Evaluating the Quality of Fed Funds Lending Estimates Produced from Fedwire Payments Data

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Abstract

A number of empirical analyses of interbank lending rely on indirect inferences from individual interbank transactions extracted from payments data using algorithms. In this paper, we conduct an evaluation to assess the ability of identifying overnight U.S. fed funds activity from Fedwire® payments data. We find evidence that the estimates extracted from the data are statistically significantly correlated with banks' fed funds borrowing as reported on the FRY-9C. We find similar associations for fed funds lending, although the correlations are lower. To be conservative, we believe that the estimates are best interpreted as measures of overnight interbank activity rather than fed funds activity specifically. We also compare the estimates provided by Armantier and Copeland (2012) to the Y-9C fed funds amounts.

Key words: federal funds market, data quality, interbank loans, fed funds, Fedwire, Y-9C

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1. Introduction

In the aftermath of the 2007-8 financial crisis, researchers became increasingly interested in better understanding patterns in overnight interbank lending. Several research papers were written at this time using estimates of overnight federal funds ("fed funds") lending in the US, and similar interbank lending in other countries, extracted from bank payments data using algorithms based on Furfine (1999).[1]

The fed funds market is an important market because it is the means by which the Federal Reserve implements monetary policy, and because the fed funds rate impacts interest rates in the US economy. Interbank lending is important more broadly because it is the most immediate source of liquidity for financial intermediaries and thus an important indicator of the functioning of the banking and financial system. Problems in the efficiency of interbank markets can lead to inadequate allocation of capital and lack of risk sharing among banks.

Because interbank loans, which are also referred to as trades, are typically transacted over-the-counter, information is not publicly available.[2] The Federal Reserve Bank of New York (FRBNY) collects daily data on fed funds trades from interbank brokers who arrange trades between banks. The FRBNY publishes the daily average (effective rate) and range of fed funds traded rates. Information on non-brokered fed funds loans that are traded directly between banks is not included.

The second source of data on interbank lending, which has been used in academic research, is transactions inferred from an algorithm based on the methodology of Furfine (1999). Furfine's original algorithm aims to identify overnight interbank trades settled on Fedwire® Funds Service,[3] the large-value payments system operated by the Federal Reserve. Furfine isolates a group of candidate opening (send) legs of overnight loans and matches them with potential repayment (return) legs based on various factors such as the plausibility of implied interest rates. In doing so, he was able to infer numerous conclusions regarding the microstructure of the fed funds market. Furfine quantifies the amount of previously known lending by small banks to large banks and uncovers that large banks are often net sellers of fed funds. Furfine also measures an intraday pattern of fed funds trading and market concentration and shows evidence of network trading patterns and relationship lending.

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[1] See Afonso, Kovner, and Schoar (2011), Afonso (2012), Ashcraft, McAndrews, and Skeie (2011), Ashcraft and Bleakley (2006), Ashcraft and Duffie (2007), Acharya and Merrouche (2010), Bartolini, Hilton and McAndrews (2010), McAndrews (2009), Bech and Atalay (2008), Bech and Klee (2009), and Allen, Chapmanz, Echenique, and Shum (2012)

[2] One exception to this is the e-MID (electronic market for interbank deposits) active in Italy. See Angelini et al (2009) for more information.

[3] "Fedwire" is a registered service mark of the Federal Reserve Banks.

Demiralp, Preslopsky, and Whitesell (2004) use a variation of Furfine's algorithm to assess the fraction of trades that are brokered within the fed funds market, as well as bank usage of arbitrage opportunities in the fed funds market. They mention the difficulty of identifying the prominence of Type I and Type II errors associated with usage of the algorithm, but document that algorithm-estimated results correspond well with trends displayed in brokered data. Kuo, Skeie, and Vickery (2012) extend Furfine's original algorithm to a term maturity beyond overnight in order to assess the reliability of LIBOR during the peak of the financial crisis, and find that LIBOR was significantly understated during the crisis in comparison to the algorithm-estimated rates, a conclusion also supported by a comparison of LIBOR to TAF auction rates.[4]

In addition to research in the US, variants of this algorithm are used by researchers at central banks in the UK, ECB, Canada, Norway, Netherlands, and other countries to extract transactions inferred to be overnight interbank loans from payments data. Heijmans, Heuver, and Walraven (2010) apply a term based algorithm to data from the TARGET2 settlement system in order to analyze trading patterns in the Dutch interbank market. They find that the algorithm estimates are closely correlated with data from e-MID and contend that usage of the algorithm is useful, at least for monitoring purposes.[5] Akram and Christophersen (2010, 2011) use the algorithm to analyze the Norwegian interbank market using data from Norges Bank. They propose a new benchmark rate called NONIA which is based on averages derived from the algorithm estimated rates. They show that NONIA is often more reliable in identifying interbank borrowing costs than panel-quote derived rates such LIBOR and NIBOR, especially during times of crisis.[6]

