices relative to prices of nominal securities, offsetting the benefits that come from TIPS having no inflation risk. Despite the importance of TIPS liquidity and the market's large size, there is virtually no quantitative evidence on the securities' liquidity. This article sheds light on this phenomenon using novel tick data from the interdealer market. The authors identify several features of the TIPS market also present in the nominal securities market, but some unique features as well. As in the nominal market, there is a marked difference in trading activity between the most recently issued ("on-the-run") and previously issued ("off-the-run") securities, as trading drops sharply when securities go off the run. In contrast to the nominal market, there is little difference in bid-ask spreads or quoted depth between these securities, but there is a difference in the incidence of posted quotes. These results suggest that trading activity and quote incidence may be better cross-sectional measures of liquidity in the TIPS market than bid-ask spreads or quoted depth. Intraday patterns of trading activity are broadly similar in both markets, but TIPS activity peaks somewhat later, likely reflecting differences in the use and ownership of these securities. Announcement effects also differ between markets, with TIPS auction results and CPI releases eliciting particularly strong increases in trading activity, likely indicating these announcements' special importance to TIPS valuation.

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Donald P. Morgan, Benjamin Iverson, and Matthew Botsch

This article presents arguments and evidence suggesting that the bankruptcy abuse reform (BAR) of 2005 may have been one contributor to the destabilizing surge in subprime foreclosures. Before BAR took effect, overly indebted borrowers could file bankruptcy to free up income to pay their mortgage by having their credit card and other unsecured debts discharged. BAR eliminated that option for better-off filers through a means test and other requirements, thus making it harder to save one's home by filing bankruptcy. By way of evidence, the authors show that the impact of BAR was greater in U.S. states where one would expect it to have a larger impact—namely, in states with high bankruptcy exemptions. Filers in low-exemption states were not very protected before BAR, so they were less likely to be affected by the reform. The authors estimate that for a state with an average home equity exemption, the subprime foreclosure rate after BAR rose 11 percent relative to average before the reform; given the number of subprime mortgages in the United States, that figure translates into 29,000 additional subprime foreclosures per quarter nationwide attributable to BAR.

Morten L. Bech, Antoine Martin, and James McAndrews

Settlement Liquidity and Monetary Policy Implementation—Lessons from the Financial Crisis

- The U.S. dollar clearing and settlement system performed dependably during the financial crisis, processing record volumes and values of trades executed in stressed financial markets.
- Emergency policy measures employed by the Federal Reserve to provide liquidity and stability to the financial system during and after the crisis had important effects on settlement liquidity and thus on the efficiency of clearing and settlement system activity.
- The measures led to a substantial decrease in daylight overdrafts extended by the Federal Reserve and an improvement in payment settlement timing.
- The reduction in overdrafts lowered the Federal Reserve's credit risk while the earlier settlement time suggested significant efficiency gains and diminished operational risks.

1. Introduction

The U.S. dollar clearing and settlement system was little noticed during the recent financial crisis, mainly because it performed dependably, processing record volumes and values of trades made in stressed financial markets.[1] Its successful operation was in part a result of the collaborative efforts undertaken by stakeholders over decades to improve risk management and operational resiliency. Under the smooth surface, though, the dollar clearing and settlement system experienced important changes during the crisis.

This article focuses on the ease with which market participants can discharge their payment and settlement obligations. We denote this as *settlement liquidity*. Our main interest is on the settlement liquidity of the Federal Reserve's Fedwire Funds Service, the major large-value payment system in the United States. We discuss how to measure settlement liquidity, and document the evolution of some of its key drivers over time. In particular, we show how the policy measures aimed at achieving financial and economic stability during and after the financial crisis have had a major impact on settlement

[1] Exceptions include the tri-party repo market (see Copeland, Martin, and Walker [2010]), the settlement fails that plagued several fixed-income markets, and the uncertainty that initially surrounded the settlement process of credit default swaps following credit events. Ultimately, the process was orderly (Senior Bank Supervisors Group 2008).

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liquidity and thus on the efficiency and inherent risks of payment and settlement system activity.

The massive expansion of reserve balances since fall 2008 and the payment of interest on reserve balances have altered the intraday liquidity management practices of financial

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institutions. This has led to a notable quickening of settlement relative to the prior period and a substantial decrease in daylight overdrafts extended by the Federal Reserve. Importantly, the earlier time at which payments are settled implies significant efficiency gains as well as a reduction in operational risks. Moreover, the decrease in daylight overdrafts reduces credit risk for the Federal Reserve and the public sector more broadly, when taking into account the effects on the deposit insurance fund in the case of a bank failure.

Interestingly, both of these improvements were the desired goals of the revisions to the Federal Reserve's Payment System Risk policy, proposed in March 2008, adopted in late 2008, and implemented on March 24, 2011.[2] By offering collateralized overdrafts at no fee, the Federal Reserve aimed to facilitate intraday risk management and efficient payment flows for the banking system while mitigating the credit exposures of the Federal Reserve Banks from daylight overdrafts. To a large extent, the desired outcome was achieved ahead of the policy changes.

The amount of reserves available to the banking system and the opportunity cost of holding such reserves are at the center of any monetary policy implementation framework. Hence, we believe that this period offers important lessons for the choice of such a framework, especially now that the Federal Reserve has the authority to pay interest on reserves. A system for implementing monetary policy that keeps the opportunity cost of holding reserves very close to zero may contribute significantly to a more efficient and safe payment system.

[2] http://www.federalreserve.gov/newsevents/press/other/20100930a.htm.

Our study proceeds as follows: Section 2 provides an overview of the clearing and settlement system. The system is viewed as a network of platforms connected via funding links. In section 3, we introduce the concept of settlement liquidity—the ease with which financial institutions can discharge their payment and settlement obligations. Section 4 discusses measurement of settlement liquidity and section 5 shows how such liquidity has varied over time and improved recently. In section 6, we argue that changes in monetary policy implementation were the main driver of the significant enhancements in settlement liquidity, while in section 7 we draw some policy lessons going forward. Section 8 concludes.

2. The Clearing and Settlement Network

An often overlooked, but crucial, part of the financial system is the clearing and settlement system.[3] *Clearing* refers to "the process of transmitting, reconciling and, in some cases, confirming payment orders or security transfer instructions prior to settlement, possibly including the netting of instructions and the establishment of final positions for settlement" and *settlement* refers to the "act that discharges

The clearing and settlement system for U.S.-dollar-denominated wholesale transactions is the largest and arguably the most important in the world. It is probably also the most complex.

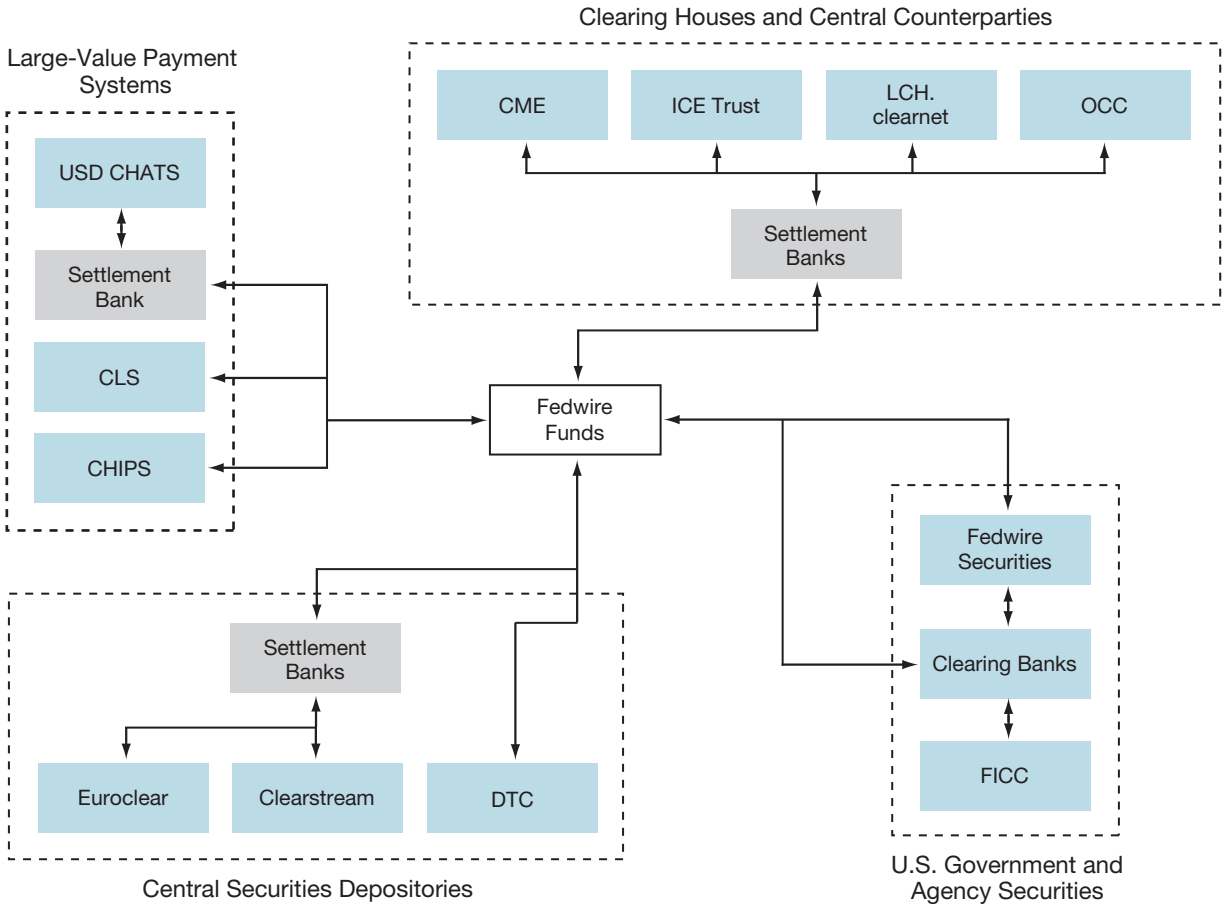
obligations in respect of funds or securities" (Bank for International Settlements 2003).[4] Often a distinction is made between systems that process retail and wholesale transactions.

The clearing and settlement system for U.S.-dollar-denominated wholesale transactions is the largest and arguably the most important in the world. It is probably also the most complex, in part due to the greater diversity of financial products traded in dollars than in any other currency. In any case, the clearing and settlement system consists of a multitude

[3] The clearing and settlement system is at times referred to as the "plumbing" of the financial system. The analogy is fitting in the sense that—as with plumbing—very few people know how it works, but everyone realizes that it is messy when it does not.

[4] Some clearing and settlement systems are vertically integrated with a single trading platform or exchange, while others are horizontally integrated across different products.

The U.S. Dollar Wholesale Clearing and Settlement Network



of different platforms that have evolved over time and stretches across borders and time zones. Together, these clearing and settlement platforms form the nodes in an intricate network, with the nodes linked together by funding relationships. A simplified graphical representation of this network is shown in the exhibit; it includes the most important wholesale clearing and settlement platforms.

The Federal Reserve's Fedwire Funds Service (Fedwire Funds) sits at the center of the network. Fedwire Funds is the system that commercial banks use to send large-value or time-critical payments to each other across the accounts of the Federal Reserve. Fedwire Funds is a real-time gross settlement (RTGS) system that provides irrevocable and unconditional settlement during 21.5 hours of a business day. (It is described in more detail in Box 1.) The remaining platforms are grouped into four categories, based either on the type of clearing and settlement platforms they contain or the type of financial instruments that platforms settle in unison.[5]

[5] In the exhibit, note that clearing banks (blue boxes) can also be settlement banks (gray boxes).

Box 1

The Fedwire Funds Service

The Federal Reserve's Fedwire Funds Service is a real-time gross settlement (RTGS) system that enables participants to initiate credit transfers of balances held at the Federal Reserve that are immediate, final, and irrevocable once processed.[a] The service is generally used to make large-value, time-critical payments among participants and serves as a settlement mechanism for other, ancillary payment and settlement systems.[b] As such, it serves as the backbone of the U.S. payment and settlement system.[c]

Fedwire traces its origin back to the years immediately following the creation of the Federal Reserve in 1914. In 1918, the Federal Reserve inaugurated a network of wire communications among the individual Reserve Banks. This new system of wire-initiated book-entries allowed funds to be transferred on behalf of the member banks and helped abolish regional and seasonal exchange rates for the U.S. dollar associated with the costs of physically shipping gold and currency across the country (Garbade and Silber 1979). Over the years, Fedwire grew more sophisticated as technological advances were implemented (see Gilbert, Hunt, and Winch [1997]).

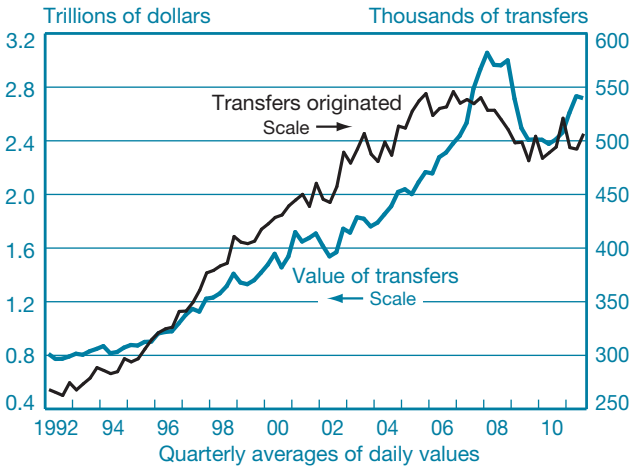
Currently, Fedwire's operating day begins at 9:00 p.m. Eastern time on the preceding calendar day and ends at 6:30 p.m. ET.[d] Institutions that hold an account with the Federal Reserve are eligible to participate in Fedwire.[e] In 2008, approximately 7,300 participants made funds transfers.

Fedwire processes an astonishing amount of payments every day. During the first quarter of 2010, slightly less than 500,000 payments worth $2.4 trillion were originated on average each day.[f] More than 920,000 payments were processed on the highest-volume day and payments worth almost $4.1 trillion were exchanged on the highest-value day.[g]

The beginning was more modest. During the first year of Fedwire operation, the system was used only by a limited number of member banks, and the Federal Reserve Bank of New York processed around 100 wires per day; ten years later, the Bank was processing about 600 wires per day (Bech and Hobijn 2007). By the early 1990s, the volume of transfers originated over Fedwire had increased many-fold, to just short of 270,000 payments on average per day.[h] Over the next fifteen years, the volume of transfers roughly doubled and the number of payments peaked at 545,000 per day during the last quarter of 2006 (see Chart 1 above). The value of transfers originated across Fedwire saw even stronger growth during the decade and a half preceding the financial crisis. Value quadrupled. In the early 1990s, roughly $800 billion in payments was exchanged on average per day, but dollar volume reached more than $3.2 trillion on average for the month of September 2008.

Chart 1

Value and Volume of Payments Originated over Fedwire



Source: http://www.federalreserve.gov/paymentsystems/fedfunds_qtr.htm.

[a] For a discussion of RTGS systems, see, for example, Bank for International Settlements (2005) and Bech and Hobijn (2007).

[b] The maximum payment allowed is one penny short of $10 billion.

[c] The Federal Reserve also provides the Fedwire Securities Service. The Securities Service is a book-entry depository and settlement system for securities issued by the U.S. Treasury, other federal agencies, government-sponsored enterprises, and certain international organizations such as the World Bank.

[d] For example, the Fedwire Funds Service opens for a nonholiday Monday at 9:00 p.m. on the preceding Sunday. Under certain circumstances, operating hours may be extended.

[e] Depository institutions represent the majority of eligible Fedwire participants, but certain other financial institutions, such as government-sponsored enterprises, are also eligible to participate.

[f] Both the value and volume settled over Fedwire vary considerably from day to day. Part of this variation follows regular patterns, such as the first and last business days of a month or quarter, as well as certain key settlement dates for financial securities. Hence, it is helpful to smooth out this variation when trying to ascertain the long-run trends and changes thereto. Unless otherwise noted, the figures cited reflect quarterly averages of daily values.

[g] As of July 2, 2010.

[h] Data on the average daily volume and average daily value of transfers over the Fedwire Funds Service are available at http://www.frbservices.org/operations/fedwire/fedwire_services _volume_value_statistics.html.

Box 1

The Fedwire Funds Service (*Continued*)

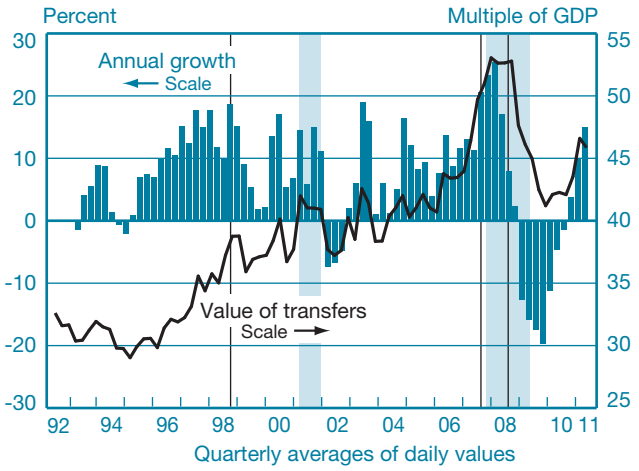
Needless to say, part of the growth of dollars transferred over Fedwire reflects the concurrent growth in prices and size of the overall economy. Hence, it is also instructive to scale turnover with that growth. A natural candidate is U.S. GDP. From this perspective, the annual value of transfers across Fedwire was equivalent to roughly thirty times GDP in the early 1990s. In other words, a value equivalent to the economic output of the United States was transferred via Fedwire every eight to nine business days. Following fifteen years of almost uninterrupted growth, turnover exceeded more than fifty times U.S. GDP during 2008, with a notable runup in 2007, before falling to forty times GDP in the first quarter of 2010 (see Chart 2 below).

While Fedwire is referred to as a large-value payment system, it also handles a surprisingly large number of payments of relatively modest size. During the first quarter of 2010, more than 5 percent of payments were for less than $300, the median payment was below $17,500, and 75 percent of payments were for less than $125,000 (about half the average price of a single-family home). However, at the same time, the service also processed a small percentage of very large payments, and these payments constitute a substantial share of the total value transferred. For example, 1 percent of all payments were larger than $70 million during the first quarter of 2010, and this top 1 percent accounted for more than 85 percent of the total value of payments.

Chart 2

Value of Payments Originated over Fedwire

Annual Growth and Value to GDP



Sources: U.S. Department of Commerce, Bureau of Economic Analysis, GDP Press Release (Table 3); http://www.federalreserve.gov/paymentsystems/fedfunds_qtr.htm; authors' calculations.

Notes: Vertical lines denote September 23, 1998, August 9, 2007, and September 15, 2008. Bands denote NBER recessions.

2.1 Nodes of the Clearing and Settlement Network

The first group of platforms—starting in the upper-left-hand corner—consists of a number of wholesale or large-value payment systems. We begin with the Clearing House Interbank Payment System (CHIPS)—a private sector system operated by the Clearing House Payments Company.[6] At times, CHIPS is referred to as a *hybrid* system, as it employs an algorithm that combines both gross settlement (like Fedwire Funds) and end-of-day netting features (like more traditional interbank payment systems).[7] Historically, CHIPS settled the vast majority of international dollar transactions, such as the dollar legs of foreign exchange transactions and eurocurrency loans. Settlement of the dollar legs of foreign exchange transactions has become a smaller part of CHIPS business because of the introduction of the Continuous Linked Settlement (CLS) system in the early 2000s. CLS primarily settles foreign exchange transactions via a risk-reducing mechanism known as payment versus payment (PvP). PvP ensures that a final transfer of one currency occurs if and only if a final transfer of the other currency or currencies takes place.[8]

In addition, a limited number of large-value payment systems around the world clear dollar payments in their local jurisdictions. These systems are commonly referred to as *offshore* systems and are exemplified in the exhibit by the U.S. dollar Clearing House Automated Transfer System (CHATS) in Hong Kong. The U.S. dollar CHATS is built on the same infrastructure and operates in the same manner as the local Hong Kong dollar system. Like Fedwire, it provides RTGS for U.S. dollar payments; like CLS, it allows for PvP of U.S. versus Hong Kong dollars.[9]

The second group of platforms—moving clockwise in the exhibit—comprises clearing houses and central counterparties (CCPs). Clearing houses are infrastructures that provide clearing services to institutions such as commodity and stock exchanges. CCPs facilitate clearing and risk management by becoming the buyer to every seller and seller to every buyer of a specified set of financial contracts, such as those executed on a particular exchange or set of exchanges. The largest clearing

[6] Established in 1853, the Clearing House Payments Company is the nation's oldest banking association and payments company (see http://www.theclearinghouse.org).

[7] See Bech, Preisig, and Soramäki (2008) for a discussion.

[8] The risk that a counterparty does not deliver the other leg of a foreign exchange transaction is known as Herstatt risk, after a German bank that failed in the early 1970s.

[9] CHATS also provides delivery versus payment (DvP) for U.S.-dollar-denominated securities (bonds and equities) listed in Hong Kong.

houses and CCPs processing transactions in dollars are CME Clearing, ICE Trust, LCH.clearnet, and the Options Clearing Corporation (OCC). CME Clearing provides clearing for the Chicago Mercantile Exchange (CME), the Chicago Board of Trade, the New York Mercantile Exchange, and the Commodity Exchange, Inc. ICE Trust is a limited-purpose trust company that serves as a central clearing facility for credit default swaps. LCH.clearnet, formed by a merger of the London Clearing House Limited and Paris-based Clearnet, clears a broad range of asset classes in fifteen currencies. The U.S.-based OCC offers clearing and settlement services for futures, options on futures, and certain securities lending contracts.

The next group consists of different platforms associated with the clearing and settlement of U.S. government and agency securities. Besides the Fedwire Funds Service, the Federal Reserve provides the Fedwire Securities Service—the central securities depository (CSD) for U.S. government and agency securities. A CSD holds securities and enables transactions in these securities to be processed by book-entry.

Most financial institutions cannot hold accounts with the Federal Reserve and, hence, hold their U.S. government and agency securities with one or more custodial agents.

In addition to safekeeping, a CSD often incorporates clearing and settlement functions (Bank for International Settlements 2003). Fedwire Securities settles transactions using a DvP mechanism. As with PvP, the mechanism ensures that both legs of a transaction (here, cash and securities) are settled at the same time.

However, most financial institutions cannot hold accounts with the Federal Reserve and, hence, hold their U.S. government and agency securities with one or more custodial agents.[10] The main custodial agents are JPMorgan Chase and Bank of New York Mellon. These institutions are also the clearing banks for the tri-party repurchase agreement (repo) market that many broker-dealers use to finance their trading operations. As a result, the two banks are often just referred to as *the clearing banks*. In addition, many broker-dealers use the services of the Fixed Income Clearing Corporation (FICC) to clear interdealer trades. FICC services include trade comparison and multilateral netting.

The last group of platforms in the exhibit consists of the largest CSDs for other dollar-denominated securities. The group includes the Depository Trust Company (DTC), Clearstream, and Euroclear. DTC is based in New York, while Clearstream and Euroclear are based primarily in Luxembourg and Belgium, respectively.[11] These CSDs service many different asset classes including, but not limited to, equities, corporate and municipal bonds, investment funds, and money market instruments, as well as certain information services for over-the-counter derivatives.

2.2 Funding Links in the Clearing and Settlement Network

Importantly, Fedwire Funds is linked to all the other platforms in the wholesale clearing and settlement system. The links to other platforms or systems are either *direct* or *indirect*. A direct link implies that participants prefund their activities in the linked system by using Fedwire Funds to transfer funds into a designated Federal Reserve account belonging to the ancillary platform.[12] Once clearing and settlement positions are finalized by the ancillary platform, participants with a positive net position receive via Fedwire Funds back funds owed. The systems with a direct link to Fedwire Funds are Fedwire Securities, CHIPS, CLS, and DTC.

For all other platforms, the link is indirect, as the funding of the ancillary platforms occurs via intermediaries known as settlement banks. That is, participants transfer funds to the Federal Reserve account of a settlement bank via Fedwire Funds—if required—with the beneficiary being the clearing and settlement platform in question.[13] Once settlement is completed, the account of net sellers at the settlement banks is credited. Participants may then choose to leave the funds with the settlement banks or request that they be transferred to another institution, typically via Fedwire.

A key fact, to which we return to below, is that any funds transferred to an ancillary clearing and settlement system are not available for other transactions over Fedwire. In other words, these systems can act as "funding sinks." This is a concern particularly if Fedwire itself is running low on

[10] Different types of market participants typically use different custodial agents. Active dealers normally use the clearing banks. Institutional investors—such as pension funds, insurance companies, hedge funds, and nonfinancial corporations—use the services of a custodial bank (which could be one of the clearing banks). Individual and smaller institutional investors typically leave the securities with their dealer for safekeeping. In the case of Treasuries, individual investors can also use the U.S. Treasury's Treasury Direct service.

[11] Clearstream International was formed in 2000 through the merger of Cedel International and Deutsche Börse Clearing.

[12] In the case of Fedwire Securities, the link is even stronger, as the two components of Fedwire share the same cash account.

[13] In the case of multiple settlement banks, the clearing and settlement system may consolidate the funds during the day at one of the settlement banks, known as the concentration bank. In principle, CHIPS may be used as well.

available funds for settlement or if the amounts transferred are not closely managed. However, any "underfunding" of the ancillary systems—either in the aggregate or from the perspective of an individual participant—will tend to delay the completion of their respective settlement processes.