This paper summarizes an effort to evaluate the quality of the estimates of overnight fed funds activity extracted from US Fedwire-payments data by the algorithm ("estimates" or "algorithm estimates") used at the FRBNY. We evaluate the quality of the estimates by comparing the algorithm-produced estimates to the amount of fed funds lending and borrowing reported by bank holding companies (BHCs) at quarter end on their regulatory filings (FR Y-9C).[7] We are thus comparing the stock of overnight loans reported to the Federal Reserve with the sum of the flow of transactions estimated by the algorithm to be fed funds loans on the last day of the quarter. A priori, even if the algorithm worked perfectly, we would expect amounts to differ from the algorithm's estimates for the following reasons: First, the Y-9C definition of fed funds includes only domestic entities of the BHC. Second, the Y-9C is unlikely to include borrowing

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[4] More information on this extended algorithm is provided in a companion paper Kuo, Skeie, Vickery, and Youle (2013).

[5] See Laine, Nummelin, and Snellman (2011) for another usage of the algorithm on data from TARGET2.

[6] The algorithm has also been used to infer loans made over the Bank of England's CHAPS Sterling settlement system (see Millard and Polenghi (2005) and Wetherilt Zimmerman and Soramaki (2010)), Switzerland's payment system, SIC (see Guggenheim, Kraenzlin, and Schumacher (2010),The Bank of Canada's LVTS payment system (see Allen, Hortacsu, and Kastl (2011)), and historical trade data from Amsterdam (see Quinn and Roberds (2010)).

[7] Consolidated Reports of Income and Condition (FR Y-9C) are available from the Federal Reserve online at http://chicagofed.org/webpages/banking/financial_institution_reports/bhc_data.cfm.

from non-bank financial intitutions.[8] Third, the algorithm will not include transactions that are settled on a bank's books. Finally, the algorithm will misattribute transactions of correspondent banking clients to the correspondent bank.

When we compare the algorithm estimates to the quarter-end fed funds borrowing reported by banks on their balance sheets, we find a positive, statistically significant relationship between *Fed Funds Purchased* and the estimates produced by the algorithm, with the algorithm estimates explaining as much as 78 percent of the quarterly variation in *Fed Funds Purchased*, and with an estimated coefficient from a regression of estimates on Y-9C actual of 0.887. While the correlation between the lending estimates and *Fed Funds Sold* on the Y-9C remains positive and statistically significant, the adjusted r-squared is lower (25%), and the coefficient is smaller (0.302). The result applies to a panel of banks over time, and thus there are likely to be specific banks in specific quarters for which the algorithm estimates may differ substantially from those reported on the Y-9C.

While we find that the amounts estimated by the algorithm are informative about fed funds activity, we are also interested in understanding if there is any bias in the estimates over and above the level differences between the estimates and the Y-9C amounts. This bias may emerge from characteristics of banks' payments that make some banks more likely to have payments misclassified as fed funds by the algorithm (such as being a large bank; or being one of the two tri-party repo clearing banks).[9] We calculate the difference between the Y-9C amounts and the estimates of fed funds borrowing and find no statistically significant association between this difference and bank characteristics such as assets, the percentage of non-performing loans (NPLs), or the percentage of repo financing. We do find that the algorithm is likely to substantially overstate fed funds activity for the two clearing banks. For fed funds lending, we find that the algorithm is likely to overstate lending for banks that finance themselves through repo transactions.

We are unable to evaluate the quality of the interest rates calculated by the algorithm for each bank, because the Y-9C aggregates interest on fed funds with interest on repo transactions. However, we compare the daily weighted-average interest rates to those collected by the FRBNY Markets Group in their survey of fed fund brokers. The rates in transactions identified by the algorithm as fed funds and the rates surveyed by the FRBNY are extremely similar – the adjusted r-squared approaches 100% and the estimated coefficient is 0.997. This similarity may seem unsurprising because we begin with a window around the effective rate. However, the correlation is high, which is reassuring, given that the algorithm selects transactions within a

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[8] The Y-9C definition also excludes transactions with Federal Home Loan Banks (FHLBs), so we exclude these from the estimates before executing the comparison.
[9] Copeland, Martin and Walker (2010) provide a detailed analysis of tri-party repo market in which settlement of tri-party repo transactions occur on the books of one of the two tri-party clearing banks.

window that spans 50 basis points above the maximum brokered rate in a particular day (high) and 50 basis points below the minimum brokered rate (low) on that day. In the time period we study, the effective fed funds rate ranged from 4 basis points to 541 basis points, and the algorithm window ranged from 0 basis points to 1500 basis points, so the window is large relative to the effective rate.[10] We are also unable to evaluate with the Y-9C data the ability of the algorithm to correctly identify counterparties, because we can evaluate only the assets and liabilities of particular banks and do not know their fed funds counterparties.

In summary, we find evidence that the estimates produced by the algorithm are potentially good proxies for overnight fed funds borrowing as reported by bank holding companies on their federally mandated, publicly available regulatory filings, although these estimates are subject to limitations. Specifically, the quality of the estimates appears to decline after the introduction of interest on excess reserves (IOER) starting on October 8, 2008.[11] The quality also appears to be lower for estimating lending and for the two clearing banks, which settle secured repo lending (tri-party repo). We believe that the estimates produced by the algorithm can more conservatively be defined as estimates of broader overnight interbank activity, rather than fed funds, which has specific regulatory definitions. The acknowledged limitations of the algorithm are likely to be important. The results produced by the algorithm are best interpreted as estimates, rather than as precise data on fed funds as obtained through regulatory authority.

The paper proceeds as follows. In section 2, we describe the algorithm used by the FRBNY and its limitations along with a discussion of why it is difficult to evaluate the quality of the estimates. In section 3, we present the methodology underlying our evaluation and report the outcome of this approach. In section 4, we compare this evaluation to the test proposed by A&C and evaluate the quality of that test. Section 5 concludes.

2. The FRBNY algorithm

A. Methodology

Furfine (1999) proposed an algorithm to extract payments likely to be fed funds transactions from the payments sent over the Fedwire Funds Service. This algorithm has been adapted over

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[10] The window can fall below 100 basis points when the minimum rate falls below 50 basis points, because the minimum rate is set to 0. The window became particularly large around the Lehman bankruptcy when the divergence between the daily high and low brokered rates was particularly large.

[11] At this point, the Federal Reserve used IOER to target the effective fed funds rate. The Federal Reserve no longer needed to sterilize the increasingly large level of reserves that flowed into the banking system as a by-product of the Federal Reserve's liquidity facilities and Large-Scale Asset Purchases (LSAP). Large reserve balances provided banks with liquidity buffers that dramatically decreased their need for fed funds borrowing.

the years by researchers at the FRBNY and Federal Reserve Board (FRB). The current FRBNY algorithm ("the algorithm") follows these general steps (see Appendix A for additional details):

- Step 1: Drop transactions by settlement institutions from pool of payments transferred over the Fedwire Funds Service.
- Step 2: Identify overnight loans by identifying all transfers from one institution to another in amounts equal to or greater than $1 million and ending in five zeros when there is a payment of a slightly higher amount in the opposite direction on the following business day. The difference between the two payments is interpreted as the interest rate on the loan. This set of potential fed funds loans is then refined by limiting the pool of overnight loans to include only those transactions for which the range of possible loan rates for the day are positive and within a window of 50 basis points below the minimum brokered fed funds rate (low) and 50 basis points above the maximum brokered fed funds rate (high) published by the Markets Group of the Federal Reserve Bank of New York from a daily survey of the four largest federal funds brokers.[12]
- Step 3: Identify a unique rate per fed funds loan using the median rate of matching payments

While transactions data are available at the ABA level, researchers may also aggregate up to the desired legal entity. For the purpose of this evaluation, we aggregate to the bank holding company level, dropping intrabank transactions between commercial bank subsidiaries of the same bank holding company.[13] For convenience, we refer to the transactions extracted from payments data from this algorithm as "the estimates."

Depending on the purpose of the data usage, researchers may also separate matched payment pairs in which the return leg has a business function of "CTR," which denotes "customer transfer" and means that a transfer is likely to be originated by a bank customer, rather than the bank itself. The predominant business function code is "BTR," which denotes "bank transfer." Earlier work by McAndrews (2009) finds that the customer transfer code on return legs is a good proxy for a Eurodollar loans in a set of brokered transactions, whereas a return-leg code that is not a customer transfer is a good proxy for fed funds loans. It is unclear if the customer code is used in every transaction which is customer driven. In this analysis, we exclude transactions that have a return leg tagged with the customer transfer code.