The same is true for the settlement banks, with a small caveat. The difference is that there is not necessarily a one-to-one relationship between the funds transferred to the settlement banks via Fedwire and the funding available for the clearing and settlement systems. This lack of correspondence occurs if the settlement bank either provides intraday credit to the participants or facilitates netting of positions across participants or systems.

The dollar clearing and settlement system is an intertwined collection of diverse subsystems in use around the globe. Fedwire Funds (and by extension, the Federal Reserve) plays a vital role in the smooth operation of this system as the provider of final settlement in central bank money.

In sum, the dollar clearing and settlement system is an intertwined collection of diverse subsystems in use around the globe. Fedwire Funds (and by extension, the Federal Reserve) plays a vital role in the smooth operation of this system as the provider of final settlement in central bank money. While the system affords significant benefits to the global economy, its sheer size, complexity, and interconnectedness imply risks and challenges that have to be carefully controlled by stakeholders. At the top of the list is the need to ensure that the clearing and settlement platforms—both in the aggregate and individually—are liquid. We now discuss *settlement liquidity*.

3. Settlement Liquidity

The recent financial crisis underscored the importance of liquidity for the smooth functioning of the financial system. Liquidity can mean different things depending on the context in which it is used. For our purposes, it is important to stress that, regardless of its definition, liquidity can depend both on the actions taken by the agents in the economy and on factors outside their control.

In the financial system, it is often useful to distinguish between different types of liquidity. One dimension of liquidity is the availability of credit or ease with which financial institutions can take on leverage. This is generally referred to as *funding liquidity*. Another dimension is the ease with which market participants can transact or the ability of markets to absorb large purchases and sales with little impact on prices. This is generally referred to as *market liquidity*. A third dimension of liquidity, relevant for payment and settlement systems, is the ease with which market participants can discharge their settlement and payment obligations at a time either agreed upon by the parties to the transaction or determined by market conventions. We refer to this form of liquidity as *settlement liquidity*. All else equal, a liquid clearing and settlement system is more efficient, as obligations are settled more quickly, reducing the uncertainty with regard to the finality of transactions between agents. Ensuring a liquid system is an important policy goal for a central bank.

The different types of liquidity are interlinked. The link between market and funding liquidity is well documented (Brunnermeier and Pedersen 2009). Traders provide market liquidity, and their ability to do so depends on the availability of funding. Conversely, traders' funding—that is, their capital and margin requirements—depends on the assets' market liquidity. There are also important links between settlement liquidity and market and funding liquidity. For example, if it is difficult to settle a financial asset, then trading might be curtailed or be unnecessarily risky. The events in the repo market that preceded the failure of Bear Stearns in March 2008 and the bankruptcy of Lehman Brothers in September 2008 highlighted the links between funding liquidity and settlement liquidity. In the U.S. tri-party repo market, the ease with which a dealer can fund its securities currently depends on the willingness of its clearing banks to provide intraday credit. That credit contributes to the dealer's settlement liquidity. Should the clearing bank refuse to extend credit, the dealer would be unable to settle its deliveries of securities and would be unlikely to survive. Uncertainty concerning settlement liquidity in that market may have contributed to Bear Stearns' and Lehman Brothers' difficulties (see Adrian, Burke, and McAndrews [2009, Box 3] and Copeland, Martin, and Walker [2010]).

Liquidity can depend both on the actions taken by the agents in the economy and on factors outside their control.

4. Measuring Settlement Liquidity

Liquidity in financial markets is difficult to quantify and can vary unexpectedly. Rarely is it possible to devise a single, all-encompassing measure and, thus, proxies are often used. Market liquidity, for example, is studied using bid-ask spreads, trading volume or trading frequency, trade or quote sizes, and price-impact coefficients, among other proxies (see Fleming [2003]). During the financial crisis, the spreads between the London interbank offered rate in different currencies and the rate on same-maturity overnight indexed swaps were widely used as proxies for funding liquidity.

In the context of central banks, liquidity is often taken as synonymous with the amount of reserves (that is, overnight balances) supplied to the banking system via open market operations or lender-of-last-resort facilities (see, for example, Cecchetti and Disyatat [2010]). While injections of additional reserves into the banking system in general tend to improve liquidity, this is not a perfect measure in the clearing and settlement system.

First, focusing solely on reserves ignores the substantial amount of credit that central banks provide intraday to ensure the smooth operation of the clearing and settlement system. For example, prior to the financial crisis, the peak amount of intraday credit supplied by the Federal Reserve averaged about $150 billion per day, or 17 percent of the size of the Federal Reserve's balance sheet when reserves averaged $20 billion (see Box 2). It is important to observe that an increase in intraday credit extensions adds to the Federal Reserve's credit risk exposure, as the Federal Reserve guarantees the finality of payments transferred across Fedwire.[14]

Liquidity in financial markets is difficult to quantify and can vary unexpectedly. Rarely is it possible to devise a single, all-encompassing measure and, thus, proxies are often used.

The sum of overnight reserves and intraday credit is a better measure of settlement liquidity, but it ignores two important sources of funds from the perspective of an individual participant in the clearing and settlement system: incoming payments and credit extensions from other participants, such as interbank loans, as outlined in McAndrews and Rajan (2000). While these sources of funds do not add to the available stock, they facilitate the redistribution of the settlement asset, increasing its potential use. If the speed by which the settlement asset is circulated is high and if participants are willing to extend credit to one another, then funds are going to be more readily available where needed. However, if the opposite is true, then settlement liquidity is going to suffer.[15] In other words, settlement liquidity may depend crucially on the actions taken by the participants. It is thus important to consider measures that can shed light on changes in behavior, and these are rarely captured well by dollar amounts. However, any measure of settlement liquidity that takes behavior into account is likely to be—at least to some extent—system-specific, as incentives often depend on the exact nature of the institutional details.

5. Settlement Liquidity of Fedwire Funds

In the context of an RTGS system such as Fedwire Funds, one approach to measuring settlement liquidity is to focus on the degree to which payments are being delayed. For many types of payments, banks have considerable flexibility in choosing the time at which payments are settled, as they only need to be settled on a particular day but not at a specific time during the day. Delays may be costly for certain types of payments. A cost of delay arises for several reasons. For example, delaying customer payments may have reputational costs for a bank if customers value early settlement. Delaying a payment also exposes a bank to the risk that an operational problem with the settlement system could prevent the bank from settling the payment later that day. Hence, all else equal, banks should not wish to delay payments.

However, there are benefits to delaying payments. Suppose "Thrifty Bank" must make a payment to "Receiver Bank," but lacks enough reserves to do so. Thrifty Bank could borrow from the central bank, but this may be costly—either because the central bank charges a fee for the credit it provides or because it requires Thrifty Bank to post collateral, which has a cost because the assets serving as collateral cannot be put to another use. However, Thrifty Bank could delay the payment, which in general would result in a cost of delay being suffered by itself, its customer, and the intended receiver of the payment. Now, if Thrifty Bank delays the payment, it may later receive a payment from another bank, say "Flush Bank." The payment from Flush Bank would increase Thrifty Bank's reserve position, allowing it to make its delayed payment to Receiver Bank without the need to borrow from the central

[14] Finality means that once a payment is made, it is not possible for the Federal Reserve to claw back the amount should the sender not repay any intraday credit used to fund the payment.

[15] One way to classify the different types of settlement liquidity is by using the notions of inside and outside settlement liquidity. The former represents liquidity generated within the system itself and the latter represents funds supplied from the outside. The measures we emphasize are analogous to velocity measures of money.

Box 2

Daylight Overdrafts

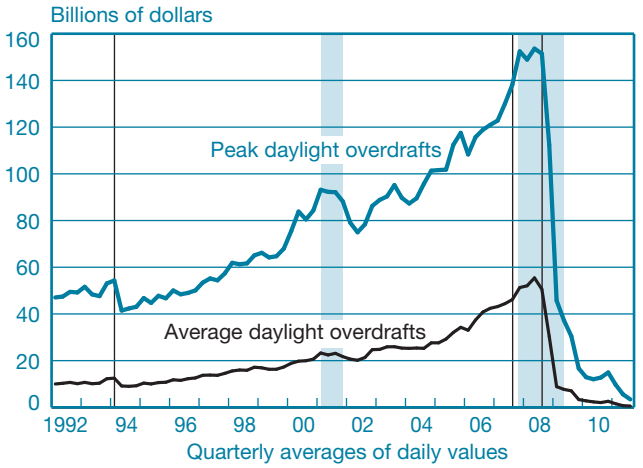
The Federal Reserve provides daylight overdrafts to depository institutions under certain conditions to promote the efficient functioning of Fedwire.[a] First, Fedwire participants must satisfy a range of regulatory criteria designed to ensure that they are adequately capitalized to have access to intraday credit. This allows only relatively creditworthy institutions to borrow. Nonetheless, the value of assets held by a financial institution, such as a bank, can fluctuate rapidly. Consequently, there is a small risk that a Fedwire participant could have access to uncollateralized credit before the Federal Reserve realizes that the participant's financial condition has deteriorated. Second, since 1986 the Federal Reserve has been imposing quantitative limits, known as caps, on the overdrafts a bank can incur.[b] The need for access to intraday credit (that is, a nonzero cap) is based on a self-assessment by the individual bank (for banks in good condition), and the size of a potential cap is tied to the bank's capital. In 1994, the Federal Reserve began applying a fee for every dollar of daylight overdrafts it extends. At first, the fee was set at 24 basis points (the annual rate quoted on the basis of a twenty-four-hour day), but in 1995 it was raised to the current 36 basis points.

When trying to understand the use of daylight overdrafts, it is important to take into account that they vary considerably over the course of the operating day. Hence, it is helpful to focus on both the average and peak levels of daylight overdrafts. In the early 1990s, the average aggregate amount of daylight overdrafts was around $10 billion, while peak daylight overdrafts hovered just below $50 billion (see Chart 1, right). The introduction of fees in 1994 led to a decrease in the use of daylight overdrafts, but the fee hike in 1995 did not. Nonetheless, while the application of fees and caps has been instrumental in making banks manage their use of daylight overdrafts more closely, the fees did not prevent daylight overdrafts from growing—at least in intraday terms.[c] By early 2007, average and peak daylight overdrafts increased to about $45 billion and $125 billion, respectively.

Yet at the height of the crisis, following the bankruptcy of Lehman Brothers, average and peak daylight overdrafts reached even higher levels. Over the maintenance period that ended on October 8, 2008, daylight overdrafts averaged $83 billion and peak daylight overdrafts averaged $246 billion.[d] Since fall 2008, however, daylight overdrafts have decreased dramatically and reached their lowest levels in more than twenty-five years.

Chart 1

Fedwire Funds Daylight Overdrafts



Source: http://www.federalreserve.gov/paymentsystems/psr_data.htm.

Notes: Vertical lines denote January 1, 1994, August 9, 2007, and September 15, 2008. Bands denote NBER recessions.

[a] As discussed in Martin and McAndrews (2010), reserves borrowed intraday are a substitute for reserves held overnight.

[b] For many depository institutions, the overdrafts were de facto secured by prepositioned collateral at the discount window. Hence, as a practical matter, the uncollateralized risk exposure to the Federal Reserve is likely to be smaller than the outstanding amount of daylight credit.

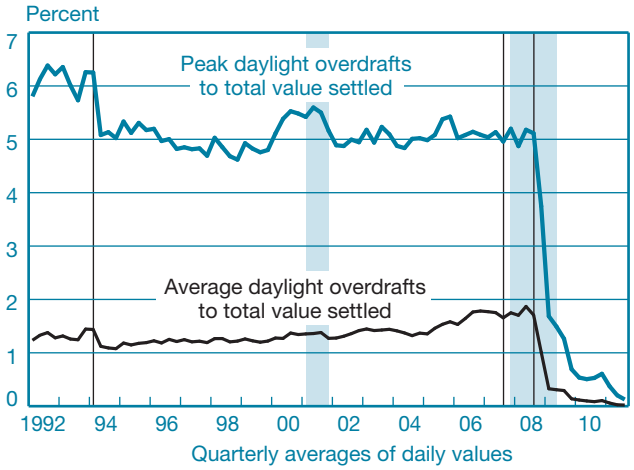
[c] The introduction of fees had a much larger and permanent effect on daylight overdrafts incurred in the Fedwire Securities Service. See Coleman (2002) and Mills and Nesmith (2008).

[d] See http://www.federalreserve.gov/paymentsystems/psr_dlod.htm.

Box 2
Daylight Overdrafts (*Continued*)

As shown in Chart 2 below, the decrease in daylight overdrafts was not driven by a decline in the total amount of payments sent. Indeed, when daylight overdrafts are measured relative to the total amount of payments, the decrease is still apparent. This is striking because the use of daylight overdrafts had been more or less unchanged over the decade and a half preceding 2008. In fact, following the implementation of priced overdrafts in 1994, peak daylight overdrafts have been remarkably stable, at around 5 percent of total payment value (average overdrafts increased slightly faster than the value of payments in the mid-2000s). During the first quarter of 2010, average and peak daylight overdrafts were $3 billion and $13 billion, respectively. These levels are less than a third of the daylight overdrafts experienced in the early 1990s and less than a tenth of their peak measures.

Chart 2
Fedwire Funds Daylight Overdrafts Relative to Value Transferred



Sources: http://www.federalreserve.gov/paymentsystems/fedfunds_qtr.htm; http://www.federalreserve.gov/paymentsystems/fedfunds_qtr.htm; authors' calculations.

Notes: Vertical lines denote January 1, 1994, August 9, 2007, and September 15, 2008. Bands denote NBER recessions.

bank. This imposes a delay cost on the system, but reduces the cost of funds for Thrifty Bank and shifts these costs to other members of the payment system. As a result, all members of the payment system have an incentive to put off their payments, resulting in excessive delays.[16]

It is difficult to measure delay because a system operator with access to transaction data can typically observe the time at which a payment is settled, but not the time at which an institution becomes aware that a payment must be sent. For example, a payment settled at 3:00 p.m. may have been delayed several hours if the sending bank learned about the payment at 8:00 a.m., or just a few minutes if the payment request was received at 2:58 p.m. Hence, computing an accurate measure of settlement delay can be challenging. Instead, one typically has to rely on changes in settlement times to identify changing liquidity conditions and, ultimately, gauge efficiency.[17] For this to be a suitable approach, it must be the case that the underlying arrival process of payment requests reasonably can be assumed to be fixed.

Given the difficulties measuring settlement liquidity, estimating the benefits of settlement liquidity requires a quantitative model of the participants' possible actions. Atalay, Martin, and McAndrews (2010) calibrate the benefits of earlier payments using Fedwire data. Their quantitative results suggest that benefits in terms of reduced delays and overdraft charges are economically significant, on the order of tens or hundreds of millions of dollars per year.

For the decade prior to the financial crisis, the distribution of settlement times on Fedwire generally drifted later in the day (see Armantier, Arnold, and McAndrews [2008]). In particular, payments in the 40th-90th percentiles, which settle in the afternoon, moved even later.[18] Chart 1 shows the evolution of the distribution of timing on Fedwire over the last fourteen years. The horizontal lines in the chart measure the time by which the 10th-90th percentiles of value settled on Fedwire were completed; the vertical lines indicate several discrete events that may have affected the timing of Fedwire payments. From an operational risk perspective, waiting to send large payments until late in the day increases the potential magnitude of liquidity dislocations and risk in the financial

[16] For example, strategic submission delays by participants can reduce the liquidity and thus the efficiency of a system. Using a game-theoretical framework, Bech and Garratt (2003) show that banks may have incentives to delay their payments (see also Angelini [1998] and Martin [2004]). Bech and Garratt (forthcoming) show how illiquidity in the interbank payment system following a widescale disruption, such as the events of September 11, 2001, is dependent on the strategic actions taken by the participants. The incentives to delay payment are likely to become particularly strong during periods of high uncertainty. The payment system's participants are expected to be reluctant to send payments to any institution that is perceived to be unlikely to make its own payments, either because of operational difficulties or because it may default. But institutions that do not receive the payments they expect will have incentives to delay, propagating the problem further. Such situations can result in significant delays relative to a "normal" day (McAndrews and Potter 2002). Bech and Soramäki (2001) and Martin and McAndrews (2008) show how a liquidity-saving mechanism can mitigate this trade-off.

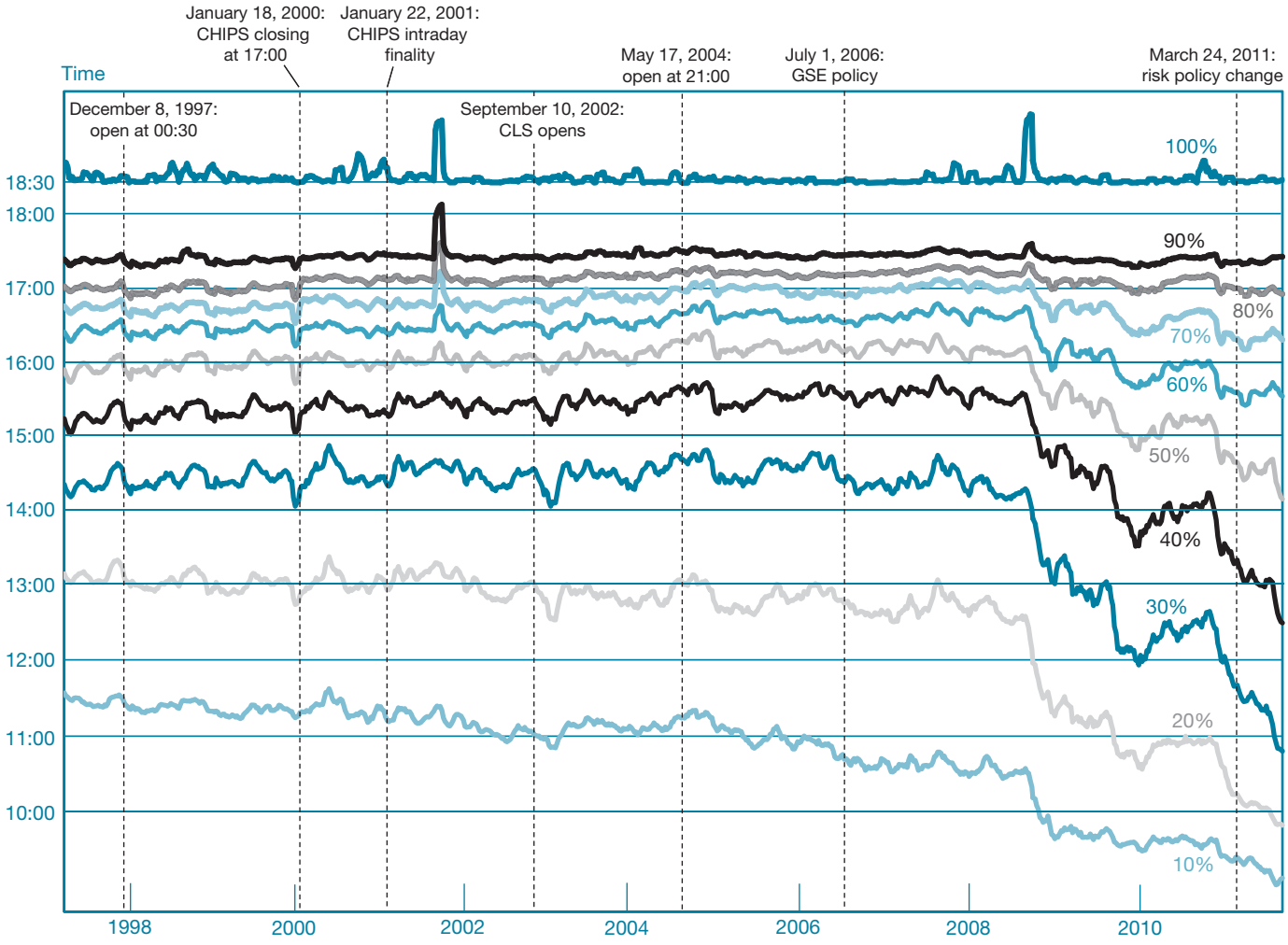
[17] See, for example, Armantier, Arnold, and McAndrews (2008) and Becher, Galbiati, and Tudela (2008) for analyses of the timing of payments in Fedwire and in the CHAPS system in the United Kingdom.

[18] The extraordinary, but temporary, delays that occurred after September 11, 2001, are clearly visible in Chart 1 as well. During normal times, the last half-hour of Fedwire operation is closed for customer payments in order to allow banks time to square their accounts prior to the close. Hence, normally the value settled through the last half-hour is less than 2 percent. However, due to the disruptions, Fedwire opening hours were extended and payments occurred much later.

Chart 1

Deciles of Fedwire Value Settled throughout Day

Deciles of Fedwire 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 related to CHIPS, CLS, DTC, and principal and interest payment funding.

industry should an operational disruption occur. An increase in such risk is particularly troublesome in an era of heightened concern about operational disruptions generally (Board of Governors of the Federal Reserve System 2008).

Previous research has ascribed this development to a confluence of drivers. Armantier, Arnold, and McAndrews (2008) find that much of the later settlement of payments was driven by three factors. First, increases in the number and value of Fedwire payments between 1998 and 2006 contributed to later payments overall by increasing the demand for scarce liquidity. Second, increases in industry concentration were found to have an empirical association with later settlement, and accounted for some of the additional delays. Finally, changes in the timing of ancillary payment systems, particularly CHIPS, contributed to later Fedwire settlement. In 2000, CHIPS changed its settlement time from 4:30 p.m. to 5:00 p.m. and Fedwire payments followed the pattern set by CHIPS.

In addition, the Payments Risk Committee—a private sector group of senior managers from banks active in the United States and sponsored by the Federal Reserve Bank of New York—studied the increase in late-day activity in many markets that directly or indirectly rely on same-day settlement via Fedwire. The study suggests that many financial institutions

send payments late in the day, in part because the instructions to execute payments are received late (Payments Risk Committee and Wholesale Customer Advisory Group 2007, p. 3).

Remarkably, as shown in Chart 1, a fundamental change has occurred in the settlement dynamics of Fedwire since fall 2008, resulting in a dramatic quickening of settlement times. In the immediate aftermath of the Lehman bankruptcy, there was a sharp but temporary increase in late-day payments driven by the uncertain environment. High uncertainty gives banks an incentive to wait as long as possible for some of this uncertainty to be resolved before sending payments. For example, banks that play a correspondent role for other banks have an incentive not to send payments on behalf of client banks that may fail during the day. This increase dissipated within a matter of weeks, and all measures of settlement time have moved sharply earlier since.

Remarkably . . . a fundamental change has occurred in the settlement dynamics of Fedwire since fall 2008, resulting in a dramatic quickening of settlement times.

There are many ways to measure the wholesale quickening of payments. As shown in Chart 1, the 30th percentile of payment value settled after 2:00 p.m. until 2008; as of mid-2011, it settled more than three hours earlier, just after 11:00 a.m. Alternatively, as of mid-2011, less than 45 percent of the value of payments settled after 3:30 p.m., an unprecedented drop of 15 percentage points compared with the previous norm. Moreover, the share of payments settled after 5:00 p.m. is close to the level of 20 percent seen a decade ago.[19]

Interestingly, it is not only the settlement timing of Fedwire that has improved. As suggested by our review of the clearing and settlement network above, improvements in the settlement liquidity of Fedwire Funds are likely to spread to other parts of the network. A lack of information on settlement timing and funding prevents us from tracing such effects for many parts of the system. However, available data from CHIPS show that such positive spillovers are indeed at work.

[19] In addition, the amount of payments settled during the last half-hour of Fedwire operation is at its lowest level, likely reflecting the fact that banks have less incentive to manage their end-of-day balances closely, as the opportunity cost of holding such balances overnight is smaller with the implementation of interest on reserves.

6. Why Did Settlement Liquidity Improve?

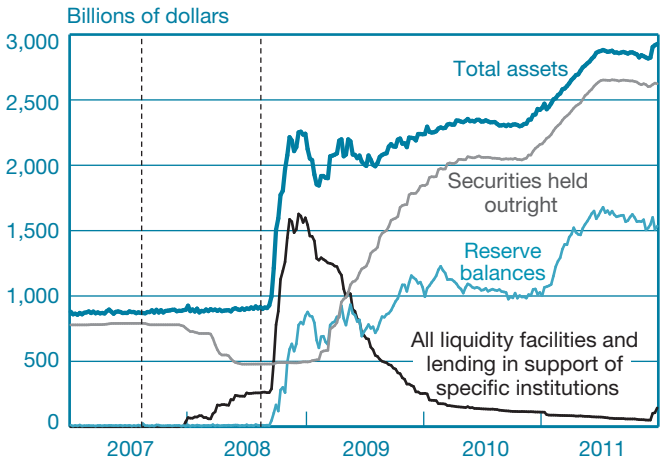
A natural question to ask is why settlement timing for Fedwire Funds has improved so substantially since fall 2008. We show that the improvements in settlement timing were a by-product of the Federal Reserve's policy responses to the financial crisis and subsequent recession. These policy responses were not intended primarily to improve payment system efficiency, but nonetheless provided banks incentives to modify their payment behavior. In particular, the unprecedented increase in reserve balances eliminated virtually any need for banks to delay their submission of payment requests. During the days following the bankruptcy of Lehman, stress and uncertainty in the financial system mounted rapidly. In an attempt to restore liquidity and stability to the U.S. financial system in general and the banking system in particular, public authorities took a number of unprecedented actions.[20] The increase in reserve balances was so large that the Federal Reserve was not able to sterilize it by selling U.S. Treasuries, as it had done earlier in the crisis. Consequently, the level of reserve balances ballooned from $10 billion on average during August 2008 to $850 billion by year-end.

A natural question to ask is why settlement timing for Fedwire Funds has improved so substantially since fall 2008. We show that the improvements in settlement timing were a by-product of the Federal Reserve's policy responses to the financial crisis and subsequent recession.

In addition, the Federal Reserve bought $1.725 trillion in Treasuries, agency debt, and agency mortgage-backed securities (MBS) from late 2008 through early 2011. However, reserve balances did not start to grow further throughout much of 2009 because the increase in reserves from the large-scale asset purchases was partially offset by a runoff in the use of the Federal Reserve's emergency liquidity facilities. The level of

[20] For example, the Federal Reserve, with the full support of the Treasury, agreed to provide support to American International Group, and the Federal Reserve augmented many of its existing lending facilities, such as the Term Auction Facility and reciprocal currency arrangements (swap lines) with foreign central banks. In addition, the Federal Reserve took several steps to ease investor concerns about the money market mutual fund industry and support the functioning of the commercial paper market.

Chart 2
Reserve Balances



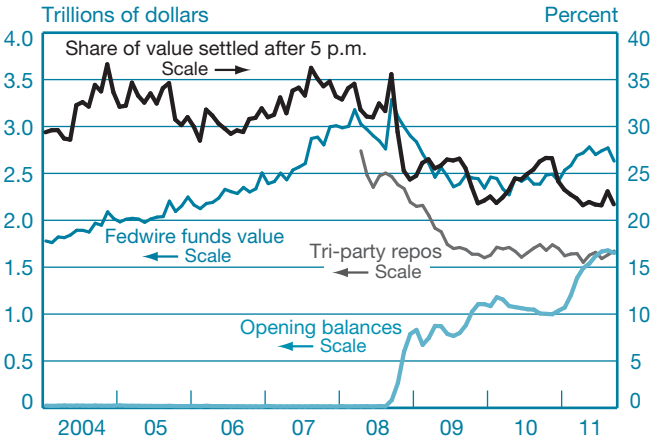
Source: Federal Reserve Statistical Release H.4.1.

Notes: Vertical lines denote August 9, 2007, and September 15, 2008. "All liquidity facilities" includes term auction credit; primary credit; secondary credit; seasonal credit; Primary Dealer Credit Facility; Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility; Term Asset-Backed Securities Loan Facility; Commercial Paper Funding Facility; and central bank liquidity swaps. "Lending in support of specific institutions" includes net portfolio holdings of the three Maiden Lane LLCs and preferred interests in AIA Aurora LLC and ALICO Holdings LLC.

reserve balances grew further, to more than $1 trillion in the last quarter of 2009 and reached $1.2 trillion in February 2011. Following the completion of securities purchase programs, reserve balances slowly began to fall back to $1 trillion, due to principal payments and a continuing runoff in the liquidity facilities. However, in August 2010 the Federal Reserve announced that it would keep its holdings of longer-term securities constant at their then-current level by reinvesting principal payments from agency debt and agency MBS in longer-term Treasury securities. This halted the fall in reserve balances. Then, in November, the Federal Open Market Committee (FOMC) announced that it intended to purchase an additional $600 billion of longer-term Treasury securities by the end of the second quarter of 2011. Consequently, reserves grew to more than $1.5 trillion. The evolution of reserves, as well as other components of the Federal Reserve's assets, is displayed in Chart 2.[21]

[21] With the banking system awash in reserves, the rate at which banks were willing to buy and sell these funds—the federal funds rate—dipped well below the intended policy target rate set by the FOMC in the weeks following the Lehman bankruptcy. This situation created a tension for the Federal Reserve: While the emergency measures were helping to improve market functioning, the resulting increase in reserve balances was exerting downward pressure on the federal funds rate. See Bech and Klee (2011) for a discussion.

Chart 3
Opening Balances, Fedwire Funds Value, Tri-Party Repos, and Settlement Time



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

With so many reserves in the banking system, banks no longer need to economize on their reserves; as a result, payments are being made more quickly, which reduces delays and resolves uncertainty for businesses and individuals. As illustrated in Chart 3, the changes in settlement time (measured by the proportion of payments settled after 5:00 p.m.) since the Lehman bankruptcy appear to be inversely related to the amount of opening balances available. The share of total value settled after 5:00 p.m. has generally dropped as reserve balances have increased. However, the chart also suggests that other factors may have influenced the improvement in settlement timing, such as the value of payments settled over Fedwire Funds and the amount of tri-party repos traded. We explore this in the following section using regression analysis.

6.1 Regression Analysis

To measure the relative importance of the potential drivers of improved settlement liquidity, we extend the Fedwire timing analysis of Armantier, Arnold, and McAndrews (2008; hereafter "AAM"). We perform nine regressions, one for each decile of payment value settled below 100 percent. In each regression, the dependent variable is defined as the change in the time at which the corresponding decile ("percentiles" in AAM) of value settled on a specific day, measured in the number of seconds since the day's Fedwire opening. The same set of explanatory variables is used in each of the nine regressions.

In addition to the explanatory variables employed by AAM, we include the total amount of opening balances available to banks on the specific day, a measure of tri-party repo activity, and a measure of the distribution of balances across banks: the Herfindahl-Hirschmann Index (HHI) of balances.[22] Furthermore, we estimate the decile regressions over two sample periods. The first period, which we label *pre-Lehman*, runs from August 2002 through August 2008. The second period, which we label *post-Lehman*, runs from September 2008 through March 2011.

A couple of technical points are worth highlighting. First, following AAM, we rely on the approach developed by Newey and West (1987) to correct the estimated standard errors to address possible serial correlation and heteroskedasticity problems. Second, in the original AAM analysis it was reasonable to treat the settlement time percentiles as being stationary, as they fluctuated around a relatively fixed mean with relatively constant volatility over the sample. However, when using our post-Lehman period this is no longer a reasonable assumption, as the time series properties have changed significantly. To address issues of nonstationarity (unit roots), we estimate the regressions in changes rather than in levels, as in the original AAM paper.[23]

In sum, we estimated the following equations:

$$\Delta p_t^{10} = \beta_0^{10} + \beta_1^{10} \times \Delta OpenBal_t + \beta_2^{10} \times \Delta 3PRepo_t + \Delta x_t^{AAM'} \times \beta_{AAM}^{10} + \varepsilon_t^{10}$$

$$\Delta p_t^{20} = \beta_0^{20} + \beta_1^{20} \times \Delta OpenBal_t + \beta_2^{20} \times \Delta 3PRepo_t + \Delta x_t^{AAM'} \times \beta_{AAM}^{20} + \varepsilon_t^{20}$$

$$\cdots$$

$$\Delta p_t^{90} = \beta_0^{90} + \beta_1^{90} \times \Delta OpenBal_t + \beta_2^{90} \times \Delta 3PRepo_t + \Delta x_t^{AAM'} \times \beta_{AAM}^{90} + \varepsilon_t^{90},$$

where Δ denotes the change from one business day to another in a variable, p_t^i; $i \varepsilon \{10,20,\ldots,90\}$ denotes the time at which first the 1st-9th deciles in terms of value settled on day t; $OpenBal_t$ is the opening balances at day t; $3PRepo_t$ is the proxy for tri-party-repo-related payments on day t, as discussed below; and x_t^{AAM} is a vector of the explanatory variables used in the original AAM paper.

[22] The explanatory variables used by AAM can be organized into five categories: value and volume, Federal Reserve policies and operations, settlement system activities, other control variables, and calendar effects. A full list as well as the sources can be found in Appendix A.

[23] This choice can be justified by noting that it is better to under-difference rather than over-difference the data. Ordinary least squares is inconsistent in the former case and consistent but inefficient in the latter. We use robust standard errors to partly mitigate this concern.

The regressions for the 30th, 60th, and 90th percentiles are presented in Table 1, with the exception of calendar and some policy dummies only relevant for the pre-Lehman period.[24] We summarize the main results here. As expected, our results for the pre-Lehman period are consistent with those reported in AAM. The small differences can be explained, in part, by the different sample periods. The key insights are highlighted in Chart 4, which consists of a 2x3 matrix of panels. Each column focuses on one of three explanatory variables: opening balances, tri-party-repo-related payments, and customer transfers. The rows reflect the two sample periods. Each panel shows the estimated coefficients for the 1st-9th decile as well as the 95 percent confidence intervals around them.

The first column of panels looks at the effect of opening balances on the settlement time distribution. In the pre-Lehman period, the estimated effects are positive for all deciles, which is somewhat counterintuitive. However, the estimates are insignificant—at the standard 5 percent level—for all deciles with the exception of the 7th. In contrast, for the post-Lehman period, our analysis finds the expected negative relationship between opening balances and settlement time. The estimated effects are significant for the first six deciles as well as the last decile but insignificant for 7th and 8th deciles.

The second column of panels presents the estimated effects for a new variable relative to the original AAM analysis. This variable seeks to capture the amount of payments transferred across Fedwire Funds related to tri-party repos.

As a proxy, we use any payment larger than $1 billion that flows from (or to) one of the clearing banks—JPMorgan Chase or Bank of New York Mellon—to (or from) one of the two main custodial banks for the major tri-party-repo cash providers (for example, money market mutual funds)—State Street and Northern Trust.

Prior to the Lehman bankruptcy, our tri-party payment proxy is found to have no effect on settlement timing. The estimated effects are not significantly different from zero for any deciles. For the post-Lehman period, lower values of tri-party-repo-related payments are found to drive settlement time earlier for the 3rd-6th deciles.

Finally, the last column focuses on payments identified as customer transfers. The parameters corresponding to the total value transferred by banks on behalf of their customers over Fedwire prior to the Lehman bankruptcy are negative and significant for all deciles below 40 percent. As noted in AAM, Fedwire Funds payments seem to settle earlier when the value of transactions transferred by banks' customers is high. This result may be explained by the fact that banks face a higher cost

[24] We ran the regression with and without a constant term, and our results were unaffected.

Table 1

Regression Results (Excluding Calendar Dummies)

Explanatory Variables	30 Percent, Pre-Lehman	30 Percent, Post-Lehman	60 Percent, Pre-Lehman	60 Percent, Post-Lehman	90 Percent, Pre-Lehman	90 Percent, Post-Lehman
Change in sum of opening balances	0.136	-0.131**	0.0700	-0.0613*	0.0526	-0.0273*
	[0.0950]	[0.0377]	[0.0564]	[0.0254]	[0.0488]	[0.0113]
Change in HHI of opening balances for top 100	0.000381	0.0337*	0.000632	0.0162*	-0.000791	0.00550
	[0.000657]	[0.0140]	[0.000329]	[0.00714]	[0.000461]	[0.00399]
Change in customer transfer value	-0.0474**	-0.0229	0.00757	0.0402	0.00975**	0.0338*
	[0.0119]	[0.0236]	[0.00755]	[0.0293]	[0.00378]	[0.0162]
Change in DTC final payout value	0.00639	-0.469	0.0389	0.328	0.00276	-0.0958
	[0.0465]	[0.535]	[0.0214]	[0.417]	[0.0229]	[0.186]
Change in eurodollar borrowing value	0.0500	0.0211	0.0214	0.103	-0.0174	0.0589*
	[0.0374]	[0.0576]	[0.0201]	[0.0531]	[0.0159]	[0.0261]
Change in eurodollar lending value	0.138**	0.0395	0.0850*	0.0862	0.0366	0.0462
	[0.0522]	[0.0536]	[0.0337]	[0.0598]	[0.0216]	[0.0268]
Change in length of an extension of Fedwire operating hours	0.0760*	0.0382	0.0460**	0.0260	0.172*	0.0384**
	[0.0350]	[0.0552]	[0.0174]	[0.0259]	[0.0737]	[0.0122]
Change in value of fed funds deliveries	0.103*	-0.0972	0.0264	0.0189	-0.00168	0.000221
	[0.0456]	[0.0753]	[0.0231]	[0.0499]	[0.0334]	[0.0272]
Change in deviation from fed funds target rate	-3.240	-3.302	-8.300*	-5.861	-3.620	0.878
	[4.859]	[4.610]	[3.391]	[3.665]	[2.338]	[1.624]
Change in value of fed funds returns	0.0666	-0.169*	0.0274	-0.146**	-0.0279	-0.0240
	[0.0341]	[0.0781]	[0.0222]	[0.0419]	[0.0225]	[0.0225]
Change in final payouts, total value of payments	0.0626	-0.103	0.0671**	-0.0156	0.00851	-0.00987
	[0.0422]	[0.0706]	[0.0217]	[0.0322]	[0.0129]	[0.0160]
Change in HHI of value sent	0.158**	0.158**	0.0578	0.110**	0.0165*	0.0430*
	[0.0420]	[0.0353]	[0.0329]	[0.0371]	[0.00799]	[0.0197]
Change in fed funds target rate	537.9	98.77	325.7	653.8*	-147.2	-107.9
	[543.0]	[286.1]	[305.3]	[292.1]	[318.7]	[183.4]
Change in tri-party repo activity	-0.00401	0.426**	-0.0115	0.227**	-0.0675*	0.0298
	[0.0738]	[0.119]	[0.0389]	[0.0738]	[0.0306]	[0.0322]
Change in total volume of Fedwire (nonsettlement)	0.0414**	0.0147	0.0115	-0.0242	0.00199	-0.0153
	[0.0159]	[0.0200]	[0.00673]	[0.0172]	[0.00584]	[0.00995]
Change in September 11-18, 2001	-24.33	—	36.62*	—	79.83**	—
	[15.23]	—	[15.71]	—	[27.69]	—
Constant	-0.0392	0.0631	-0.0267	0.107	-0.0241	0.0557
	[0.135]	[0.301]	[0.0696]	[0.198]	[0.0678]	[0.0983]
Observations	1,810	760	1,810	760	1,810	760
R^2	0.449	0.535	0.595	0.535	0.480	0.501

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

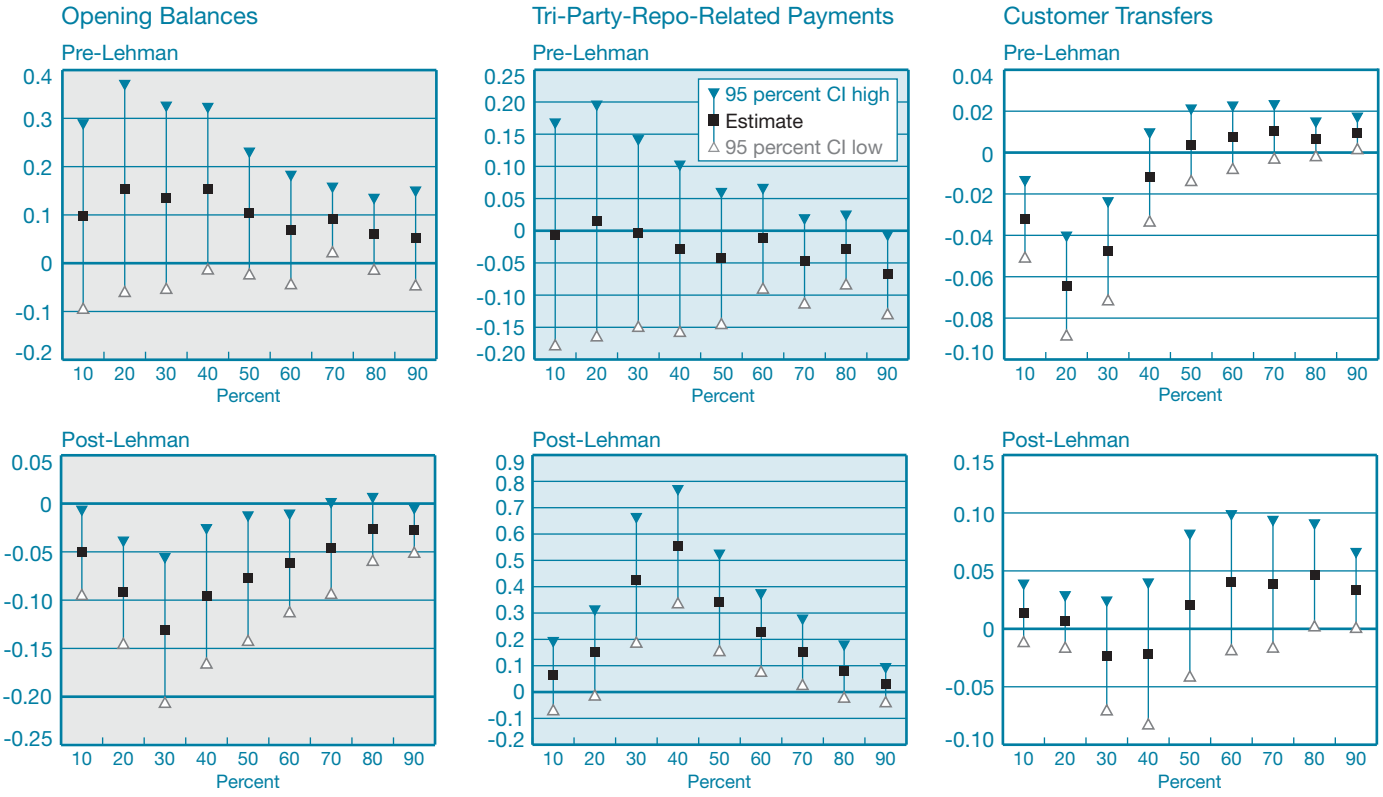
Notes: Standard errors are in brackets. HHI is the Herfindahl-Hirschmann Index. The eurodollar borrowing and lending values as well as the federal funds deliveries and returns are estimated variables; the precise quality of the estimates has not been determined.

**$p < 0.01$.

*$p < 0.05$.

Chart 4

Estimated Parameters and 95 Percent Confidence Intervals (CIs) from the Regressions for Pre- and Post-Lehman Sample Periods



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

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

Interestingly, this effect disappears in the post-Lehman period, suggesting that banks currently do not change their behavior depending on whether or not they have more payments on behalf of customers. One interpretation is that banks submit all their payments earlier, as the opportunity cost of funds is low.

The size of the effects can be better understood by reviewing Table 2. In the table, we again show the coefficient estimate and use asterisks to display its level of significance. Under each coefficient, we calculate the variable's mean estimated impact on the timing of Fedwire, holding all other variables constant, where the mean is taken over the sample period (so we multiply the mean change in the variable over the period by its coefficient estimate). Finally, at the bottom of the table, we present in each column the actual change in timing for that percentile of Fedwire value. First, consider the estimated effects of opening balances, shown in the first row.[25] The coefficients are significant at the 10 percent level, at least, for the 10th-60th percentiles as well as for the 90th percentile. For the 30th percentile, the effect of opening balances alone is to quicken the time of settlement by three hours and three minutes, while the actual time of settlement quickened by three hours and thirty-seven minutes. No other variable led to quicker payments by more than forty-five minutes. The HHI of the distribution of balances for the top 100 investors, shown in the second row, fell over the period, and this distribution of balances seemed to also affect payment timing considerably. For example, all else equal, this distribution of balances led payments to settle forty-three minutes earlier for the 30th percentile. Table 2 makes clear that both the level and distribution of balances had very large

[25] Note that the sum of time for the variables displayed in Table 2 need not equal the actual time change. Each time in a cell is equal to the estimated coefficient multiplied by the average daily change in that specific variable multiplied by the number of days in the sample period, holding all other variables equal to their sample means. Hence, because there is no "total effect" in the columns, they should not equal the actual time, even with estimation error. Nevertheless, they represent a way to measure the influence or explanatory power of the separate variables on timing.

Table 2

Estimated Coefficients and Effects on Timing for Post-Lehman Period

	Percentile								
Explanatory Variables	10	20	30	40	50	60	70	80	90
Change in sum of opening balances									
Coefficient	-0.0503*	-0.0917**	-0.1313**	-0.0956**	-0.0772*	-0.0613*	-0.0458	-0.0259	-0.0273*
Effect on timing	-1:10	-2:08	-3:03	-2:13	-1:47	-1:25	-1:04	-0:36	-0:38
Change in HHI of opening balances for top 100									
Coefficient	0.0181**	0.0176*	0.0337*	0.024*	0.0088	0.0162*	0.0071	0.0032	0.0055
Effect on timing	-0:23	-0:22	-0:43	-0:30	-0:11	-0:20	-0:09	-0:04	-0:07
Change in customer transfer value									
Coefficient	0.0141	0.0067	-0.0229	-0.0213	0.0204	0.0402	0.0389	0.0467*	0.0338*
Effect on timing	-0:07	-0:03	0:11	0:10	-0:10	-0:19	-0:19	-0:23	-0:16
Change in DTC final payout value									
Coefficient	0.6192	0.4665	-0.4688	0.5587	-0.2970	0.3278	-0.3297	-0.2230	-0.0958
Effect on timing	-0:01	0:00	0:00	-0:01	0:00	0:00	0:00	0:00	0:00
Change in eurodollar borrowing value									
Coefficient	0.0625**	0.0489	0.0211	0.0735	0.1178**	0.1030	0.0920	0.0848*	0.0589*
Effect on timing	-0:07	-0:05	-0:02	-0:08	-0:13	-0:12	-0:10	-0:11	-0:06
Change in eurodollar lending value									
Coefficient	0.0325	0.0390	0.0395	0.0806	0.0962	0.0862	0.0953	0.0794	0.0462
Effect on timing	-0:04	-0:05	-0:06	-0:12	-0:14	-0:12	-0:14	-0:11	-0:06
Change in length of an extension of Fedwire operating hours									
Coefficient	-0.0171	0.0453	0.0382	0.0688	0.0442	0.0260	0.0472*	0.042**	0.0384**
Effect on timing	0:04	-0:12	-0:10	-0:18	-0:11	-0:06	-0:12	-0:11	-0:10
Change in value of fed funds deliveries									
Coefficient	0.0041	-0.0914	-0.0972	-0.1549*	-0.0678	0.0189	0.0262	0.0108	0.0002
Effect on timing	0:00	0:10	0:11	0:18	0:08	-0:02	-0:03	-0:01	0:00
Change in deviation from fed funds target rate									
Coefficient	-1.7189	-9.6522*	-3.3020	-10.0093	-2.5737	-5.8609	0.9172	3.6761	0.8779
Effect on timing	0:01	0:05	0:01	0:05	0:01	0:03	0:00	-0:02	0:00
Change in value of fed funds returns									
Coefficient	-0.0594	-0.1259*	-0.1686*	-0.2491**	-0.2326**	-0.1463**	-0.1166**	-0.0504	-0.0240
Effect on timing	0:04	0:09	0:12	0:18	0:17	0:10	0:08	0:03	0:01
Change in final payouts, total value of payments									
Coefficient	-0.0344	-0.1068*	-0.1030	-0.0184	-0.0383	-0.0156	-0.0171	-0.0312	-0.0099
Effect on timing	-0:02	-0:06	-0:06	-0:01	-0:02	0:00	-0:01	-0:01	0:00
Change in HHI of value sent									
Coefficient	0.0445*	0.0977**	0.1585**	0.1478**	0.1172**	0.1103**	0.1128**	0.0705**	0.043*
Effect on timing	-0:02	-0:05	-0:08	-0:08	-0:06	-0:06	-0:06	-0:03	-0:02
Change in fed funds rate									
Coefficient	83.5125	1,085.895**	98.7725	63.6994	1,145.6930	653.774**	287.0886	-14.1479	-107.8923
Effect on timing	-0:02	-0:36	-0:03	-0:02	-0:38	-0:21	-0:09	0:00	0:03
Change in tri-party repo activity									
Coefficient	0.0634	0.1508	0.4257**	0.5536**	0.3406**	0.2273**	0.1544*	0.0810	0.0298
Effect on timing	-0:02	-0:06	-0:19	-0:25	-0:15	-0:10	-0:07	-0:03	-0:01
Change in total volume of Fedwire (nonsettlement)									
Coefficient	-0.0112	0.0078	0.0147	0.0178	-0.0080	-0.0242	-0.0153	-0.0222	-0.0153
Effect on timing	-0:04	0:02	0:05	0:06	-0:02	-0:08	-0:05	-0:08	-0:05
Actual change in timing (hours)	-1:47	-3:01	-3:37	-3:02	-2:10	-1:39	-0:57	-0:36	-0:24

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

Notes: "Coefficient" is in minutes/billions of dollars; "effect on timing" is in hours. HHI is the Herfindahl-Hirschmann Index. The eurodollar borrowing and lending values as well as the federal funds deliveries and returns are estimated variables; the precise quality of the estimates has not been determined.

**$p < 0.01$.
*$p < 0.05$.

impacts on the timing of Fedwire payments over the period, while other variables, with the exception of the decreased tri-party repo activity proxy, had relatively small effects.

All told, our statistical analysis is consistent with the hypothesis that the large increase in reserve balances induced banks to change their intraday liquidity management practices, as it eliminated much of the incentive that banks had to economize on funds by holding back payments. As a result, payments are being settled more quickly, which reduces delays and resolves uncertainty for businesses and individuals.

7. Payment System Risk and Monetary Policy

As mentioned in the introduction, in March 2008 the Board of Governors of the Federal Reserve System proposed revisions to its daylight overdraft policy that could improve settlement liquidity on Fedwire. The revisions followed a review of long-term developments, including the increased use of daylight overdrafts and increased Fedwire payments late in the day described in the previous section. The stated goal of the new policy was to reduce the credit risk borne by the Federal Reserve and bring forward the time of payment settlement.[26] The revisions included a new approach with a fee-based incentive for depository institutions to collateralize overdrafts. Under the new voluntary collateral regime, the pledging of collateral to cover daylight overdrafts would be encouraged by providing collateralized daylight overdrafts at a zero fee and by raising the fee for uncollateralized daylight overdrafts to 50 basis points.[27] The policy changes were approved in December 2008 and implemented March 24, 2011.

The new regime is now in place, but its goals were largely achieved prior to implementation, as documented in the previous sections and in Box 2. The amount of daylight overdrafts, and thus the size of the potential risk exposure of the Federal Reserve from this particular source, was lower in 2010 than at any time in more than twenty-five years. Payments are currently being submitted and settled much earlier than has been the case in the last ten years.

We did not find a consistent effect of this policy change in our regression analysis. Recall that the change went into effect on March 24, 2011, and we tried to model the change as a step function by adding a dummy variable to the estimation for that day and for some subsequent days. However, the sign of the dummy varied depending on which day we modeled the change as being effective, so we believe that the result is not robust to specification of the way that the policy was understood and put into effect within banks. Consequently, we cannot be sure how this policy change affected Fedwire timing.

Similar overall effects of increases in reserve balances have been observed in the settlement systems of other countries, as central banks have injected large amounts of reserves into their respective banking systems during the financial crisis. The residual demand for funds for payment purposes and the utilization of intraday credit facilities have diminished.[28] It is important to note that, while the increase in the supply of reserves arose as a response to the crisis, the Federal Reserve does not necessarily need to return to its previous monetary policy implementation framework as the need for accommodative monetary policy subsides. Indeed, because it can pay interest on excess reserves, the Federal Reserve can increase the policy rate without changing the supply of reserves if it needs to. As noted by Keister, Martin, and McAndrews (2008), the quantity of reserves and the interbank interest rate can be set independently within the operational framework of a so-called floor system.[29] This would allow the gains in settlement liquidity to be sustained while avoiding the need for banks to shuffle collateral back and forth to the Federal Reserve—potentially intraday—to satisfy the requirements of the new Payment System Risk policy.[30]

The amount of daylight overdrafts, and thus the size of the potential risk exposure of the Federal Reserve from this particular source, was lower in 2010 than at any time in more than twenty-five years.

[26] While reducing the credit risk of the Federal Reserve is an admirable goal in and of itself, one should keep in mind that part of any given risk reduction achieved may just reflect a shift of risk to other public authorities, such as the Federal Deposit Insurance Corporation.

[27] This refers to an annual rate based on a twenty-four-hour day.

[28] As a corollary, the overnight rate for reserves in many countries has been trading close to the rate at which the central bank remunerates reserves (see Bowman, Gagnon, and Leahy [2010]).

[29] When the quantity of reserves is large, the interbank interest rate will be close to the interest paid on reserves. Changing the interest on reserves allows the Federal Reserve to steer the interbank interest rate to the rate set by the FOMC for the conduct of monetary policy. At the same time, the quantity of reserves can be large enough to meet the needs of the banking system even in times of high stress and uncertainty.

[30] In addition, the increased level of reserves has not only improved the efficiency of the payment system, it has also—notwithstanding the issue of a soft floor—improved the precision by which monetary policy is being implemented in a subtle way by removing idiosyncratic variation in the effective federal funds rate observed previously across days depending on the amount of payments settled over Fedwire Funds (Hilton 2005).

The fact that monetary policy can be conducted with a large quantity of excess reserves is illustrated by the case of New Zealand. In 2006, the Reserve Bank of New Zealand implemented a new liquidity management regime that discontinued its intraday credit facility. Instead, the Bank chose to supply a significantly higher level of reserves sufficient to enable participants to settle payments efficiently (see Reserve Bank of New Zealand [2006]).[31] This change of policy was decided on and implemented before the start of the recent crisis and is intended to be permanent.

8. Conclusion

The dollar clearing and settlement system performed dependably during the financial crisis. This performance reflects decades of collaborative efforts to develop policies and robust operational procedures to maintain a resilient system serving the payment needs of the economy. The crisis led to some extreme levels of activity on the Fedwire Funds Service. Very high values and volumes of transactions were demanded at different times during and immediately preceding the crisis, but their settlement was managed smoothly.

The Federal Reserve's monetary policy response to expand its balance sheet starting in September 2008 and to remunerate interest on reserves starting on October 9, 2008, provided a natural experiment for the behavior of Fedwire Funds. In particular, economic theory had posited that ample, low-opportunity-cost reserves would reduce delays in the payment system that exist because of banks' incentives to avoid the cost of acquiring reserves for settlement purposes. Our review of bank behavior strongly supports this theory; as banks were endowed with larger reserve balances and as the opportunity cost of holding balances fell with the payment of interest on those balances, payments were made earlier and earlier during the day. It is unlikely that the time at which the underlying payment orders were submitted by banks and their customers changed dramatically; hence, it appears that payment delays decreased as reserves increased and their opportunity costs fell, just as theory would predict. Our regression analysis suggests that the higher level of balances accounts for the lion's share of the quickening of payment timing that has occurred since fall 2008.

In addition to the quickening of payments, the significant increase in reserve balances resulted in a dramatic reduction in the demand for daylight credit provided by the Federal Reserve. Because banks were no longer constrained by their lack of reserves, they did not need to draw on credit supplied by the Federal Reserve Banks when making a payment. This reduced level of daylight credit has the benefit of reducing the risk exposure of Federal Reserve Banks and the deposit insurance fund, whose losses—in the event of a failure of a bank that at the time of its failure had pledged loans and securities to the Federal Reserve Bank to collateralize a daylight overdraft—would be greater than the collateral available to pay other creditors of the bank. In a sense, under a high-reserve system as is currently the case, banks largely "prepay" for their liquidity needs by maintaining large reserve balances with which they can fund their outgoing payments. In that sense, provision of large reserve balances by the Federal Reserve Banks reduces the provision of daylight credit by them. By paying interest on reserves, maintaining these balances is made less expensive for banks, as they suffer little or no opportunity costs by holding reserves overnight and throughout the day.

This natural experiment of much higher reserve balances and the payment of interest on those balances has resulted in much faster payments being made with much less credit provided by the Federal Reserve. This outcome supports the objectives of the changes made by the Federal Reserve to its Payment System Risk policy in 2008, which were to speed payments and lessen the risk exposure to the Federal Reserve. The reduced delay of payments has large benefits to society, as shown by prior research. These observations lead us to suggest that maintaining high balances in bank accounts and paying interest on those balances, as described by Keister, Martin, and McAndrews (2008), can be a good way to capture the benefits of a more efficient and safe payment system.

[31] The change was necessitated by a growing scarcity of New Zealand government securities.

Appendix A: Data

Our primary 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 Fedwire Funds transfers between April 1997 and September 30, 2011. Our variables are defined below. As noted earlier, there are a number of calendar day dummies that are excluded from the regression results in Table 1. In both the pre- and post-Lehman regressions, the following calendar dummies have been suppressed from output (where necessary, these variables are defined below): *MBS P&I payment day*, *day after a holiday*, *day before a holiday, first of the month*, *last business day of quarter, last five business days of year*, *NYSE closed early*, *NYSE holiday/or closure*, *day of the week, maintenance period day.*

In addition, in the pre-Lehman regression results the following dummies have been suppressed: *CHIPS intraday finality, CHIPS extension, Opening hours moved to 21:00, CHIPS end-of-day settlement at 17:00, CLS Bank Opens, GSE Daylight Credit Removed.*

Definitions

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 (GSEs) and international institutions after the Federal Reserve's Payment 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.

Opening Balances are currently found using the IAS opening balances from DORPS (the Federal Reserve's Daylight Overdraft Reporting and Pricing System) daily activity data as the opening balance for each master account. Prior to the third quarter of 2010, the opening balance for each master account was calculated by adjusting the DORPS end-of-minute balance for the first minute of the operating day and for Fedwire Funds activity that occurred during that first minute.

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 Daylight Credit Removed is a binary variable equal to 1 on and after July 1, 2006. The Federal Reserve changed its Payment 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 payment 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 (MBS). These are generally the largest interest and redemption payment days of the month.

MBS P&I payment 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.

Opening hours moved to 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).

Maintenance period day is the day of the maintenance period that the date falls on.

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 transfers 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 (2000).

Fed funds returns is the total value of 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 (2000).

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).

Tri-party repo activity is defined as all payments larger than $1 billion that on a given day flow from (or to) one of the two clearing banks—JP Morgan Chase or Bank of New York Mellon—to (or from) one of two main custodial banks—State Street and Northern Trust—for the major cash providers (such as money market mutual funds) in the tri-party-repo market.

Eurodollar lending value is the estimated total value of eurodollar lending over Fedwire. Interbank loans were identified from Fedwire Funds transactions, as in Furfine (2000). Among these, loans with business function code "CTR" are labeled eurodollar transactions.

Eurodollar borrowing value is the estimated total value of eurodollar borrowing over Fedwire. Interbank loans were identified from Fedwire Funds transactions, as in Furfine (2000). Among these, loans with business function code "CTR" are labeled eurodollar transactions.

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-payment 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 close of operations.

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.

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

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 payment system was disrupted by the terrorist attacks of 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.

HHI of opening balances for top 100 is the Herfindahl-Hirschmann Index of the 100 participants in Fedwire with the largest opening balances.

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.

Appendix B: Settlement Institutions

CHIPS

CHIPS is a private, large-value U.S. dollar payment system owned and operated by the Clearing House Payments Company (Bank for International Settlements 2005). As of April 2007, CHIPS had 45 members and settled 329,000 transactions valued at $1.7 trillion per day (source: http://www.chips.org/about/pages/001221.php). 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 (Bank for International Settlements 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. 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 (source: http://www.cls-group.com/news/article.cfm?objectid=78EA8ED8-EC63-6345-C60967F0ECA7E5C3).

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 Eastern time—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 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).

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Michael J. Fleming and Neel Krishnan

The Microstructure of the TIPS Market

- The potential advantages of Treasury inflation-protected securities have yet to be fully realized, mainly because TIPS are not as liquid as nominal Treasury securities.
- The less liquid nature of TIPS may adversely affect prices relative to those of nominal securities, offsetting the benefits of TIPS having no inflation risk.
- A study of TIPS, using novel tick data from the interdealer market, provides new evidence on the liquidity of the securities and how liquidity differs from that of nominal securities.
- Analysis of various liquidity measures suggests that trading activity and the incidence of posted quotes may be better cross-sectional gauges of TIPS liquidity than bid-ask spreads or quoted depth.
- Differences in intraday trading patterns and announcement effects between TIPS and nominal securities likely reflect the different use, ownership, and cash-flow attributes of the securities.

1. Introduction

The introduction of Treasury inflation-protected securities (TIPS) in the United States in 1997 offered multiple potential benefits. First, the development was intended to offer investors a security that would enable them to hedge inflation. Second, by taking on the risk of inflation, the U.S. Treasury Department would not have to pay an inflation risk premium on its securities, thereby lowering its expected borrowing costs.[1] And third, the securities would provide a market-based measure of inflation expectations. It would be possible to gauge market expectations of inflation by comparing the yields on nominal Treasury securities with yields on inflation-protected securities of comparable maturities.

These potential benefits have not been fully realized, mainly because TIPS lack market liquidity compared with nominal securities.[2] This lack of liquidity is thought to result in TIPS yields having a liquidity premium relative to nominal securities, which offsets the inflation risk premium.[3] Similarly, the presence of a liquidity premium in TIPS yields complicates inferences of inflation expectations, particularly if the

[1] Campbell and Shiller (1997) estimate the inflation risk premium for a five-year nominal bond to be between 50 and 100 basis points. Buraschi and Jiltsov (2005) estimate the ten-year inflation risk premium to average 70 basis points.

[2] Market liquidity is defined here as the cost of executing a trade, which can depend on the trade's size, timing, venue, and counterparties. It is often gauged by various measures, including the bid-ask spread, the price impact of trades, quoted depth, and trading activity.

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premium changes over time. However, despite the importance of TIPS liquidity and the market's large size ($728 billion as of November 30, 2011), there has been virtually no quantitative evidence on the securities' liquidity.

The Federal Reserve publishes data on trading volume in Treasury securities that show that trading activity in TIPS is much lower than activity in nominal securities.[4] However, the Fed data are aggregated over the week and across all TIPS and provide information only on trading volume. So these data are unable to provide information about activity in particular TIPS, activity over the day or week, or other measures of TIPS liquidity, such as bid-ask spreads.

In this article, we use novel tick data from the interdealer market to characterize the liquidity of the market for TIPS.

In this article, we use novel tick data from the interdealer market to characterize the liquidity of the market for TIPS. We examine how trading activity breaks down across sectors, over securities' life cycles, and during the trading day. We also characterize liquidity using a variety of measures, including the bid-ask spread, the price impact of trades, quoted depth, and the incidence of two-sided quotes (that is, both a posted bid price and a posted offer price). Lastly, we analyze how major announcements affect TIPS activity and how the market adjusts to these announcements.

Our study relates most closely to the literature examining the microstructure of the nominal Treasury securities market, particularly studies that characterize the liquidity of the market (Fleming 1997), liquidity over securities' life cycles (Fleming 2002; Goldreich, Hanke, and Nath 2005; Barclay, Hendershott, and Kotz 2006), and the announcement adjustment process (Fleming and Remolona 1999; Balduzzi, Elton, and Green 2001; Fleming and Piazzesi 2005). Our work also relates to studies of announcement effects in the indexed markets, especially that of Beechey and Wright (2009), which also analyzes intraday data but is different in its focus on liquidity and the announcement adjustment process as opposed to price-level effects.

[3] D'Amico, Kim, and Wei (2008) estimate that the liquidity premium was about 1 percent in the early years of the TIPS program. Pflueger and Viceira (2011) find that the liquidity premium is around 40 to 70 basis points during normal times, but was more during the early years of TIPS and during the 2008-09 financial crisis. Sack and Elsasser (2004) argue that TIPS have not reduced the Treasury's financing costs because of several factors, including lower liquidity. Roush (2008) finds that TIPS have saved the government money, except during the early years of the program. Dudley, Roush, and Ezer (2009) show that the ex ante costs of TIPS issuance are about equal to the costs of nominal securities issuance.

[4] The data are available at http://www.newyorkfed.org/markets/primarydealers.html.

Examining the TIPS market, we find a marked difference in trading activity between on-the-run and off-the-run securities, as in the nominal market.[5] There is little difference in bid-ask spreads or quoted depth between on-the-run and off-the-run securities in the TIPS market, in contrast to the nominal market, but we do find a sharp difference in the incidence of posted quotes. Our findings suggest that trading activity and the incidence of posted quotes may be better cross-sectional measures of TIPS liquidity than bid-ask spreads or quoted depth.

We also find several differences between TIPS and nominal securities in intraday patterns and announcement effects, a result that likely reflects the different use, ownership, and cash flow attributes of the securities. In particular, we find that intraday TIPS activity peaks later in the morning than does intraday nominal activity. Moreover, TIPS auctions and consumer price index (CPI) announcements spur significant increases in TIPS trading activity, whereas employment reports do not.

Our study proceeds as follows. Section 2 discusses institutional features of the market for TIPS. In Section 3, we describe the tick data used in our empirical analysis. Section 4 reports our empirical results, including trading activity by sector, the liquidity of on-the-run and off-the-run securities, price impact estimates, intraday patterns in trading activity and liquidity, and the effects of major announcements. Section 5 concludes.

2. Market Structure

TIPS were introduced by the U.S. Treasury Department in January 1997. The principal of these securities is adjusted for inflation over time according to the non-seasonally-adjusted consumer price index for all urban consumers. The Treasury makes semiannual interest payments, which are a fixed percentage of the inflation-adjusted principal. The greater of the inflation-adjusted principal and the original principal is paid at maturity.

The Treasury currently issues TIPS with original maturities of five, ten, and thirty years. New five-year notes are issued once a year in April and then reopened in August and December (a reopening refers to the additional issuance of an outstanding security). New ten-year notes are issued in January and July; the January notes are reopened in March and May and the July notes in September and November. New thirty-year bonds are issued in February and reopened in June and October. Twenty-year bonds are not currently issued, but were between 2004 and 2009.[6]

[5] On-the-run securities are the most recently issued securities of a given maturity. Off-the-run securities are previously issued securities of a given maturity.

[6] In November 2009, the Treasury announced it was reintroducing the thirty-year inflation-indexed bond, which had previously been issued between 1998 and 2001. At the same time, it discontinued issuance of twenty-year bonds.

TIPS are sold in the primary market via single-price auctions, like nominal Treasury securities, and are disproportionately purchased at auction by domestic investment accounts. Analyzing Treasury Department data, Fleming (2007) finds that investment funds (which include mutual funds and hedge funds) account for 30.2 percent of TIPS sold at auction, but only 11.5 percent of nominal notes and bonds. In contrast, dealers and brokers account for 56.3 percent of TIPS sold at auction versus 63.6 percent of nominal notes and bonds, and foreign and international investors account for 8.2 percent of TIPS sold at auction and 21.1 percent of nominal notes and bonds.[7]

The secondary-market structure for TIPS is also similar to that for nominal Treasury securities. Trading takes place in a multiple-dealer over-the-counter market. The predominant market makers are the primary government securities dealers—those dealers who have a trading relationship with the Federal Reserve. The primary dealers trade with the Fed, their customers, and one another. Nearly all interdealer trading occurs via interdealer brokers.

Much of the activity in TIPS occurs on an outright cash-for-security basis, as is typical in the nominal market. However, a large share of TIPS activity occurs via "breakeven inflation" trades, whereby a particular inflation-indexed security is traded against a proportionate quantity of a particular nominal security.

Interdealer brokers provide dealers and other financial firms with electronic screens posting the best bid and offer prices provided by the dealers (either electronically or by phone) along with the associated quantities. Quotes are binding until and unless withdrawn. Dealers execute trades by contacting the brokers (either electronically or by phone), who post the resulting trade price and size on their screens. The brokers thus match buyers and sellers while ensuring anonymity, even after a trade. In compensation for their services, the brokers charge a fee.

An interesting feature of interdealer trading is the brokers' expandable limit order protocol. As explained in Boni and Leach (2004), a Treasury market trader whose order has been executed has the right of refusal to trade additional volume at the same price. In addition to such "workups," electronic systems allow traders to enter "iceberg" orders, whereby they can choose to show only part of the amount they are willing to trade. There is an incentive to display quantity, however, or at least enter it as hidden, because shown quantity takes priority over hidden quantity, and hidden quantity at a given price is executed against before a workup starts. Fleming and Mizrach (2009) find that hidden depth accounts for only a small share of total depth in the nominal market.

Much of the activity in TIPS occurs on an outright cash-for-security basis, as is typical in the nominal market. However, a large share of TIPS activity occurs via "breakeven inflation" trades, whereby a particular inflation-indexed security is traded against a proportionate quantity of a particular nominal security. Some TIPS are also traded via issue-for-issue switch trades, whereby a particular inflation-indexed security is traded against a proportionate quantity of another inflation-indexed security. In contrast to the nominal market, there is no organized futures market in TIPS.[8]

Data on outstanding ownership of TIPS are less comprehensive and more dispersed than information on buyers of securities at auction. Positions data reported to the Federal Reserve Bank of New York by the primary dealers show that the dealers' aggregate holdings of TIPS averaged $2.2 billion over the period March 2, 2005, to March 26, 2008 (a period closely corresponding to our sample period), and ranged from -$3.2 billion to $8.1 billion. In contrast, nominal Treasury note and bond holdings averaged -$125.6 billion over this period and ranged from -$178.6 billion to -$65.1 billion. Examining Securities and Exchange Commission 13F filings of institutional investment managers, Fleckenstein, Longstaff, and Lustig (2010) find that, in their sample, investment firms hold 21 percent of TIPS, versus only 5 percent of maturity-matched nominal bonds.

3. Data

Our analysis is based on proprietary tick data covering a subset of outright TIPS trading in the interdealer market. The database provides a record of trades and quotes for every inflation-indexed security outstanding. The trade data include price, quantity, and initiator (buyer or seller). The quote data include the best bid and offer prices and the total displayed quantities available at those prices (albeit not hidden quantities). Trades and quotes are time-stamped to the second.

[7] Some of the investment accounts may have foreign investors as clients, so these data may understate the proportion of funds coming from foreign accounts.

[8] Futures on five- and ten-year TIPS were listed on the Chicago Board of Trade between July 1997 and March 1998, and futures on the thirty-year bond were listed between April 1998 and June 2000.

Our sample period runs from March 4, 2005, to March 27, 2008. We retain 757 trading days in our analysis after excluding 32 holidays and 11 trading days for which data are missing for much of the day.[9] We retain trading days when data are available for all securities except the on-the-run ten-year note (244 days), the just-off-the-run ten-year note (29 days), and/or the on-the-run twenty-year bond (224 days). When on-the-run data are missing, we impute trading activity based on the securities' share of overall TIPS volume for days when data are not missing.[10]

Twenty-seven TIPS are outstanding over all or part of our sample period, comprising three five-year notes, seventeen ten-year notes, four twenty-year bonds, and three thirty-year bonds. Eleven of the twenty-seven TIPS were first issued during the sample period, comprising two five-year notes, six ten-year notes, and three twenty-year bonds. Two TIPS matured during the sample period, both ten-year notes.

Outright TIPS trading in our sample averages $563 million per day. In contrast, total interdealer trading in TIPS over this same period, as reported by the primary dealers (and including significant double-counting), averages $2,612 million per day. A comparison of these numbers suggests that the outright trading in our data set accounts for about 43 percent of interdealer TIPS trading.[11] Breakeven inflation trading and issue-for-issue switch trading likely account for much of the difference.[12]

Meanwhile, primary dealers reported nominal interdealer trading over the same period of $232 billion per day, on average. In other words, TIPS accounted for just over 1 percent of Treasury trading in the interdealer market during our sample period. In contrast, TIPS accounted for about 7 percent of marketable Treasury debt at the beginning of our sample period and 10 percent at the end.[13] The turnover ratio for TIPS is thus only about one-seventh to one-tenth the turnover ratio for nominal Treasury securities.

As noted, a feature of interdealer trading is the presence of workups and iceberg orders. Our data are processed in a manner that aggregates the outcome of each workup into a single trade (most microstructure studies of the nominal Treasury market process their data in the same manner). That is, any particular trade in our data set was conducted at a particular price, and at virtually the same time, but may have occurred in a sequence of steps, possibly with multiple counterparties. Based on this trade definition, we find an average daily number of sixty-seven trades over our sample and an average trade size of $8.7 million.[14]

4. Results

4.1 Trading Activity by Sector

Trading activity in TIPS is concentrated in notes, more so than might be implied by issuance amounts alone. In terms of daily trading volume by sector, $403 million (or 71.7 percent of all TIPS activity) occurs in ten-year notes, $110 million (19.5 percent) in five-year notes, and $50 million (8.9 percent) in twenty- and thirty-year bonds (Table 1). Bonds account for 25.9 percent of TIPS outstanding at the beginning of our sample period and 27.2 percent at the end. It follows that the turnover ratio for bonds is less than one-third that for notes.[15] A similar pattern is observed in the nominal market, likely reflecting greater hedging and speculative trading demand for notes.[16]

[9] In particular, we exclude days for which we are missing at least two consecutive hours of activity for all TIPS during New York trading hours (defined as 7:30 a.m. to 5 p.m. Eastern time). We also impose a filter to exclude data thought to be erroneous or unrepresentative by dropping prices that are less than $80 or more than $160 (per $100 par) and bid-ask spreads that are less than zero or more than $1 (per $100 par).

[10] We do not impute trading activity on days for which we are missing just-off-the-run note data. Such an imputation would not substantively affect our results given the relative inactivity of the note and the few days of data that are missing.

[11] It is somewhat problematic to compare these numbers directly, because our outright volume may include some trading by nonprimary dealers and because the interdealer numbers reported to the Fed (on the "FR 2004 Report") include significant double-counting. That said, discussions with market participants suggest that virtually all interdealer broker trading of TIPS is in fact between primary dealers. Assuming that only primary dealers trade on interdealer platforms, then our data coverage share equals our outright volume divided by one-half of FR 2004 interdealer broker volume. An additional minor complication is that our data exclude when-issued trading in new securities that occurs between the time a security is announced for auction and the time the security becomes the on-the-run security (which occurs the day following auction).

[12] A comparison with the FR 2004 data also shows that our data cover a declining share of trading activity over time. Additional data from the interdealer market suggest that this decline is explained by a shift in activity from outright trading to breakeven inflation trading and issue-for-issue switch trading.

[13] The percentages are calculated using the Treasury's Monthly Statement of the Public Debt from February 2005 and March 2008, available at http://www.treasurydirect.gov/govt/reports/pd/mspd/mspd.htm.

[14] We calculate trade size, quote size, and bid-ask spread averages by first averaging on a daily basis and then averaging across days. It follows that our reported average trade size need not (and does not) equal average daily volume divided by the average number of trades.

[15] Assuming a 26.5 percent issuance share, 8.9 percent divided by 26.5 percent equals 0.335, whereas (1-8.9 percent) divided by (1-26.5 percent) equals 1.239, which is 3.7 times larger than 0.335.

[16] Over the period March 2, 2005, to March 26, 2008, for example, dealers reported average daily trading volume of $125.4 billion in nominal notes and bonds with times to maturities of more than six but not more than eleven years, and $29.5 billion in nominal notes and bonds with times to maturities of more than eleven years.

Table 1
Trading Activity by Sector

Sector	Volume (Millions of Dollars, Par Value)	Number of Trades	Trade Size (Millions of Dollars, Par Value)
Five-year	109.6	10.8	9.6
Ten-year	403.2	45.0	9.4
Twenty-year	36.4	7.3	4.7
Thirty-year	13.4	4.2	3.3
Total	562.6	67.3	8.7

Source: Authors' calculations, based on proprietary data from the interdealer market.

Notes: The table reports average daily outright trading activity in TIPS over the March 4, 2005, to March 27, 2008, period. Sector buckets are defined according to securities' time to maturity at issuance.

Table 2
Trading Activity by Time to Maturity

Time to Maturity	Volume (Millions of Dollars, Par Value)	Number of Trades	Trade Size (Millions of Dollars, Par Value)
Zero to five years	314.4	30.5	10.3
Five to ten years	198.4	25.3	7.7
More than ten years	49.8	11.4	4.3
Total	562.6	67.3	8.7

Source: Authors' calculations, based on proprietary data from the interdealer market.

Notes: The table reports average daily outright trading activity in TIPS over the March 4, 2005, to March 27, 2008, period. The zero-to-five-year bracket includes all trading in on-the-run five-year notes, which sometimes have slightly more than five years to maturity; the five-to-ten-year bracket includes all trading in on-the-run ten-year notes, which sometimes have slightly more than ten years to maturity.

An alternative breakdown of volume, by time to maturity, shows that most activity occurs in TIPS maturing within five years (Table 2). Interestingly, only half of the volume in TIPS originally issued as ten-year notes occurs when the securities have more than five years to maturity (198.4/403.2 = 0.49). This finding suggests that some ten-year notes continue to be actively traded years after issuance.

The pattern for number of trades is similar to that for volume but less skewed toward notes, reflecting the latter's higher average trade size, which ranges from $9.6 million for five-year notes to $3.3 million for thirty-year bonds.

Table 3
Trading Activity by On-the-Run/Off-the-Run Status

Panel A: On-the-Run Securities

Sector	Volume (Millions of Dollars, Par Value)	Number of Trades	Trade Size (Millions of Dollars, Par Value)
Five-year	86.6	8.8	9.3
Ten-year	136.8	17.5	7.2
Twenty-year	29.7	6.0	4.6

Panel B: Off-the-Run Securities

Sector	Volume (Millions of Dollars, Par Value)	Number of Trades	Trade Size (Millions of Dollars, Par Value)
Five-year	27.2	2.4	10.8
Ten-year	22.0	2.3	9.9
Twenty-year	6.4	1.2	5.3

Source: Authors' calculations, based on proprietary data from the interdealer market.

Notes: The table reports average daily outright trading activity in on-the-run and off-the-run TIPS over the March 4, 2005, to March 27, 2008, period. Off-the-run averages are per security and are not aggregated across securities.

This pattern is also observed in the nominal market (see, for example, Fleming [2003] and Fleming and Mizrach [2009]) and probably reflects the higher duration and hence interest rate sensitivity of the longer-maturity instruments.

4.2 Liquidity of On-the-Run and Off-the-Run Securities

Trading activity for on-the-run TIPS is substantially higher than it is for off-the-run TIPS (Table 3). Daily trading in the on-the-run ten-year note averages $137 million, more than six times the average trading volume ($22 million) of individual off-the-run ten-year notes. The comparable ratio for the five-year note is just over 3 ($87 million versus $27 million), and it is somewhat less than 5 for the twenty-year bond ($30 million versus $6 million). Such on-the-run/off-the-run differentials are just as striking in the nominal market (see Fleming [2002]; Fabozzi and Fleming [2005]; Goldreich, Hanke, and Nath [2005]; and Barclay, Hendershott, and Kotz [2006]), reflecting

Chart 1A

Trading Volume around Off-the-Run Date

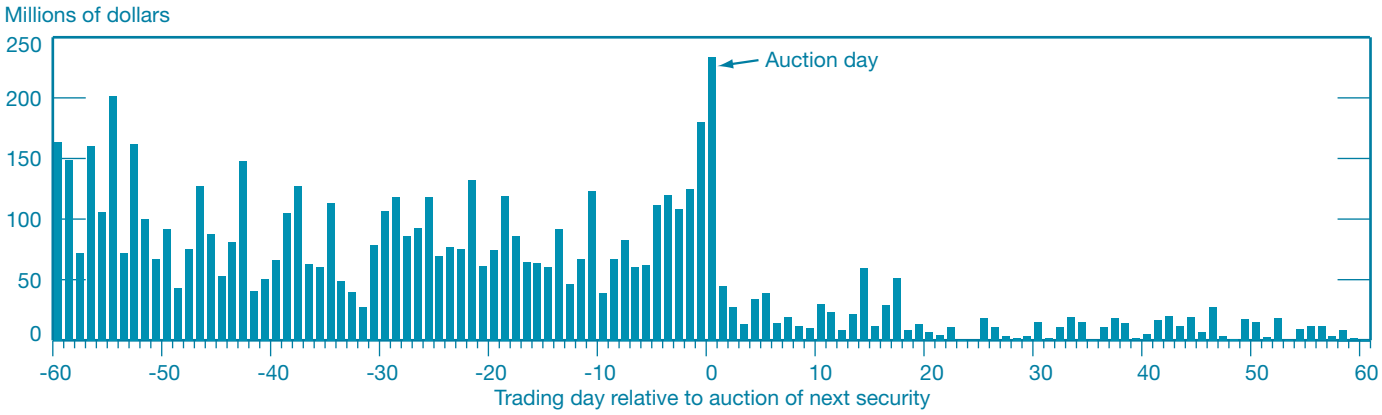
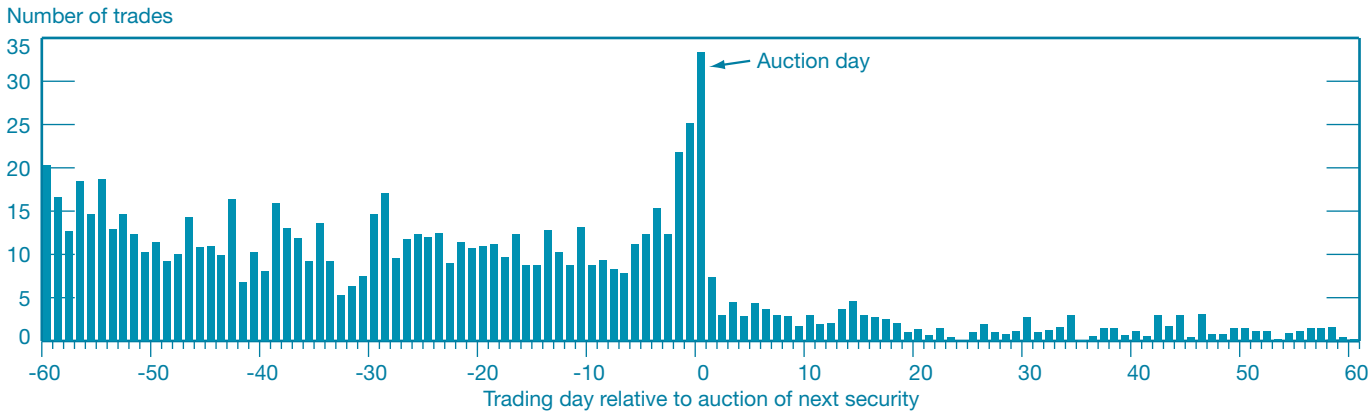


Chart 1B

Trading Frequency around Off-the-Run Date



Source: Authors' calculations, based on proprietary data from the interdealer market.

Note: The charts plot average trading activity of ten TIPS (two five-year notes, five ten-year notes, and three twenty-year bonds) that went off the run during the sample period by trading day relative to the auction day of the next security within each security's sector.

a concentration of liquidity in just a few securities and also in those securities that tend to have the largest floating supplies.[17]

While there is a similar on-the-run/off-the-run divergence in daily trading frequency, such a pattern is not evident in trade size. In fact, average trade sizes are actually slightly higher for off-the-run TIPS. For the ten-year note, for example, average on-the-run trade size is $7.2 million, whereas average off-the-run trade size is $9.9 million. Barclay, Hendershott, and Kotz (2006) uncover a similar pattern in the nominal market, whereas Goldreich, Hanke, and Nath (2005) report smaller trade sizes for off-the-run securities. One explanation for our finding is that there is a compositional change in the type of trades executed when a security goes off the run, with a proportional reduction in frequent, small speculative trades, resulting in a higher trade size despite lower overall activity.[18]

The change in trading volume that occurs when a security goes off the run is quite abrupt in the TIPS market (Chart 1A). Trading volume averages $92 million per day in the last sixty days before a security goes off the run and $14 million in the first sixty days it is off the run. Moreover, average daily volume plunges from $234 million on the last day a security is on the

[17] On-the-run securities tend to have the largest floating supplies because Treasury securities tend to be increasingly owned by buy-and-hold investors as the time since issuance passes.

[18] Barclay, Hendershott, and Kotz (2006) find that interdealer trading in the Treasury market migrates from electronic brokers to voice brokers when securities go off the run, which could be related to a compositional change in the type of trading.

Table 4

Quote Measures by On-the-Run/Off-the-Run Status and Sector

Panel A: On-the-Run Securities

Sector	Bid-Ask Spread	Quote Size	Quote Incidence
Five-year	2.6	1.3	40.7
Ten-year	3.3	1.3	57.8
Twenty-year	7.3	1.1	26.7

Panel B: Off-the-Run Securities

Sector	Bid-Ask Spread	Quote Size	Quote Incidence
Five-year	2.6	1.1	18.6
Ten-year	2.7	1.3	17.2
Twenty-year	7.3	1.1	7.3

Source: Authors' calculations, based on proprietary data from the interdealer market.

Notes: The table reports average daily quote statistics in TIPS over the March 4, 2005, to March 27, 2008, period. The quote incidence measure gauges the percentage of time (on trading days between 7:30 a.m. and 5 p.m.) that there is a two-sided quote in a security (that is, both a posted bid price and a posted offer price). Bid-ask spreads are in 32nds of a point (a point equals 1 percent of par); quote sizes are in millions of dollars, par value.

run (that is, the auction day of the next security) to $45 million the day after. The pattern is even more striking when examined in terms of trading frequency (Chart 1B). Similar patterns for nominal Treasury securities are reported by Fleming (2002), Goldreich, Hanke, and Nath (2005), and Barclay, Hendershott, and Kotz (2006).

Despite the sharp volume differential between on-the-run and off-the-run TIPS, there is virtually no difference in average bid-ask spreads or quoted depth between on-the-run and off-the-run securities (Table 4). Quoted bid-ask spreads average 2½ to 3½ 32nds of a point for on-the-run and off-the-run five- and ten-year notes (a point equals 1 percent of par), and about 7 32nds for twenty-year bonds. The average quantity available at the inside bid and offer prices is only somewhat higher than the minimum quote size of $1 million for on-the-run and off-the-run TIPS in all sectors. Such results differ markedly from those in the nominal market, where studies find a sharp widening of bid-ask spreads and a decrease in quoted depth when securities go off the run (Fleming 2002; Goldreich, Hanke, and Nath 2005).

A notable aspect of average quote sizes is that they are dwarfed by average trade sizes. For example, the average quote size for the on-the-run ten-year note is $1.3 million, but the average trade size for the note is $7.2 million. The most important reason for the discrepancy is probably the "workup" process, whereby the initial buyer and seller as well as subsequent buyers and sellers can agree to trade additional amounts at the same price. Trade sizes reflect the total amounts traded in a single workup. Studies of the nominal market have found average trade sizes to exceed average quote sizes, but to a lesser degree and only for bills and off-the-run notes, not for on-the-run notes (Fleming 2002, 2003; Goldreich, Hanke, and Nath 2005).

The results, taken together, highlight the limitations of the bid-ask spread and quoted depth as liquidity measures in the TIPS market.

An additional reason for the discrepancy between quote sizes and trade sizes is that the quote sizes reflect only *shown* amounts. Dealers can enter iceberg orders, however, whereby they commit to buying or selling a certain quantity at a certain price, with part of the quantity visible on the broker screen and the remainder hidden. Hidden amounts become visible to the market incrementally if and only if the initial shown amount is traded against. Recall that hidden depth accounts for only a small share of total depth in the nominal market.

While bid-ask spreads and quoted depth are similar for on-the-run and off-the-run securities, "quote incidence" is markedly higher for on-the-run securities. Quote incidence gauges the percentage of time in which there are two-sided quotes in a security (that is, both a posted bid price and a posted offer price). This proportion averages close to 60 percent for the on-the-run ten-year note (during New York trading hours, 7:30 a.m. to 5 p.m. Eastern time), but only about 15 percent for any given off-the-run ten-year note. That is, for off-the-run ten-year notes, there is a one-sided quote, or no quote, about 85 percent of the time.

The results, taken together, highlight the limitations of the bid-ask spread and quoted depth as liquidity measures in the TIPS market. Such spreads and depth are similar for on-the-run and off-the-run securities, although they are available much less frequently for the latter. That is, measured liquidity among TIPS in a particular sector largely varies across the quote incidence dimension as opposed to the spread or quoted depth dimensions. In contrast, liquidity is found to vary across all of these dimensions in the nominal market.

4.3 Price Impact of Trades

We assess the price impact of trades in the TIPS market by relating price changes to measures of net order flow, defined as purchases minus sales. (While every trade involves a purchase and sale, the buy or sell in such an analysis is defined by the side that initiates a trade.) Price impact is an important measure of liquidity because it gauges the extent to which prices move as a result of trading. The analysis is also useful for understanding the degree to which information relevant to TIPS prices is revealed through TIPS trading (versus through public information or trading in other markets).

Our particular analysis regresses daily price changes for the on-the-run securities of five-, ten-, and twenty-year maturities on net order flow in various sectors.[19] As in Brandt and Kavajecz (2004), the use of daily data mitigates high-frequency microstructure effects and allows us to more cleanly estimate the more permanent price impact of trades.[20] We estimate net order flow based on trading frequency, as in Fleming (2003), but describe robustness results with net order flow based on trading volume, as in Brandt and Kavajecz (2004).

Our results show the expected positive relationship between net order flow and price change: Nearly all coefficients are statistically significant at the 1 percent level (Table 5). Like Brandt and Kavajecz (2004), we find that order flow across the curve affects prices, so while the ten-year note price is affected most by order flow in securities with a remaining maturity of more than ten years, it is also affected by order flow in shorter-term securities.[21] The adjusted R^2 measures are close to 20 percent for all three price series, indicating that 20 percent of TIPS price variation can be explained by TIPS order flow alone.

We also estimate price impact by employing other model specifications. If net order flow is defined using trading volume instead of trading frequency, all of the coefficients are statistically significant at the 1 percent level, but the adjusted R^2s range only from 8 to 10 percent. If we add net volume to our model with the net number of trades, none of the volume coefficients is statistically significant at the 10 percent level either individually or as a group. Lastly, if we estimate the effects of buys and sells separately, we cannot reject the null hypothesis that the effects are equal in magnitude for order flow in a given sector for any of the price series.

[19] Price changes are calculated using closing (5 p.m.) prices from Bloomberg and net order flow is measured over the interval running from 6 p.m. one day to 5 p.m. the next day. Our analysis is limited to the 395 trading days in our sample for which we are not missing data for any on-the-run securities (although results are quite similar if we look at all 757 days in our sample). We are careful to never measure price changes across securities (so the first day a security is on the run, we estimate the daily price change from the previous day's price for that security and not from the price of the security that was on the run at the time).

[20] A higher-frequency analysis is also somewhat problematic because of the low frequency of TIPS trading. It is for this reason that we estimate price impact only for on-the-run securities and that we do not assess price impact when we examine announcement effects.

[21] For all three price series, the shorter-term order flow coefficients are insignificantly different from one another at the 10 percent level, but significantly different from the long-term order flow coefficient at the 1 percent level. In the nominal market, in contrast, Brandt and Kavajecz (2004) find order flow in the two- to five-year sector as being particularly important in explaining yield changes across the curve.

Table 5
Price Impact of Trades

Independent Variable: Net Order Flow	Dependent Variable: Price Change		
	Five-Year	Ten-Year	Twenty-Year
Constant	0.65*	1.39**	1.93**
	(0.36)	(0.60)	(0.89)
Zero to five years	0.18***	0.30***	0.34***
	(0.04)	(0.07)	(0.11)
Five to ten years	0.10	0.26***	0.51***
	(0.06)	(0.10)	(0.15)
More than ten years	0.47***	0.87***	1.45***
	(0.07)	(0.12)	(0.20)
Memo:			
Adjusted R^2 (percent)	18.1	20.9	19.7
Number of observations	395	395	395

Source: Authors' calculations, based on proprietary data from the interdealer market.

Notes: The table reports results from least squares regressions of daily price changes on net order flow over the March 4, 2005, to March 27, 2008, period. Price changes are measured for the on-the-run securities in 32nds of a point. Net order flow is measured as the daily net number of trades for all securities within a given time-to-maturity bucket. Coefficients are reported with heteroskedasticity- and autocorrelation-consistent (Newey-West) standard errors in parentheses.

***Statistically significant at the 1 percent level.
**Statistically significant at the 5 percent level.
*Statistically significant at the 10 percent level.

4.4 Intraday Patterns

Intraday trading volume in TIPS is concentrated in the mid-to-late morning, roughly 9 a.m. to 11:30 a.m., and again in the afternoon right before 3 p.m. (Chart 2A).[22] Trading frequency shows a similar pattern, whereas average trade size is more

[22] While the intraday patterns are presented only for the on-the-run ten-year note, results are qualitatively similar for other on-the-run securities.

stable across the day (Charts 2B and 2C). The morning pattern for TIPS diverges from that for the nominal market, where activity peaks between 8:30 a.m. and 9 a.m. (see, for example, Fleming [1997] and Fleming and Mizrach [2009]). The morning peak in the nominal market is largely explained by the release of several important macroeconomic announcements at 8:30 a.m. (Fleming and Remolona 1999).

The later-morning peak in activity in the indexed market may reflect differences in use and ownership between nominal and inflation-indexed securities. In particular, TIPS activity is

Chart 2A
Intraday Trading Volume of On-the-Run Ten-Year Note

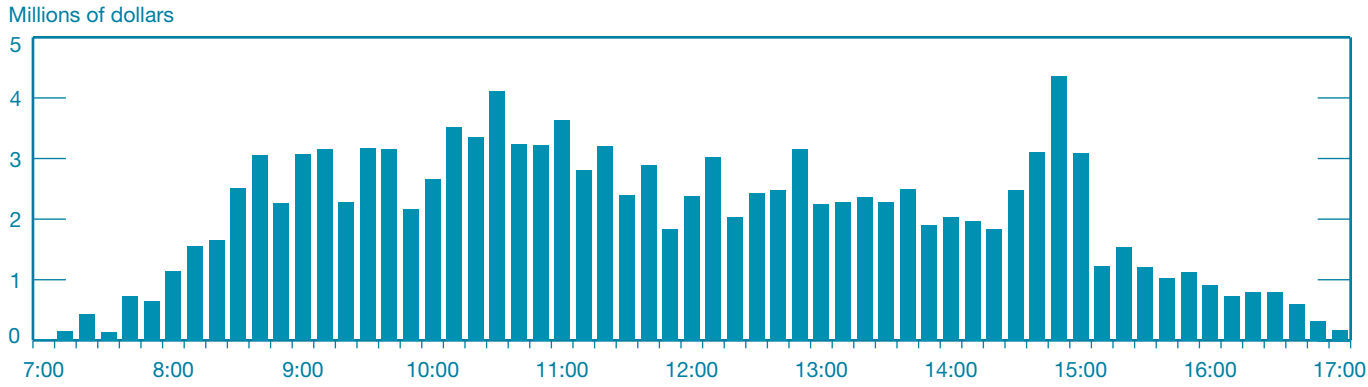


Chart 2B
Intraday Trading Frequency of On-the-Run Ten-Year Note

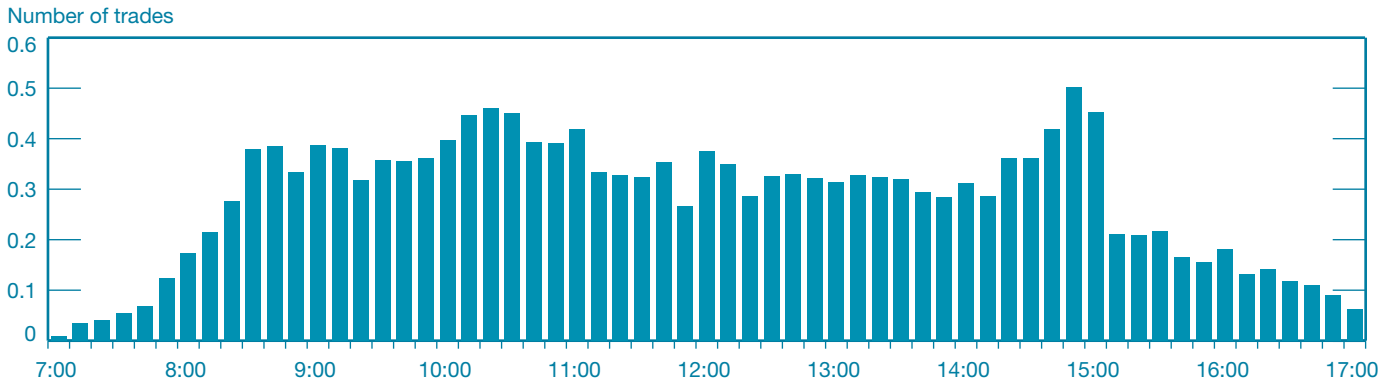


Chart 2C
Intraday Trade Size of On-the-Run Ten-Year Note

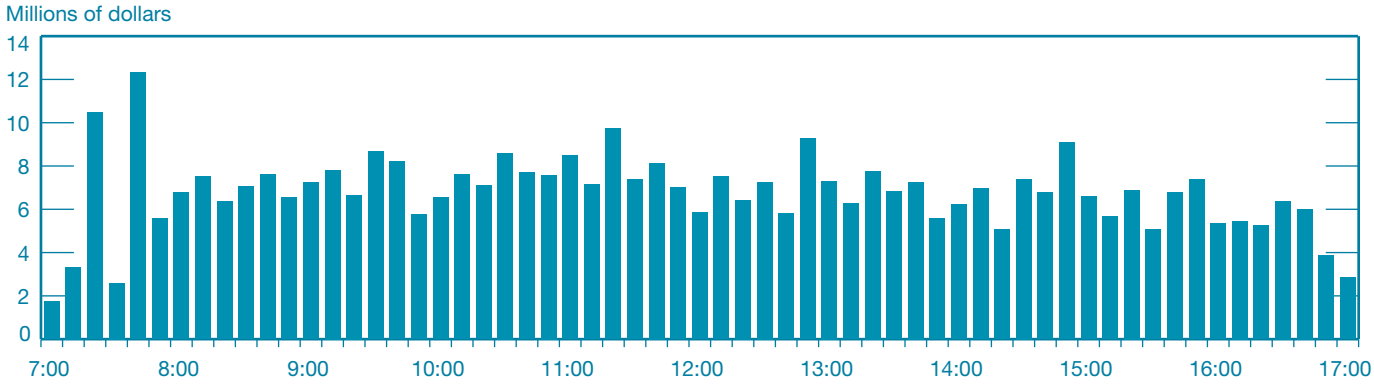


Chart 2D

Intraday Bid-Ask Spread of On-the-Run Ten-Year Note

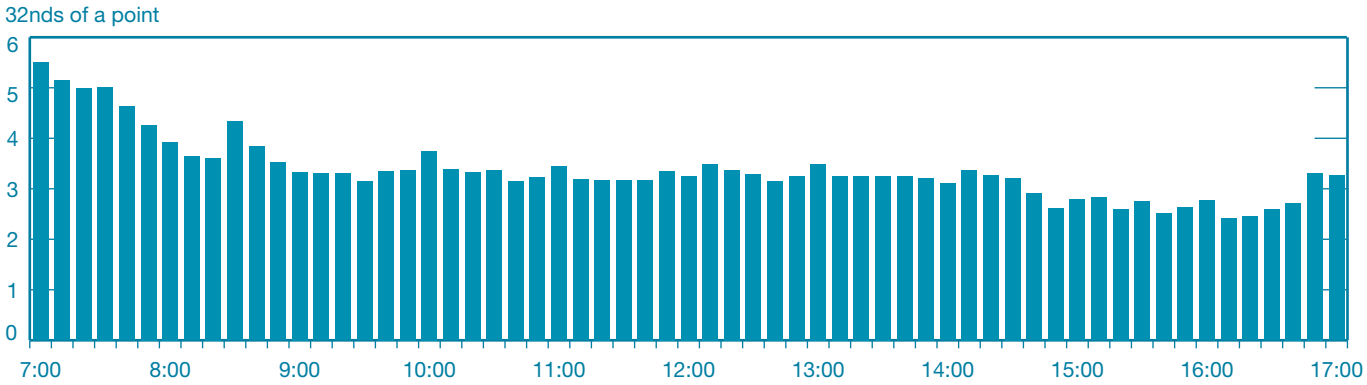


Chart 2E

Intraday Price Volatility of On-the-Run Ten-Year Note

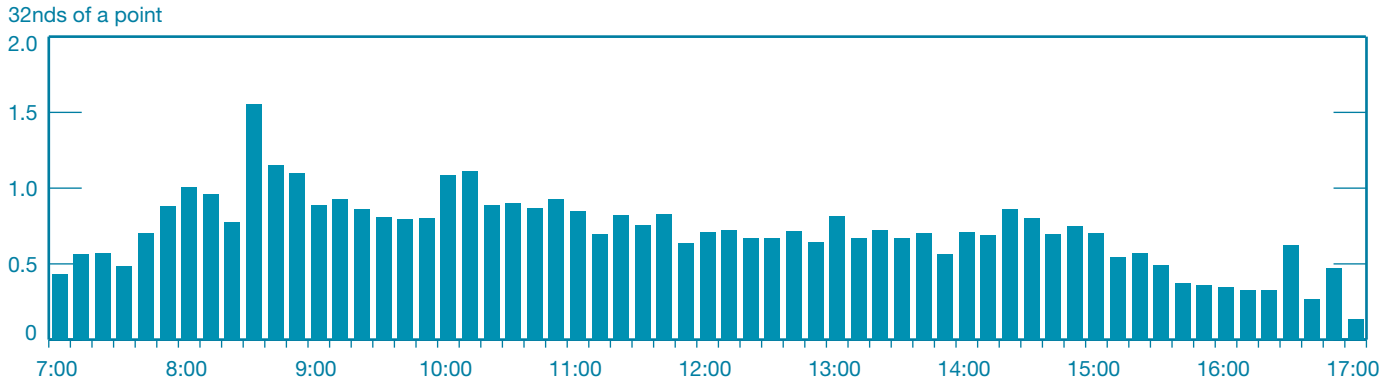
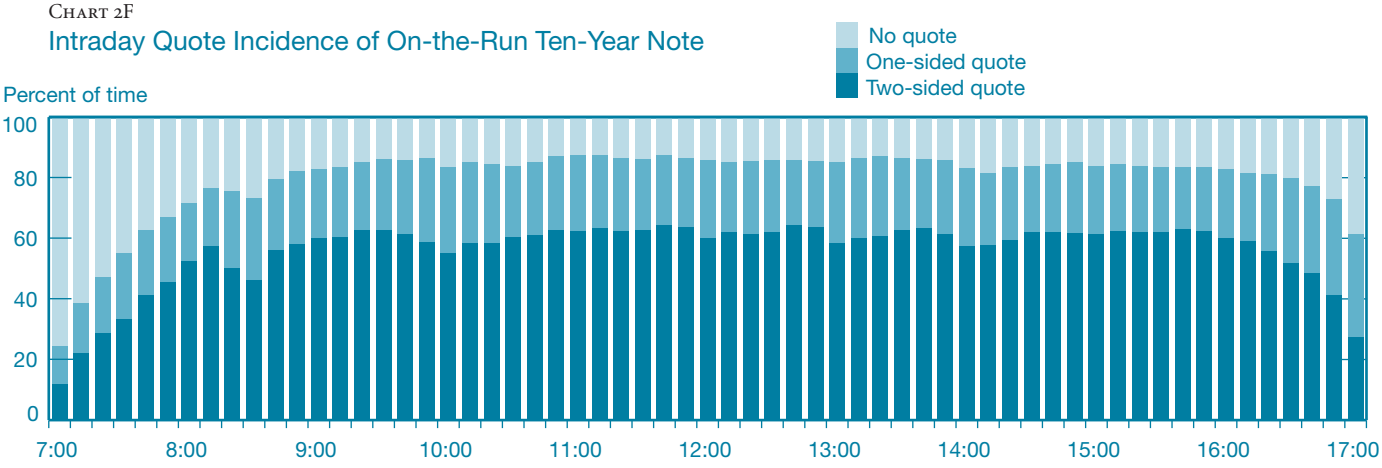


Chart 2F

Intraday Quote Incidence of On-the-Run Ten-Year Note



Source: Authors' calculations, based on proprietary data from the interdealer market.

Notes: The charts plot average levels of trading activity, liquidity, and price volatility for the on-the-run ten-year TIPS for each ten-minute interval over the trading day. The average bid-ask spread and trade size are first calculated for each ten-minute interval before averaging across days. Price volatility is calculated as the average absolute price change for each ten-minute interval. Times noted are interval start times.

probably driven more by institutional trading demands that are best met when the market is less volatile and trading costs are lower (that is, after the 8:30 a.m. and occasional 9:15 a.m. and 10 a.m. announcements). In contrast, speculative and hedging considerations may dominate in the nominal market, causing activity to peak shortly after announcements, despite the high volatility and trading costs.

The peak before 3 p.m. also occurs in the nominal market but is more pronounced for TIPS, which perhaps again reflects differences in use and ownership between nominal and inflation-indexed securities. In particular, TIPS activity is probably driven more by institutional investors, who are more likely to be managing relative to a benchmark and who therefore want to trade as close to 3 p.m. as possible to minimize tracking error (fixed-income indexes are priced at 3 p.m.). Consistent with this argument, we find that TIPS trading volume is particularly high on the last trading day of the month, when fixed-income indexes are rebalanced, and that the peak in trading before 3 p.m. is especially high on that day.

[Compared with activity in the nominal market,] TIPS activity is probably driven more by institutional trading demands that are best met when the market is less volatile and trading costs are lower.

One other difference in intraday activity between TIPS and nominal securities is that there is virtually no overnight trading of TIPS: Less than 0.1 percent of TIPS trading volume occurs outside of New York trading hours. In contrast, analyses of the nominal market find that about 5 percent of interdealer trading occurs outside New York hours (Fleming 1997; Fleming and Mizrach 2009). The dearth of overnight trading is consistent with the hypothesis that TIPS trading is driven more by lower-frequency institutional trading demands as opposed to higher-frequency hedging and speculative demands. It is consistent also with the evidence that foreign investors purchase TIPS to a lesser degree than they do nominal securities.

Bid-ask spreads for TIPS are at their widest at the beginning of the trading day, when trading is sparse (Chart 2D). Thereafter, they narrow sharply as trading volume picks up and then widen again at the end of the day as trading tapers off. Increases in the spread at 8:30 a.m. and 10 a.m. correspond to increases in price volatility (Chart 2E), which are likely explained by the release of macroeconomic announcements at those times. The pattern of bid-ask spreads is similar to that observed for nominal Treasury securities (Fleming and Remolona 1999). The volatility pattern is also similar to that in the nominal market (Fleming 1997; Fleming and Remolona 1999), albeit with less pronounced spikes at 8:30 a.m. and 10 a.m.

The intraday pattern of quote incidence for TIPS is also consistent with what one might expect given the pattern of trading activity (Chart 2F). That is, a two-sided quote is least likely to be posted at the beginning and end of the trading day, when trading activity is light.

4.5 Announcement Effects at a Daily Level

We first analyze the effects of announcements on trading activity at a daily level. At a daily frequency, announcement effects are easiest to discern for trading activity, as opposed to price volatility or bid-ask spreads, because such announcements have larger, more persistent effects on trading activity (Fleming and Remolona 1999; Balduzzi, Elton, and Green 2001).

The announcements we consider are the CPI release and the employment report (both produced by the Bureau of Labor Statistics), the Federal Open Market Committee (FOMC) post-meeting announcement, and TIPS auction results. The employment report is widely found to be the most important scheduled macroeconomic announcement in the nominal market (Ederington and Lee 1993; Fleming and Remolona 1997; Bollerslev, Cai, and Song 2000; Balduzzi, Elton, and Green 2001; Huang, Cai, and Wang 2002). FOMC announcements are also quite important (Kuttner 2001; Gürkaynak, Sack, and Swanson 2005; Fleming and Piazzesi 2005). CPI releases are also influential, but may be particularly so for TIPS given that cash flows on TIPS are tied to them. Auction results are often not included in announcement studies, but have been found to be associated with some of the sharpest price moves in the TIPS market (Dupont and Sack 1999).

We analyze announcement effects on trading activity by regressing daily trading volume and daily trading frequency on dummy variables for our various announcements.[23] The results show that TIPS trading activity is nearly twice as high on TIPS auction days as on other days and also significantly higher on CPI and, to a lesser extent, FOMC announcement days (Charts 3A and 3B). On TIPS auction days, trading volume averages $975 million, versus $527 million on nonannouncement days (days without a TIPS auction or a CPI

[23] We consider all CPI and employment report announcements in our sample, all TIPS auctions (for new securities or reopenings of existing securities), and FOMC announcements after scheduled meetings (but not unscheduled meetings).

Chart 3A

Trading Volume on Announcement and Nonannouncement Days

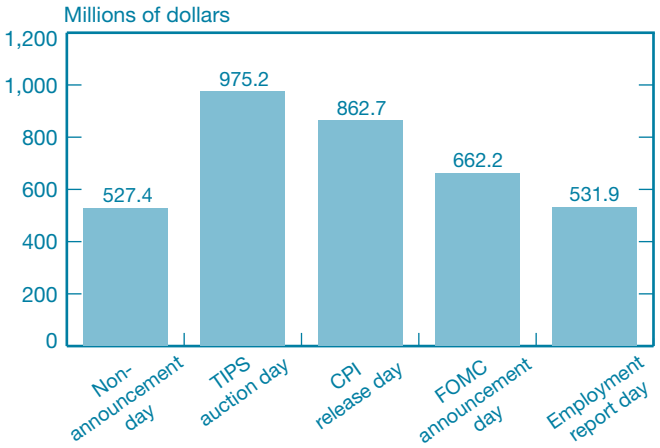
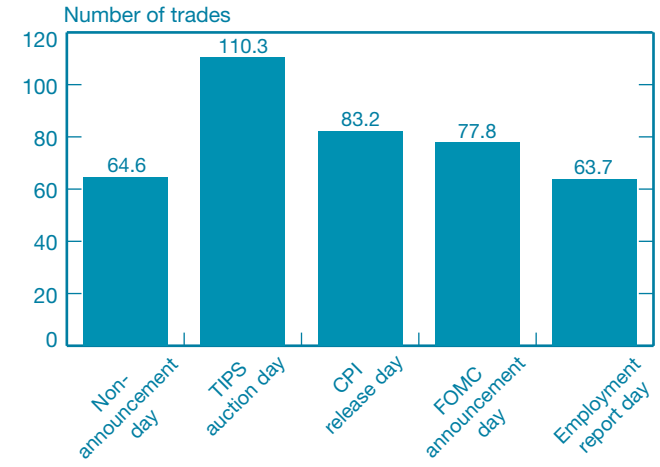


Chart 3B

Trading Frequency on Announcement and Nonannouncement Days



Source: Authors' calculations, based on proprietary data from the interdealer market.

Notes: The charts plot the coefficients from regressions of daily trading activity in TIPS on dummy variables for TIPS auction days, CPI release days, FOMC announcement days, employment report days, and nonannouncement days (days without any of the aforementioned announcements). By construction, such coefficients equal the average level of trading activity in TIPS on the various announcement days (controlling for other announcements) and nonannouncement days.

release, employment report, or FOMC announcement). On CPI and FOMC announcement days, trading volume averages $863 million and $662 million, respectively. On employment report announcement days, in contrast, volume is insignificantly different from volume on nonannouncement days. The announcement effects are similar when controlling for the day of the week.[24]

These announcement effects are somewhat different from those found in the nominal market. Recall that the employment report is widely found to be highly important in the nominal market and to spur significant increases in trading activity (Fleming and Remolona 1997; Balduzzi, Elton, and Green 2001), but it appears to have little effect on TIPS activity at the daily level. The CPI announcement is also found to elicit increases in activity in the nominal market, and large effects for TIPS in particular are not surprising. The modest increases in activity on FOMC days are also consistent with evidence for the nominal market (Fleming and Piazzesi 2005). The auction results are the most striking, and they are consistent with the limited evidence available from the nominal market.[25]

4.6 High-Frequency Analysis of Announcement Effects

A high-frequency analysis allows us to discern the effects of announcements more precisely and thus better ascertain how the market adjusts to announcements. The particular variables we consider, which are commonly examined in announcement studies in the nominal market, are price volatility, trading frequency, and bid-ask spread. As in nominal market studies, we conduct the analysis by comparing the intraday behavior of these variables on announcement days with the behavior on nonannouncement days. Such an analysis allows for a clean examination of announcement effects, controlling for the typical intraday pattern, because announcements of a given type are released at essentially the same time on announcement days. CPI and employment report announcements are released at 8:30 a.m., auction results within a few minutes of the 1 p.m. auction close, and FOMC post-meeting announcements at around 2:15 p.m.

Our findings across announcements are generally consistent with those of other studies of the nominal market. According to those studies, price volatility spikes at the time of a major

[24] There are pronounced day-of-week effects in trading activity in the TIPS market, as there are in the nominal market. In particular, trading volume is lowest on Monday, averaging $424 million. It is highest on Wednesday and Thursday, averaging $615 million and $658 million, respectively. On Tuesday and Friday, volume is somewhere in between, at $552 million and $546 million, respectively. These patterns remain when controlling for the announcements examined here.

[25] The effects of auction announcements on the nominal market have not been examined in detail, but Fleming and Remolona (1997) and Huang, Cai, and Wang (2002) do find an immediate increase in trading activity after announcements of auction results. A related literature examines market behavior around auctions (for example, Nyborg and Sundaresan [1996]), but it is not generally concerned with the effects of auctions on outstanding securities.

Chart 4A

Intraday Price Volatility on CPI and Nonannouncement Days

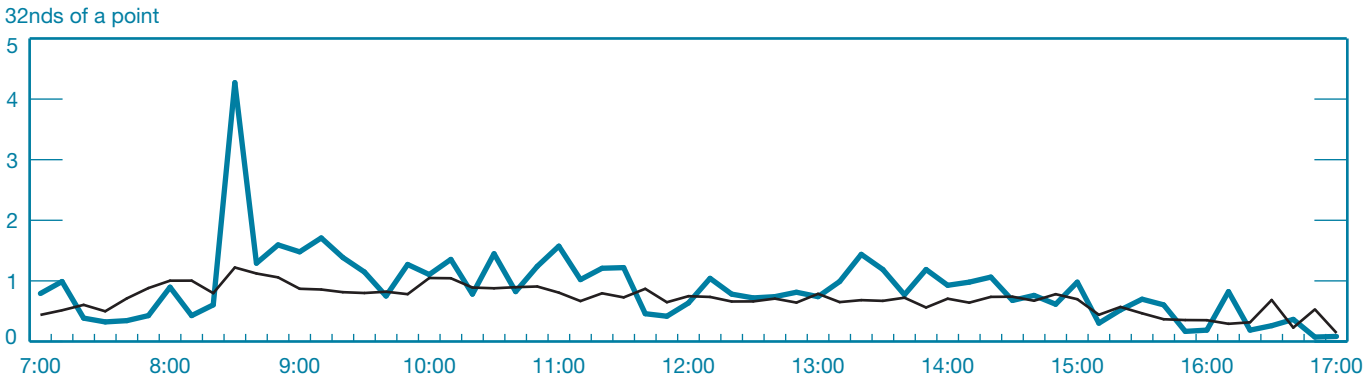


Chart 4B

Intraday Trading Frequency on CPI and Nonannouncement Days

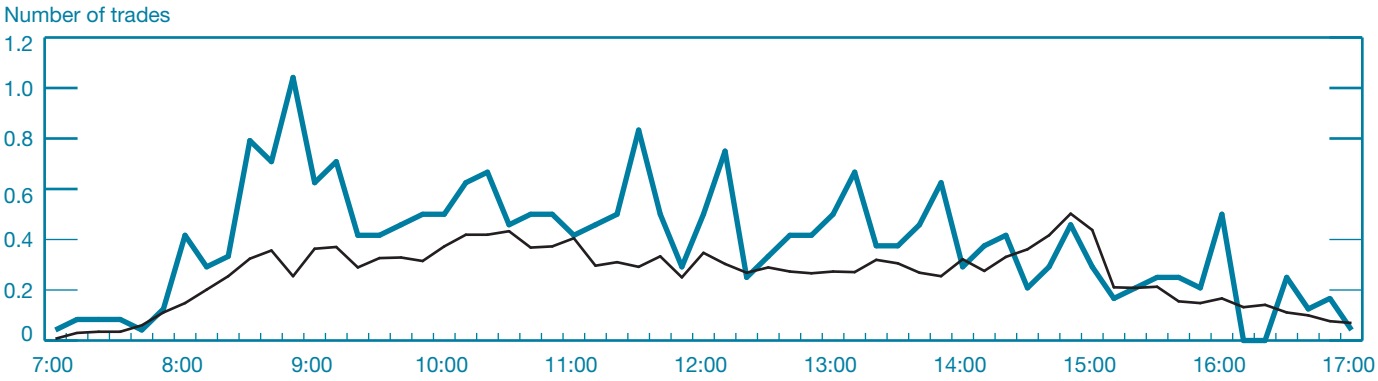
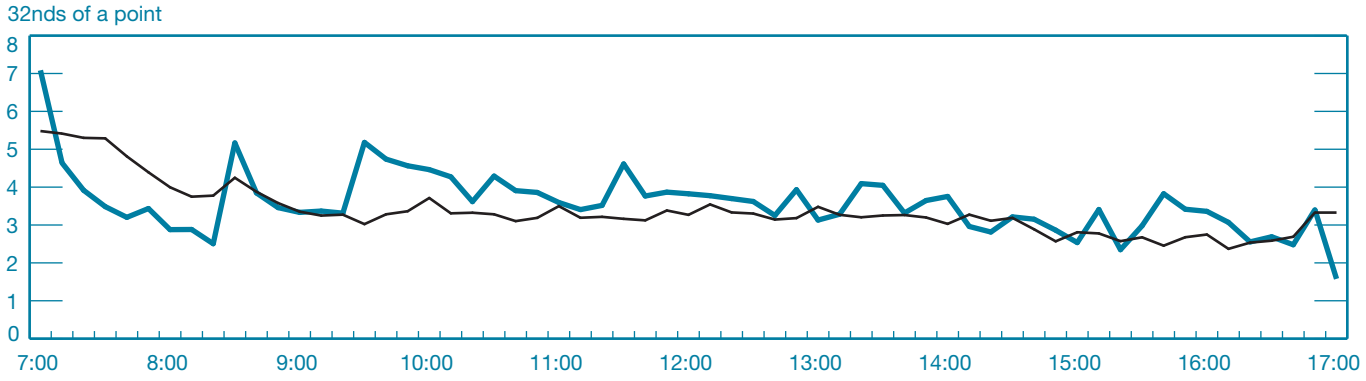


Chart 4C

Intraday Bid-Ask Spread on CPI and Nonannouncement Days



Source: Authors' calculations, based on proprietary data from the interdealer market.

Notes: The charts plot intraday patterns of price volatility, trading frequency, and bid-ask spreads for the on-the-run ten-year TIPS on CPI announcement days (in blue) and nonannouncement days (in black). Times noted are interval start times.

Chart 5A

Intraday Price Volatility on Employment Report and Nonannouncement Days

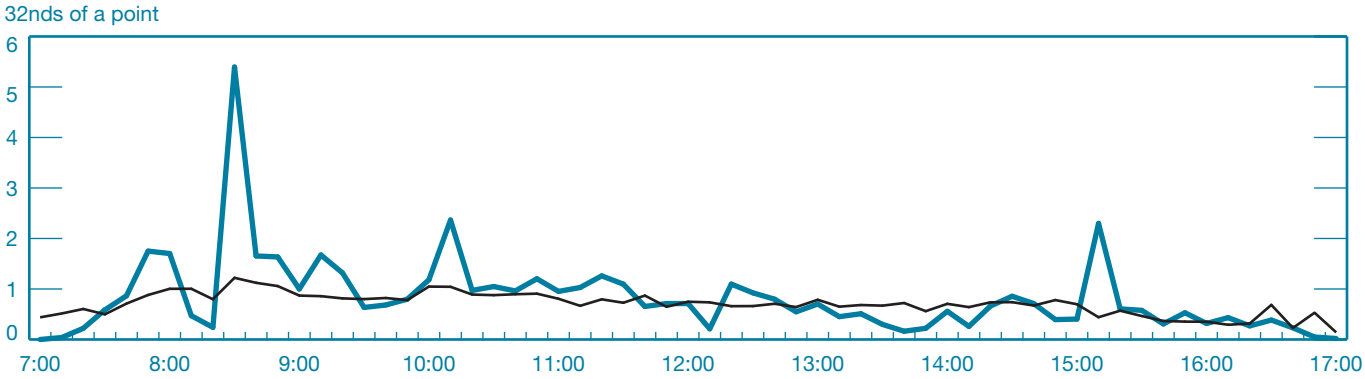


Chart 5B

Intraday Trading Frequency on Employment Report and Nonannouncement Days

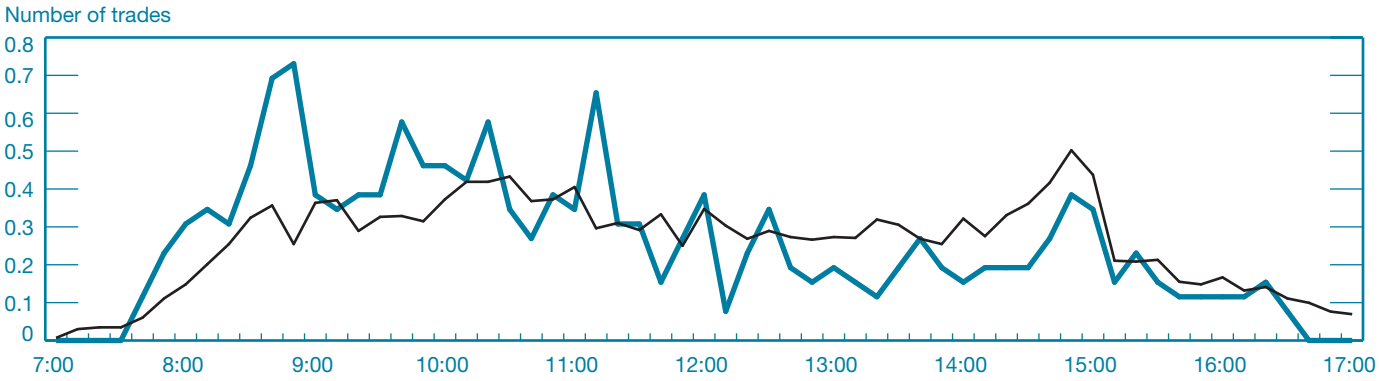
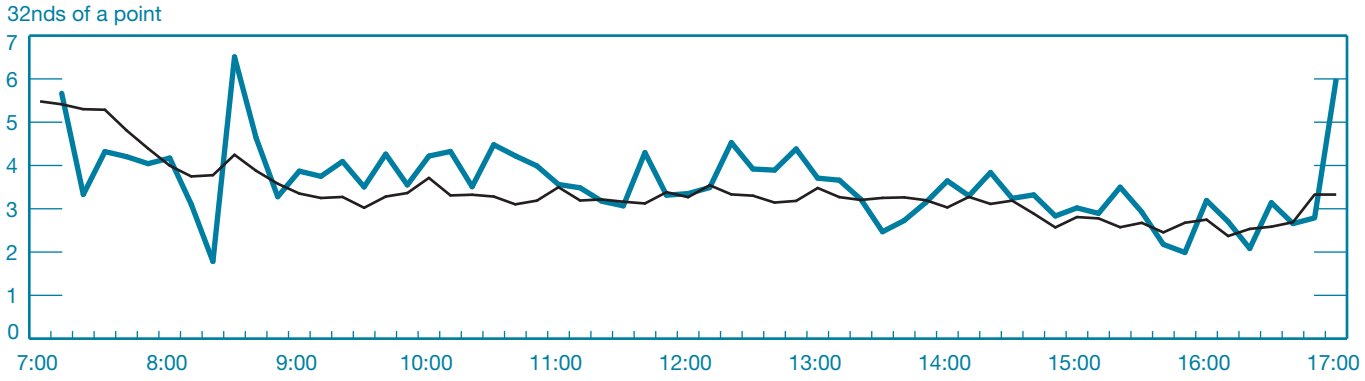


Chart 5C

Intraday Bid-Ask Spread on Employment Report and Nonannouncement Days



Source: Authors' calculations, based on proprietary data from the interdealer market.

Notes: The charts plot intraday patterns of price volatility, trading frequency, and bid-ask spreads for the on-the-run ten-year TIPS on employment report days (in blue) and nonannouncement days (in black). Times noted are interval start times.

Chart 6A

Intraday Price Volatility on FOMC and Nonannouncement Days

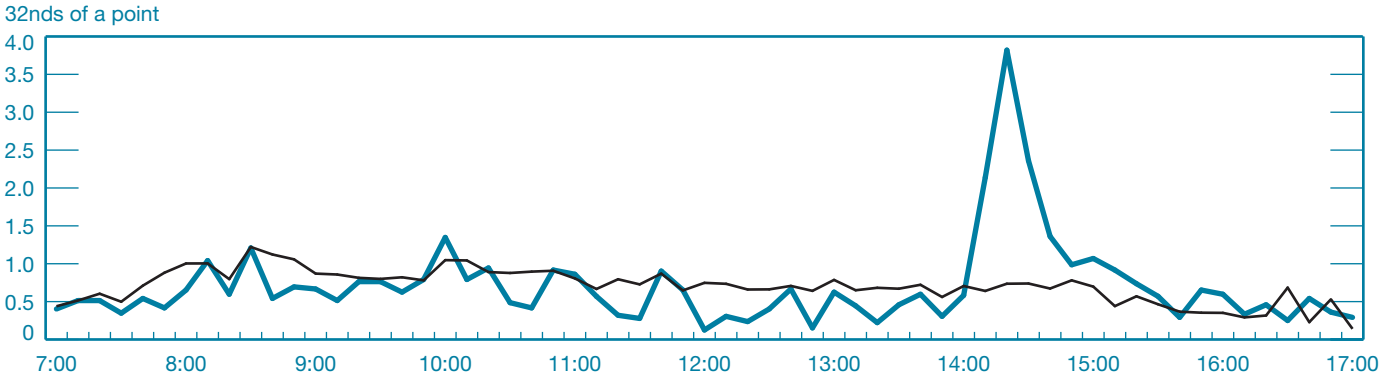


Chart 6B

Intraday Trading Frequency on FOMC and Nonannouncement Days

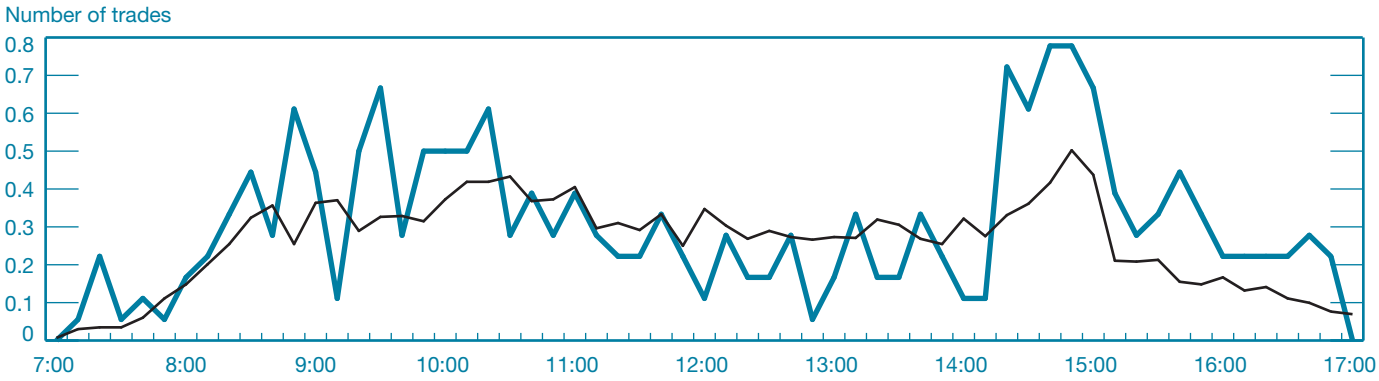
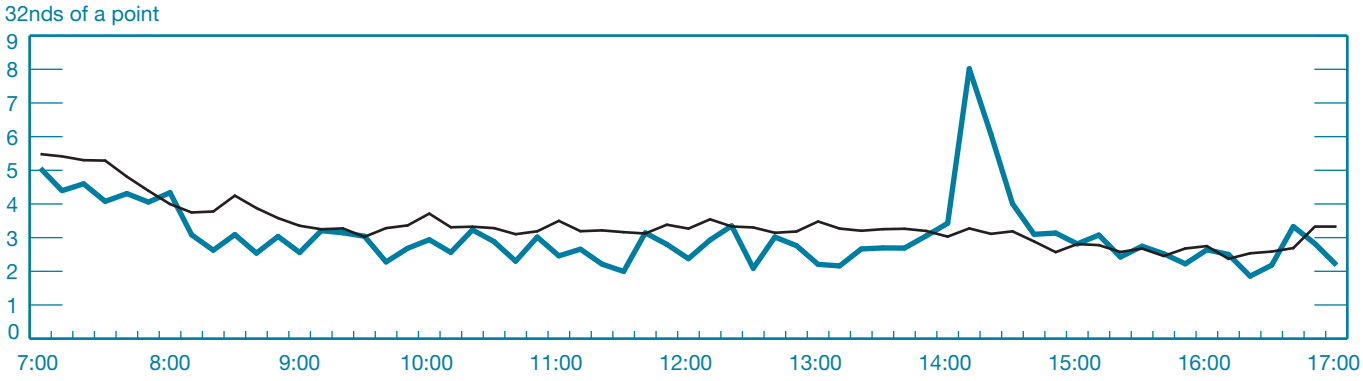


Chart 6C

Intraday Bid-Ask Spread on FOMC and Nonannouncement Days



Source: Authors' calculations, based on proprietary data from the interdealer market.

Notes: The charts plot intraday patterns of price volatility, trading frequency, and bid-ask spreads for the on-the-run ten-year TIPS on FOMC announcement days (in blue) and nonannouncement days (in black). Times noted are interval start times.

Chart 7A

Intraday Price Volatility on Auction and Nonannouncement Days

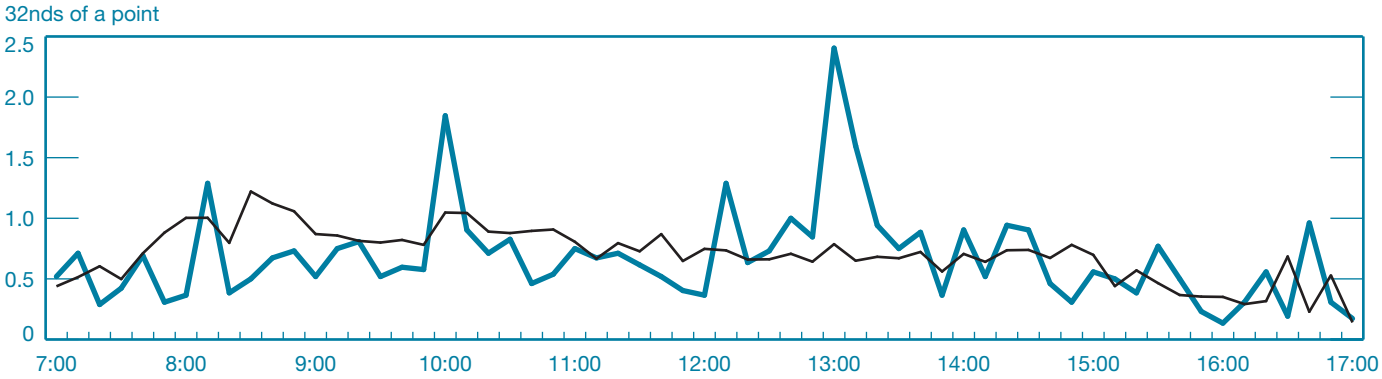


Chart 7B

Intraday Trading Frequency on Auction and Nonannouncement Days

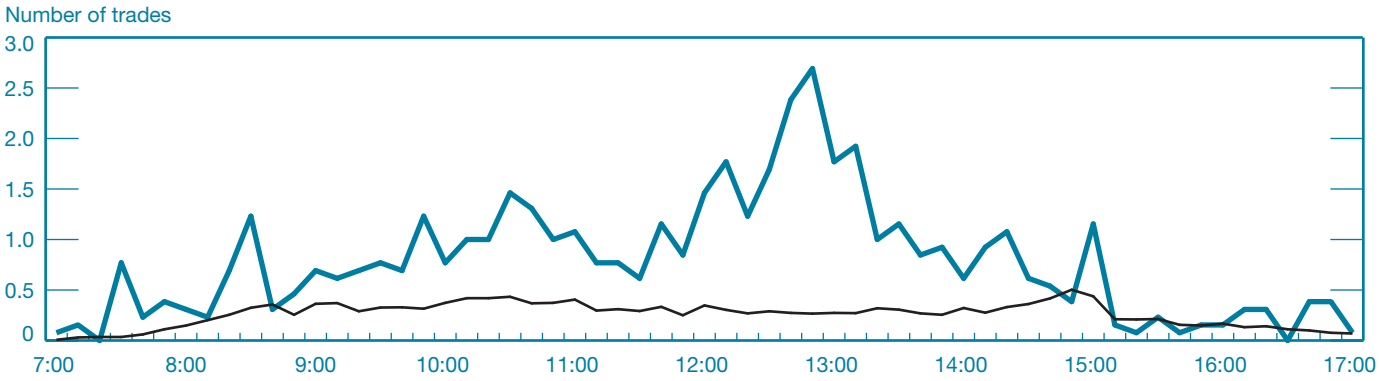
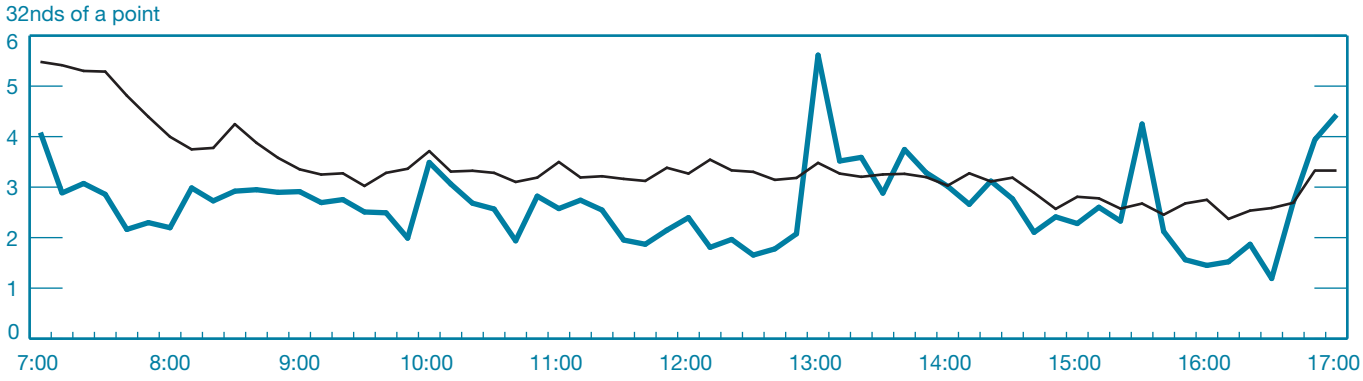


Chart 7C

Intraday Bid-Ask Spread on Auction and Nonannouncement Days



Source: Authors' calculations, based on proprietary data from the interdealer market.

Notes: The charts plot intraday patterns of price volatility, trading frequency, and bid-ask spreads for the on-the-run ten-year TIPS on TIPS auction days (in blue) and nonannouncement days (in black). Times noted are interval start times.

announcement and then remains somewhat higher than usual for some time (see, for example, Fleming and Remolona 1999]; Balduzzi, Elton, and Green [2001]; and Fleming and Piazzesi [2005]). Our price volatility findings are consistent with this result for every announcement (Charts 4A-7A).

The increases in trading activity that occur at the time of announcement are also generally consistent with findings for the nominal market, whereby trading activity jumps right after the announcement and then remains higher than usual for some time (Charts 4B-7B). The announcement that stands out in terms of trading activity is the one for TIPS auction results. In particular, trading activity on TIPS auction days is much higher than usual in the hours preceding the 1 p.m. auction close and then peaks in the ten-minute interval right before the close. While trading activity for other announcements seems to be driven by the news in the announcement, trading activity on TIPS auction days seems to be driven by positioning in advance of the auction.

Lastly, the pattern for bid-ask spreads is also consistent with findings for the nominal market, whereby spreads widen sharply at the time of the announcement but revert quickly to normal levels (Charts 4C-7C). The pattern for TIPS auction results fits this general pattern, but also indicates narrower-than-usual spreads in the hours preceding the auction close, consistent with the higher-than-usual trading activity in that time period.

Our results also offer an interesting contrast with other findings from the TIPS market. While no other study analyzes the announcement adjustment process of TIPS, Beechey and Wright (2009) examine how TIPS yields are affected by surprises associated with the CPI, FOMC, employment report, and other announcements. Consistent with the spikes in volatility we find at the times of announcements, the authors find monetary policy surprises and employment report surprises to have significant effects on TIPS yields. However, they do not find core CPI surprises to be significantly related to yields, even though we do detect significant announcement effects from the CPI in terms of volatility, yields, and bid-ask spreads. Further work is needed to resolve these contrasting results.[26]

5. Conclusion

Our analysis of the TIPS market identifies several microstructure features also present in the nominal Treasury securities market, but several unique features as well. As in the nominal market, there is a marked difference in trading activity between on-the-run and off-the-run TIPS, as trading drops sharply when securities go off the run. In contrast to the nominal market, there is little difference in bid-ask spreads or quoted depth between these securities, but there is a difference in the incidence of posted quotes. The results suggest that trading activity and quote incidence may be better cross-sectional measures of liquidity in the TIPS market than bid-ask spreads or quoted depth.

Intraday patterns of trading activity are broadly similar in the TIPS and nominal markets, but TIPS activity peaks somewhat later, likely indicating differences in the use and ownership of these securities. Announcement effects are also different, probably reflecting the types of information most important to the particular securities. The employment report is the most important announcement in the nominal market, but it elicits relatively little response in the TIPS market in terms of trading activity. In contrast, announcements of the consumer price index and the results of TIPS auctions precipitate significant increases in TIPS trading activity, likely indicating these announcements' particular importance to TIPS valuation.

[26] The contrasting results are probably not explained by differences in sample periods, which are largely similar between the two studies, or by differences in event interval, which also are similar. The differences may be explained by differential effects between core CPI and overall CPI surprises or by TIPS yields not reacting in a consistent, linear manner to core CPI surprises.

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Donald P. Morgan, Benjamin Iverson, and Matthew Botsch

Subprime Foreclosures and the 2005 Bankruptcy Reform

- After the bankruptcy abuse reform (BAR) took effect in October 2005, foreclosures on subprime mortgages surged nationwide.
- Prior to BAR, overly indebted borrowers could file bankruptcy to free up income to pay their mortgage by discharging unsecured debts; BAR eliminated that option for better-off filers through a means test and other requirements, making it more difficult to save one's home by filing bankruptcy.
- A study of the reform suggests that BAR was associated with more subprime foreclosures; BAR's effects were greater in states with high bankruptcy exemptions, as theory predicts.
- For a state with an average home equity exemption, the subprime foreclosure rate after BAR rose 11 percent relative to average before the reform; given the number of subprime mortgages nationwide, that translates into 29,000 additional subprime foreclosures per quarter nationwide.

1. Introduction

Is it just coincidence that subprime foreclosures surged right after the bankruptcy abuse reform (BAR) took effect in October 2005 (Chart 1)?[1] This article presents arguments and evidence suggesting that it is not. Before BAR, any household could file Chapter 7 bankruptcy and have its credit card and other unsecured debts discharged. By sidestepping their unsecured debts, households retained more income to pay their secured debts, such as mortgages. BAR blocks that maneuver by presenting a variety of obstacles, including a means test that forces better-off households that demand bankruptcy protection to file Chapter 13, where they must continue paying unsecured lenders.[2] When the means test binds, cash-flow-constrained mortgagors who might have saved their home by filing Chapter 7 are more likely to face foreclosure.

Legal scholars and practitioners have long recognized how filing Chapter 7 and discharging unsecured debts can help avert foreclosure:

> . . . many debtors file bankruptcy precisely so that they can *pay* their mortgage . . . by discharging other debts (Berkowitz and Hynes 1999, p. 3).[3]

[1] The full name of the reform is the Bankruptcy Abuse Prevention and Consumer Protection Act (BAPCPA). We prefer BAR over BAPCPA because it is pronounceable and because abuse prevention came first (White 2006).

[2] Chapters 7 and 13 are described in more detail in Section 2.

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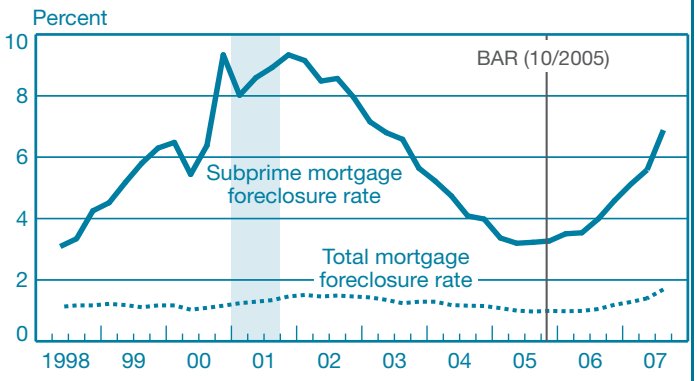
Chart 1

Subprime Foreclosures Rise after BAR



Source: Mortgage Bankers Association.

Notes: BAR is bankruptcy abuse reform. The solid line shows outstanding subprime mortgages in foreclosure in the United States; the dashed line shows outstanding total mortgages in foreclosure in the United States. The vertical band indicates an NBER recession.

> If . . . the value of your home is covered by your state's homestead exemption, Chapter 7 may be the way to go . . . by getting rid of most of your other debts, keeping up the mortgage will be just that much easier (Caher and Caher 2006, p. 190).

Our hypothesis follows directly from the first observation; if some households demand Chapter 7 protection to avoid foreclosure, limiting access to it should increase foreclosures. Our identification strategy follows from the second observation; limiting access to Chapter 7 should have a greater effect in states with high home equity exemptions.[4] Bankruptcy exemptions are the opposite of collateral—they determine how much home equity Chapter 7 filers can *keep* from unsecured creditors. We reason that homeowners in states with low home equity exemptions are less likely to demand Chapter 7, so the means test is less likely to bind in those states. In textbook terms, we identify BAR as a contraction in the "supply" of bankruptcy protection, and we predict a larger impact on foreclosures in states with high exemptions, and hence high "demand" for Chapter 7.

We extend our identification strategy by looking for differential effects of BAR across different classes of household credit. We expect BAR to reduce delinquency rates on unsecured loans in states with high exemptions because lenders in those states were most exposed to losses from bankruptcy before the reform. We contend that BAR will be unrelated to prime mortgage foreclosures because prime mortgagors are, by definition, unlikely to demand bankruptcy, regardless of exemptions.

We test our predictions by using difference-in-difference regressions of mortgage foreclosure and loan delinquency rates estimated using state-level quarterly data from 1998:1 to 2007:3. The results are largely consistent with our predictions. Given home price appreciation and economic conditions, we find that the increase in subprime foreclosures after BAR was significantly higher in states with higher home equity exemptions. Prime foreclosure rates, by contrast, were unrelated to BAR. In still starker contrast, delinquency rates on unsecured personal loans, which were made more secure under BAR, decreased more after the reform in states with higher home equity exemptions.

The estimated impact of BAR on subprime foreclosures is substantial. For a state with average home equity exemptions, the average subprime foreclosure rate over the seven quarters after BAR was 11 percent higher than the average rate before BAR. This translates to about 29,000 more subprime foreclosures nationwide per quarter attributable to the reform.[5]

Our study adds another candidate to the list of factors that may have triggered the destabilizing surge in subprime foreclosures, including declining home prices (Gerardi, Rosen, and Willen 2007), expanded mortgage supply (Mian and Sufi 2009), looser lending standards (Dell'Ariccia, Igan, and Laeven 2008; Demyanyk and Van Hemert 2007), and agency problems associated with securitization (Keys et al. 2010). Beyond those "usual suspects," we conclude that the bankruptcy reform also played a role.

Although we study foreclosures, the mechanism by which we hypothesize that BAR affects foreclosures begins with delinquency and borrower behavior. Put bluntly, BAR increases the incentives of some cash-flow-constrained mortgagors to quit paying their mortgage—rather than quit paying some other debts and use the cash flow freed up to stay current on their mortgage instead.[6] It does not, to our knowledge, increase the incentive for lenders to foreclose on

[3] Consistent with the argument, Berkowitz and Hynes (1999) estimate that mortgage rates and the probability of applicants being turned down for mortgages are declining in the level of homestead exemptions.

[4] White and Zhu (2008) find that a substantial fraction of Delaware filers in 2006 were bound by the means test. Of 586 households that filed Chapter 13, 22 percent did not pass the means test and 89 percent owed unsecured debt. Among the 90 percent of Chapter 13 filers that actually filed payment plans, 38 percent committed to repay unsecured debts. The latter represent payments that were potentially avoidable under Chapter 7 before BAR.

[5] BAR may have indirectly contributed to foreclosures *via* lower home prices. To the extent that cash-flow-constrained borrowers were forced to sell their homes in lieu of filing Chapter 7, the downward pressure on home prices would contribute to foreclosures by leading to "underwater" mortgages.

[6] Delinquent borrowers may have several options that avert foreclosure. They may be able to execute a deed in lieu of foreclosure, or short-sell the house, or modify their mortgage. Or they may be willing and able to reduce their spending enough to fulfill all their obligations. Delinquent borrowers without any of those or any other options will wind up in foreclosure, so those worst cases are the ones we study.

Table 1

How BAR Affects Debtors and Creditors, by Bankruptcy Law Chapter

Category	Pre-BAR	Post-BAR
Chapter 7 or 13 determined by	Filer	Means test
Chapter 13 repayment plan determined by	Filer	Means test
Income lenders can claim in Chapter 7 (Chapter 13)	0 (per plan)	0 (per means test)
Days financed car buyer must wait to "cram" loan[a]	0	910
Home equity lenders can claim in Chapter 7 (Chapter 13)	Table 3 (0)	Table 3 or $125,000[b] (0)
Fees + estimated legal costs to file Chapter 7 (Chapter 13) (thousands of dollars)[c]	0.6 (1.6)	2.3 +/- 0.5 (3.2 +/- 0.5)
Months between filing and discharge in Chapter 7 (Chapter 13)	0 (36-60)	6[d] (60)
Unsecured debts discharged in Chapter 7 (Chapter 13)	All - priority (all - priority plus)[e]	Less (less)
Years before refiling permitted in Chapter 7 (Chapter 13)	6 (0.5)	8 (2)
"Chapter 20" = Chapter 7 + Chapter 13 permitted?	Yes	No
Months of credit counseling required before filing	0	6

Sources: White (2007); CCH (2005).
Notes: BAR is bankruptcy abuse reform. Debtors file bankruptcy to protect themselves from creditors and debt collectors. Secured creditors are entitled to security even in bankruptcy, but credit card and other unsecured debt may be discharged. The disposition of a filer's debts and wealth differs by chapter of the bankruptcy law. Chapter 7 (liquidation) protects all income but not all assets; Chapter 13 (rescheduling) protects all assets but not all income.

[a] Pay only current book value of car.
[b] If resident less than 1,215 days or domiciled less than 710 days.
[c] Practitioner estimates reported in White (2007).
[d] See CCH (2005, p. 3).
[e] Priority debt is student loans, child support, taxes, and recent or fraudulent credit card charges.

a delinquent borrower. We study foreclosures instead of delinquency nevertheless because foreclosures seem like the ultimate outcome of interest.

To say the reform was associated with more subprime foreclosures is not to say that it did not serve its intended, first purpose of curbing bankruptcy abuse. The strategy that BAR precludes in some cases is defaulting on unsecured debts in order to make it easier to pay secured debts. If that amounts to "robbing" Peter to pay Paul, then the reform may have worked.

It could certainly be said that the timing of the reform was unlucky, coming as it did near the end of housing boom characterized by lax lending standards and regulation. No doubt those initial conditions amplified the impact of BAR on foreclosures. It is possible that the reform was wise policy that simply came at a bad time.[7]

The next section elaborates on how BAR reduced the supply of bankruptcy protection and presents some circumstantial evidence consistent with our hypothesis. Section 3 shows how the means test is more likely to bind (and thus increase foreclosures) in states with high home equity exemptions. In Section 4, we present regression evidence suggesting that BAR did in fact contribute to the surge in subprime foreclosures. Section 5 concludes.

[7] In a longer version of this article (Morgan, Iverson, and Botsch 2008), we show that an upside of BAR was cheaper auto credit.

2. Background on Bankruptcy and BAR

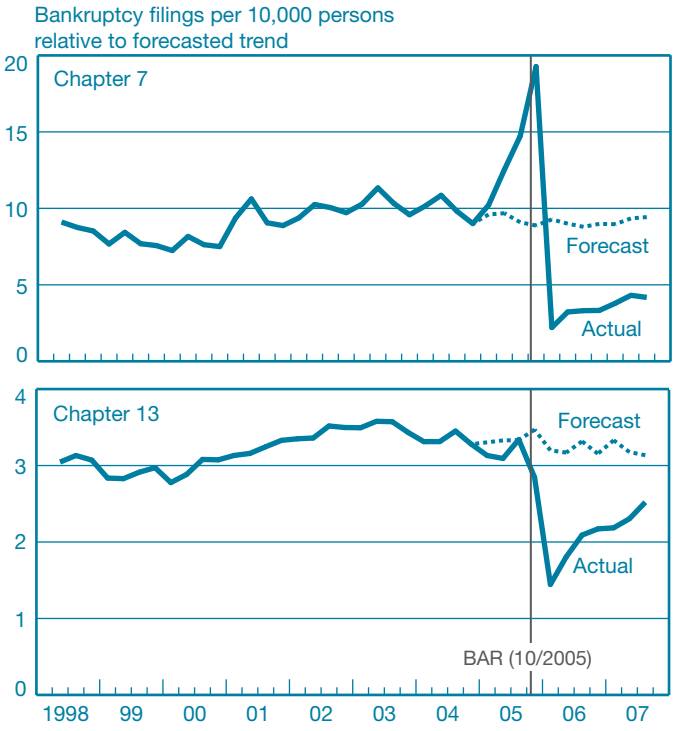
Bankruptcy is court protection of debtors from creditors and debt collectors. While a person is in bankruptcy, a judge stays all collection efforts—foreclosure, repossession of other assets, civil suits, garnishment of wages, and dunning—while the court determines which debts are discharged (forgiven) and which debts the borrower must repay from asset sales or future income. That division depends on which chapter of the bankruptcy law the borrower files under and the bankruptcy exemptions in the filer's state. Under Chapter 13 (rescheduling), filers get to keep all of their assets but commit to continue paying creditors out of future income for three to five years. Under Chapter 7 (liquidation), filers keep all of their future income but lose any home equity that is not exempt under their state's bankruptcy law. Any unsecured debts, including credit card debt and personal loans, that are not paid from the proceeds of liquidation are discharged.[8] Importantly, the discharge of unsecured debts under Chapter 7 leaves more income to pay a mortgage.

Table 1 summarizes how BAR changed filers' bankruptcy options. While virtually all of the reform's changes raised the

[8] Note that mortgage lenders' claims are secured (nondischargeable) under either chapter.

Chart 2

Households Rush to File Chapter 7 before BAR

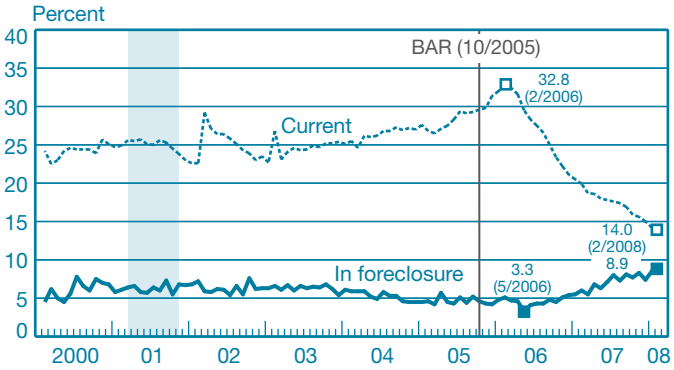


Source: Authors' calculations.

Notes: BAR is bankruptcy abuse reform. The forecast was generated from a vector autoregression model comprising two lags each of bankruptcy filings, the unemployment rate, house price appreciation, and the per capita income annual growth rate. We created the forecast by iteratively running the model and forecasting bankruptcy filings one quarter ahead for each state separately. For each step, we replaced the actual value of bankruptcy filings with the estimated value. Bankruptcy filings per 10,000 persons were averaged across the fifty states and Washington, D.C.

Chart 3

Subprime Mortgages in Bankruptcy Are More Likely to Face Foreclosure after BAR



Source: Credit Suisse (2007); data updated by authors.

Notes: BAR is bankruptcy abuse reform. The chart shows the percentage of securitized subprime mortgages—where borrowers are in bankruptcy at month t-1—that are either current or in foreclosure at month t, weighted by outstanding balance at time t. The vertical band indicates an NBER recession.

cost of filing or reduced the benefit (protection), the means test may have been the most important change. Before BAR, filers could choose which chapter to file. Now, only filers with income in the previous six months below the state median automatically qualify for Chapter 7 and the discharge. Under Chapter 13, better-off filers whose means (defined as income minus expenses recognized by the Internal Revenue Service, payments to secured creditors, and priority payments) exceed $166.67 per month must continue making payments to unsecured creditors for five years.[9] If Chapter 13 filers fail to make payments, the bankruptcy stay is removed and creditors can resume collection efforts, including foreclosure.[10]

Before testing our hypothesis formally, we note some circumstantial evidence in support of it. Chart 2 shows that filing rates under either chapter remain lower than one would predict given economic and housing market conditions. Note also that the ratio of filings (Chapter 7/Chapter 13) fell from about 3 (10/3.25) in 2004:4 to 2 (5/2.5) in 2007:3. The means test and other elements of the reform appeared to have lowered aggregate bankruptcy "supply" and the relative demand for Chapter 7.[11]

Shortly after BAR took effect, subprime borrowers in bankruptcy (under either chapter) in a given month were only about half as likely to remain current on their mortgages by the following month and twice as likely to be foreclosed upon (Chart 3). This dramatic reversal is consistent with the premise that bankruptcy became less protective after BAR, though there could have been other factors—falling home prices, for example—that were operating.[12]

Chart 4 demonstrates how higher Chapter 7 filings tend to improve the performance of mortgages relative to that of credit card loans, consistent with the premise that filing Chapter 7 is

[9] Filers with monthly means between $166.67 and $100 cannot file Chapter 7 if their means exceed 25 percent of their unsecured debts. Filers with means less than $100 per month may file Chapter 7. See http://www.usdoj.gov/ust/eo/bapcpa/meanstesting.htm.

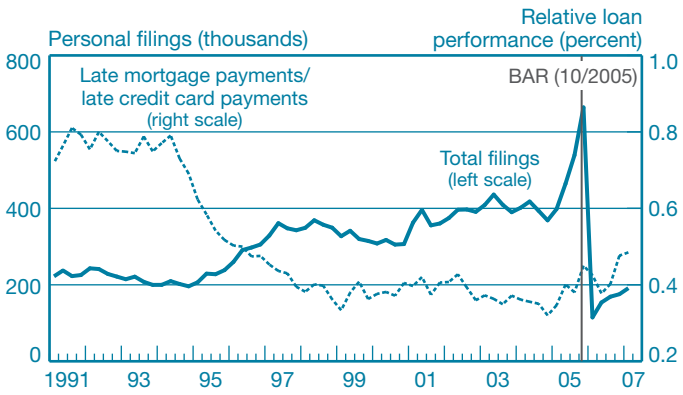
[10] Note that BAR does not change or preempt state home equity exemptions, except for new homebuyers or newly domiciled residents. Our identification strategy does *not* assume that exemptions were changed.

[11] We know from other evidence that those exemptions do affect bankruptcy demand. Ashcraft, Dick, and Morgan (2007) find that the rush to file Chapter 7 just before the bankruptcy abuse reform (Chart 2) was highest among states with riskier borrowers and high exemptions. Risky households demanded Chapter 7 while supply was high, and they demanded it most where Chapter 7 was most protective of equity owners.

[12] Credit Suisse (2007) analysts first noticed that bankruptcy filers after BAR were less likely to avert foreclosure. They concluded that BAR had affected subprime mortgagors "profoundly." Bernstein (2008) also argues that the surge in foreclosures might be partly attributable to BAR. He does not provide evidence, however.

Chart 4

Before BAR, Mortgage Performance Improves Relative to Credit Card Performance When Bankruptcy Filings Increase



Sources: U.S. courts (bankruptcy filings); banks' Reports of Condition and Income (loan performance data).

Notes: BAR is bankruptcy abuse reform. Residential real estate loans include open- and closed-ended loans secured by one-to-four-family residential properties. Total filings are the number of personal filings under Chapters 7 and 13 each quarter. Relative loan performance is the share of residential real estate loans past due/the share of credit card loans past due, where past due is defined as late ninety or more days or nonaccruing.

a way for cash-flow-constrained debtors to stay current on their mortgage. Relative performance is measured by the ratio of past due mortgages to past due credit card loans on the books of banks. Although other factors are driving the relative performance of Chapter 7 filings, the predicted negative relationship is clear. Before BAR, the correlation between filings and relative performance was -0.80 ($p < .01$); after the reform, the correlation was 0.66 ($p = 0.16$).

While the circumstantial evidence above is suggestive, it is far from definitive. What remains to be shown is that this evidence is not just coincidental. BAR took effect at the same time in every state, and other factors—namely, home price appreciation—changed at the same time. To rule out the possibility that Chart 1 and the circumstantial evidence are just coincidental, we rely on a cross-sectional identification strategy that reveals the states where BAR should have had the biggest impact.

3. BAR Is More Likely to Bind in High-Exemption States

We use a stylized example to demonstrate that BAR is more likely to bind, and thus increase foreclosures, in states with higher home equity exemptions. The intuition is that Chapter 7 is more protective in high-exemption states, so limiting access to it will matter more.

Consider two people who are identical, except one lives in Alabama, where the home equity exemption is $5,000, and the other lives in Maryland, where the exemption is zero (Table 2). Both have $5,000 of equity in their homes. For whatever reason, both find themselves income constrained in the sense that their current income after taxes and expenses cannot sustain their preferred rate of consumption. We present in Table 3 their hypothetical monthly budgets.

As Caher and Caher (2006) point out, filing Chapter 7 is (or was) a potential solution for debtors in this predicament, though the appeal depends crucially on the debtor's home equity relative to the home equity exemption in his or her state. If the Maryland borrower filed Chapter 7, his credit card debt would *not* be discharged; even under Chapter 7 protection, the judge would order him to sell ("liquidate") his house to settle his credit card debt. Absent protection from credit card lenders, the Maryland borrower seems unlikely to "demand"

We use a stylized example to demonstrate that BAR is more likely to bind, and thus increase foreclosures, in states with higher home equity exemptions. The intuition is that Chapter 7 is more protective in high-exemption states, so limiting access to it will matter more.

Chapter 7 as way of relaxing his cash-flow constraint and avoiding foreclosure. In contrast, if the Alabama borrower filed Chapter 7, all of her credit card debt would be discharged and she would keep her $5,000 in home equity. The Alabama borrower seems more likely to demand Chapter 7 than the Maryland borrower as a way to relax her cash-flow constraint and avoid foreclosure. Having her credit card debt discharged would free up $500 per month in income that she could put toward her mortgage payment. After BAR, both borrowers could find their options limited. If both fail the means test, Chapter 7 is not available to them. The key point, however, is that the lost option of Chapter 7 matters more to the Alabama borrower, because the Maryland borrower was less likely to demand Chapter 7 before BAR.

Table 4 provides a stylized example of how the BAR means test is more likely to bind and thus drive up foreclosures in states with higher home equity exemptions. The table reports hypothetical but realistic indicators of the relative probability

Table 2

States' Home Equity Bankruptcy Exemptions, Median Home Prices, and Ratios, Sorted by Exemption

State	Exemption	Price	Ratio	State	Exemption	Price	Ratio
Maryland	0	326	0	Colorado	45	231	0.17
New Jersey	0	362	0	California	50	485	0.10
Pennsylvania	0	162	0	Delaware	50	213	0.15
Alabama	5	136	0.03	Idaho	50	164	0.28
Kentucky	5	124	0.03	New York	50	284	0.18
Ohio	5	128	0.02	Alaska	54	204	0.25
South Carolina	5	158	0.03	Connecticut	75	313	0.24
Tennessee	5	144	0.03	Mississippi	75	124	0.52
Virginia	5	279	0.01	Vermont	75	182	0.38
Illinois	7.5	224	0.03	North Dakota	80	120	0.49
Georgia	10	152	0.05	Montana	100	156	0.50
North Carolina	10	160	0.05	New Hampshire	100	220	0.33
Wyoming	10	154	0.06	Arizona	150	256	0.57
Nebraska	12.5	128	0.09	Minnesota	200	188	0.87
Indiana	15	113	0.11	Rhode Island	200	280	0.63
Missouri	15	129	0.10	Nevada	350	327	1.07
Hawaii	20	496	0.06	Massachusetts	500	366	1.50
Utah	20	173	0.10	Arkansas	Unlimited	113	Unlimited
Louisiana	25	137	0.14	Washington, D.C.	Unlimited	391	Unlimited
Oregon	25	235	0.10	Florida	Unlimited	266	Unlimited
West Virginia	25	148	0.09	Iowa	Unlimited	123	Unlimited
Miami	30	145	0.18	Kansas	Unlimited	137	Unlimited
New Mexico	30	165	0.16	Oklahoma	Unlimited	110	Unlimited
Maine	35	195	0.18	South Dakota	Unlimited	115	Unlimited
Washington	40	260	0.13	Texas	Unlimited	136	Unlimited
Wisconsin	40	161	0.25	Mean[a]	60.56	206	0.24

Sources: State websites (exemptions); Moodys.com (median home prices).
Notes: Exemption is the dollar amount of home equity that unsecured lenders cannot claim under bankruptcy; price is the state median. Exemption and price are in thousands of dollars at 2005:4. The correlation between exemption and exemption/home price = 0.87.

[a]Excludes states with unlimited exemptions.

Table 3

Hypothetical Monthly Budget of Cash-Flow-Constrained Debtor in Sample States

Income after taxes	$3,000
Preferred consumption	$2,000
Secured debt payments (mortgage)	$1,000
Unsecured debt payments (credit card)	$500
Deficit	$500

Table 4

Probability that a Filer in Sample States Demands Chapter 7, before and after BAR

	Before BAR	After BAR	Difference (before - after)
Alabama debtor (high home equity exemption)	ρ	0	$-\rho$
Maryland debtor (low home equity exemption)	$\rho - \delta$	0	$-\rho + \delta$
Difference-in-difference (high - low exemption)	δ	0	$-\delta$

Note: BAR is bankruptcy abuse reform.

that the Maryland borrower and the Alabama borrower would demand Chapter 7 to avoid foreclosure before and after the reform.

Suppose that before BAR, the Alabama borrower files Chapter 7 with probability $p \geq 0$. Suppose further that the Maryland borrower is δ percent less likely to file Chapter 7 because of the low exemption there. After BAR, we assume neither borrower can file Chapter 7 because neither passes the means test. Because the Maryland borrower was less likely to file Chapter 7 before BAR, his demand declines by less than the demand of the Alabama borrower. The difference-in-difference in their demand—that is, the difference in demand before and after BAR in the high-exemption state less the difference in demand before and after BAR in the low-exemption state—is $-\delta$.[13] Because Chapter 7 demand declines more in the high-exemption state, we expect foreclosures to rise more in those states. We test that prediction in our analysis below.

The example above suggests that cash-flow-constrained Chapter 7 filers are more likely to remain constrained after BAR and thus more likely to face foreclosure. Because high-exemption states will have a larger fraction of constrained filers, we venture three hypotheses:

1. The surge in subprime mortgage foreclosure rates since BAR took effect will be higher in high-exemption states.
2. Any change in *prime* mortgage foreclosures since BAR will be invariant to state exemptions. Prime mortgagors are, by definition, unlikely to demand bankruptcy protection, so BAR is unlikely to bind.
3. Any increase in *un*secured consumer credit delinquency rates since BAR will be lower in higher exemption states.

The third hypothesis follows from the fact that constrained Chapter 7 filers are more likely to have to continue making payments on unsecured debts after BAR, so the delinquency rate on unsecured debts in high-exemption states would be expected to fall relative to the rate in low-exemption states.

4. Regression Model and Findings

We test our predictions by estimating difference-in-difference regressions:

$$Y_{st} = \alpha + \sum_{s=1}^{N-1} \alpha_s D_s + \sum_{t=1}^{T-1} \alpha_t D_t + \beta X_{st} + \gamma BAR_t EX_s + \delta BAR_t UNLIMITEDEX_s + \varepsilon_{st}.$$

[13] An analogy might be even simpler than the stylized example. If the state speed limit is 60 in one state and 70 in another, lowering the federal speed limit from 75 to 65 would presumably limit demand for speed more in the state with the higher speed limit.

The dependent variable Y_{st} is the foreclosure rate on subprime or prime mortgages, or the delinquency rate on personal loans in state s at time t. X_{st} represents four variables that might be correlated with foreclosure or delinquency rates: median home price appreciation (the year-over-year growth rate), the unemployment rate (seasonally adjusted), logged real per-capita income, and the real per-capita income growth rate (year-over-year).

We include only contemporaneous values of those control variables, but we have confirmed our main results using lagged values as well (see robustness tests below). BAR_t is a dummy variable equal to 0 for t on or before 2005:4 and equal to 1 for t after that date. EX_s is the single-filer home equity exemption in state s at 2005:4 divided by the median home price in state s at 2005:4. $UNLIMITEDEX_s = 1$ if the exemption in state s at 2005:4 was unlimited, 0 otherwise.[14] We "freeze" exemptions at their 2005:4 levels to avoid endogeneity between exemptions and foreclosure rates. We scale exemptions in case a given exemption in say, California, provides less protection than the same exemption in Idaho. Using unscaled exemptions does not change our main results in any important way (see robustness discussion). Scaled and unscaled exemptions are reported in Table 2. We collect the exemptions data from state legislative websites to ensure their accuracy as of 2005:4. To control for constant differences in the dependent variables across states, we include a matrix of fifty dummy variables (one for each state, plus Washington, D.C., less an omitted state). These state-fixed effects allow for differences in the average rate of foreclosures across states attributable, for example, to differences in foreclosure protection and credit culture. To control for constant differences in the dependent variable over time, we include a sequence of dummy variables for all but one quarter-year in the sample period. These time-fixed effects control for macroeconomic factors, such as interest rates and the aggregate business cycle. It is important to include these fixed effects, but we do not report the roughly 100 associated coefficients. Note that because the regressions include fixed effects, the "own" effects of *BAR*, *EX*, and *UNLIMITEDEX* on foreclosures are unidentified. The coefficients on the

Average annual house price appreciation over the seven quarters before BAR was 8 percent higher than appreciation over the seven quarters following BAR, implying 47,689 more subprime foreclosures outstanding per quarter since the reform.

[14] $EX_s = 0$ when $UNLIMITEDEX_s = 1$.

Table 5

Subprime Mortgage Foreclosures Rise after BAR in High-Exemption States; Personal Loan Delinquency Rates Fall

	Dependent Variable					
	Mortgage Foreclosure Rate					
	Subprime		Prime		Personal Loan Delinquency Rate	
	(1)	(2)	(3)	(4)	(5)	(6)
BAR × exemption	2.85***	2.09***	0.07	-0.05	-0.78***	-0.84***
	(0.71)	(0.68)	(0.08)	(0.06)	(0.18)	(0.16)
BAR × unlimited exemption	0.81	0.77	0.04	0.04	-0.12	-0.16
	(0.87)	(0.71)	(0.09)	(0.06)	(0.19)	(0.19)
House price appreciation		-0.11***		-0.01***		0.01
		(0.02)		(0.00)		(0.01)
Unemployment rate		0.47		0.11**		0.14**
		(0.30)		(0.04)		(0.07)
Log(per-capita income)		-9.27		-1.43*		2.88
		(9.14)		(0.84)		(1.84)
Per-capita income, annual growth		0.09		0.01		-0.01
		(0.07)		(0.01)		(0.02)
Constant	2.50***	96.21	0.53***	14.87*	2.60***	-27.72
	(0.29)	(94.75)	(0.05)	(8.67)	(0.10)	(18.96)
Observations	1,989	1,989	1,989	1,989	1,577	1,577
Adjusted R^2	0.56	0.63	0.09	0.40	0.27	0.28

Source: Authors' calculations.

Notes: BAR is bankruptcy abuse reform. Reported are regression coefficients (robust standard errors, clustered at the state level) estimated using ordinary least squares and state data from 1998:1 to 2007:3. BAR = 0 on or before 2005:4 and 1 after. Exemption = home equity exemptions in the state at 2005:4/median home price in the state at 2005:4. Unlimited exemption = 1 for states with unlimited homestead exemption at 2005:4, zero for other states. All regressions include state- and year-quarter-fixed effects.

***Statistically significant at the 1 percent level.
**Statistically significant at the 5 percent level.
*Statistically significant at the 10 percent level.

interactions—*BAR* x *EX* and *BAR* x *UNLIMITEDEX*—measure the difference-in-difference of the mean of *Y*. Said differently, those coefficients measure how the difference in the mean of *Y* after *BAR* differs with *EX* or *UNLIMITEDEX*. We predict positive coefficients on both variables in the subprime regression, smaller or zero coefficients in the prime regression, and negative coefficients in the personal loan regression.

We estimate the regressions using ordinary least squares and a panel of state-quarter data from 1998:1 to 2007:3. The foreclosure data are from the National Delinquency Survey published by the Mortgage Bankers Association (MBA). The MBA collects its data from 120 lenders with 44 million loans on one-to-four-unit residential properties.[15] The American Bankers Association collects its data from a panel of 450 banks across the country. Summary statistics and sources for all regression variables are presented in the appendix.

Regression coefficients and standard errors (clustered by state) are reported in Table 5. The signs of the key coefficients are as predicted. *BAR* x *UNLIMITEDEX* is statistically insignificant, contrary to our hypothesis, but *BAR* x *EX* is significantly positive in the subprime foreclosure regression and significantly negative in the personal loan delinquency regression.[16] Both prime and subprime foreclosure rates are negatively related to home price appreciation and unemployment, as one would expect, but only subprime foreclosures depend on BAR.

The regression estimates imply that the impact of BAR on subprime foreclosures is smaller, but of the same order, as the impact of slower house price appreciation. The coefficient on *BAR* x *EX* in column 2 indicates that for a state with average home equity exemptions/median home prices, the average subprime foreclosure rate over the seven quarters after BAR

[15] See http://www.mortgagebankers.org/NewsandMedia/PressCenter/56555.htm.

[16] We lack a good explanation for why the unlimited-exemption states (and Washington, D.C.) do not fit the regression line.

was 11 percent higher than the average rate over the period before BAR.[17] That translates to about 29,000 more subprime foreclosures nationwide per quarter attributable to BAR.[18] By comparison, a standard-deviation decrease in home price appreciation increases the foreclosure rate 13.7 percent relative to the average. Average annual house price appreciation over the seven quarters before BAR was 8 percent higher than appreciation over the seven quarters following BAR, implying 47,689 more subprime foreclosures outstanding per quarter since the reform.[19] Thus, the impact of home price deprecation is larger, but the impact of BAR is of the same order of magnitude.

The main results in Table 5 are robust to several alternative specifications. The inclusion of four lags of home price appreciation and all other economic variables does not appreciably alter the significance of the coefficient for *BAR* x *EX*. We also obtain similar results when we control for the share of subprime mortgages that are secured and the share with adjustable rates (though those data are available only after 2004:1). For those regressions, we find that the share of subprime mortgages that were securitized was positively and significantly related to the subprime foreclosure rate, which is consistent with the evidence in Keys et al. (2010) that securitization agency problems contributed to foreclosures. The size and significance of the *BAR* x *EX* coefficient do not change appreciably when we add those extra controls, however. Use of exemption levels that are not scaled by the median home price does not materially change the results.

We also find that omitting those states that experienced the highest foreclosure rates—Arizona, California, Florida, and Nevada—actually magnifies the impact of BAR on subprime foreclosures.[20] While we believe that the robust coding we have used for unlimited-exemption states is the preferable specification, simply dropping these states does not appreciably alter the coefficient estimates on *BAR* x *EX*.

[17] The coefficient estimate in regression model 2 implies that the mean foreclosure rate in a state with a mean exemption level ($25,245) was 51.5 (2.04 x 25.245) basis points higher after BAR than before, an increase of 11 percent relative to the mean foreclosure rate before BAR (4.64 percent).

[18] The average number of subprime mortgages outstanding over the post-BAR period was 5,545,799, so an increase of 51.5 basis points in the foreclosure rate in a typical (median-exemption) state implies 28,561 (.00515 x 5,545,799) more subprime foreclosures per quarter as a result of BAR.

[19] A standard-deviation increase in the unemployment rate increases the foreclosure rate about 13.4 percent. Unemployment rates *decreased* almost 70 basis points on average since BAR, implying 20,059 fewer foreclosures per quarter.

[20] With those states excluded, the coefficients (standard errors) on *BAR* x *EX* in the subprime foreclosure regression models (1 and 2) become 3.55 (0.71) and 2.68 (0.70). The coefficients in the prime foreclosure and personal loan delinquency regression do not change appreciably when the four states are excluded.

5. Conclusion

Our study suggests that the bankruptcy abuse reform of 2005 may have been one of a number of contributors to the destabilizing surge in subprime foreclosures by shifting risk from credit card lenders to mortgage lenders. The means test component of BAR gives credit card and other unsecured creditors a stronger claim on borrowers' cash flows, thus weakening the (implicit) claims of secured lenders on these funds. By making it harder for borrowers to avoid paying credit card debt, BAR made it more difficult for them to pay their mortgages, so foreclosure rates rose.

Although proponents of the reform may not have anticipated that BAR would have contributed to the surge in foreclosures, observers close to the facts saw the wave coming. Alexis McGee, President of Foreclosure.com, made this prediction six months *before* the reform took effect:

> People get in over their heads by further encumbering their homes with equity lines of credit that are exhausted with purchases of consumer products and services such as cars and expensive vacations. Then, when interest rates rise, and home values stop increasing, they can no longer refinance and file a Chapter 7 bankruptcy petition to wipe out their [unsecured] debts and hold off foreclosure by their lender . . . . [Now] they must file under Chapter 13, and pay off their debt in 60 months or less. Middle income families in this position could face the loss of their homes (*Business Wire*, April 25, 2005).

McGee was prescient.

It should be noted that BAR will not necessarily lead to higher foreclosure rates in the steady state. Once borrowers have learned that the bankruptcy rules have changed, they can be expected to reduce their demand for unsecured debt to avoid the bind that BAR creates. If so, the long-run impact of BAR on subprime foreclosures may be negligible.

Appendix

Data Sources and Summary Statistics

	Source	Number	Mean	Standard Deviation	Minimum	Maximum
Dependent variables						
Subprime foreclosure rate	Mortgage Bankers Association	1,989	5.74%	3.33%	0.00%	17.03%
Prime foreclosure rate	Mortgage Bankers Association	1,989	0.51%	0.28%	0.07%	2.11%
Sixty-month new auto loan rate	Bankrate.com	1,734	7.06%	1.29%	3.87%	11.75%
Five-year U.S. Treasury	Board of Governors of the Federal Reserve System	1,734	4.41%	1.03%	2.57%	6.59%
auto-Treasury spread		1,734	2.65%	0.65%	0.37%	6.95%
Personal delinquency rate[a]	American Bankers Association	1,577	2.03%	0.95%	0.13%	7.04%
Auto loan delinquency rate, direct	American Bankers Association	1,546	1.75%	0.94%	0.34%	8.38%
Auto loan delinquency rate, indirect	American Bankers Association	1,373	1.87%	1.01%	0.11%	8.39%
Independent variables						
Single household exemption	Code law for each state	1,989	$39,803	$67,161	$0	$550,000
Median house price	Federal Home Finance Board	1,989	$184,178	$72,663	$71,000	$620,000
exemption/median house price		1,989	0.21	0.30	0.00	1.75
Unemployment rate	BLS	1,989	4.67%	1.17%	2.10%	9.70%
House price appreciation[b]	Moody's Economy.com	1,989	6.13%	5.97%	-7.88%	51.57%
Real per-capita income in 2005:1	U.S. Census Bureau, BEA, BLS	1,989	$32,389	$5,354	$11,667	$56,951
Log(real per-capita income)		1,989	10.37	0.16	9.36	10.95
Change in real per-capita income[b]		1,989	1.85%	4.33%	-57.90%	158.56%

Notes: Data are from 1998:1 to 2007:3 for the fifty states and Washington, D.C., except where noted. BLS is Bureau of Labor Statistics; BEA is Bureau of Economic Analysis.

[a]Data are incomplete for some states.
[b]Year-over-year percentage change.

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