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[12] Data are available at http://www.newyorkfed.org/markets/omo/dmm/fedfundsdata.cfm.
[13] Based on comparisons of Call Report and aggregated Y-9C filings, there can often be a substantial amount of intrabank fed funds lending within subsidiaries of the same bank holding company.

B. Why is the quality of Fed Funds estimates difficult to estimate?

The algorithm to extract information on fed funds from payments data was developed in part because general as well as more detailed current and historical information on overnight interbank lending, such as volume, interest rates, and counterparties, was not otherwise fully available to researchers at the Federal Reserve. The algorithm quality is difficult to assess because, to the extent that interbank loan data have been collected historically by supervisors, data are either not available to researchers or have not been collected at a disaggregated level. For example, supervisory data may focus on the liabilities of a particular bank, without reference to counterparties or rates. In particular, there may be a substantial regulatory burden to collect daily the counterparty information on banks' overnight borrowing on a trade level basis. Supervisory data on overnight liabilities may combine secured and unsecured funding, or include long-term debt maturing within a day. Finally, supervisory data may not be immediately available, or may not be accessible for research purposes.

Fed funds data have also been collected historically from interbank brokers by the Markets Group of the FRBNY in the form of the daily amount of fed funds transacted, aggregated per borrowing rate, per broker. These data do not include individual fed funds transaction dollar values or number of trades, information on counterparties, transactions of non-brokered fed funds, and other types of overnight wholesale funding.

Verifying the algorithm is complicated by definitional differences. Fed funds loans may refer very narrowly to unsecured overnight loans of immediately available reserves at banks (known as "Regulation D" fed funds, as defined by the Board of Governors of the Federal Reserve System, and as used in Armantier and Copeland (2012)). The Y-9C definition appears somewhat broader as it includes all overnight loans among banks that are not secured by securities. Practitioners may use the term to include all overnight loans among financial institutions that are not repos. For example, in interviews with practitioners, some referred to overnight loans to nonbank broker-dealers as "fed funds," even though broker-dealers are not depository institutions, and thus would not fit the narrower definitions of fed funds loans. Similarly, loans transacted between two US fed funds desks but accounted for as liabilities or assets of offshore subsidiaries may be referred to as fed funds, even though Federal Reserve definitions of fed funds require transactions to be among US entities. These offshore transactions would be defined by the Federal Reserve as Eurodollars. Policymakers and academics may be interested in unsecured overnight loans more broadly among financial institutions (including non-depository institutions). The estimates produced by the FRBNY algorithm do not distinguish among these definitions, but are based on payment characteristics only.

Finally, the algorithm quality is also difficult to assess because of the separation within banks of the front office, such as trading positions and balance sheet data, and the back office, such as

payments clearing and settlement data. Anecdotally, there may be differences between trading-desk records logged at the time of trade; payments data entered when transactions are cleared and settled; and aggregated balance sheet or accounting data listed on regulatory reports at reporting frequencies. Overnight loans between banks are traded by voice over the telephone and do not require individual trade documentation between counterparties. Fed funds traders state that they at times do not distinguish between fed funds and Eurodollars. Overnight fed funds and Eurodollars between banks are at times economically equivalent, as both types of borrowing do not have reserve requirements. Regulation D specifies fed funds as exempt from reserve requirements. Eurodollar borrowing is held in offshore accounts that also avoid reserve requirements. The designation of fed funds and Eurodollars may depend, for example, on whether payments are settled on Fedwire or CHIPS. Evaluations of the algorithm may make use of aggregate balance sheet data, such as the Y-9C data.

3. Evaluating the FRBNY algorithm

A. Y-9C Regulatory Filings

All domestic bank holding companies (BHCs) with assets in excess of $500 million are required to file the FR Y-9C *Consolidated Financial Statements for Bank Holding Companies* which collects basic financial data on a consolidated basis. According to the Federal Reserve website, "The information is used to assess and monitor the financial condition of bank holding company organizations, which may include parent, bank, and nonbank entities. The FR Y-9C is a primary analytical tool used to monitor financial institutions between on-site inspections. The form contains more schedules than any of the FR Y-9 series of reports and is the most widely requested and reviewed report at the holding company level."[14] This report is required under Regulation Y and the Bank Holding Company Act of 1956 as amended.

The balance sheet schedule on the Y-9C filing includes the line items "Federal Funds purchased in domestic offices" (Item BHDM B993), and "Federal funds sold in domestic offices"(Item BHDM B987), which capture all fed funds borrowing and lending by the domestic office of the bank holding company as of the quarter end date. The definition of these items is found in Appendix B. While the definition specifically excludes term loans and repos (loans secured by securities), it may include some overnight loans secured by collateral other than securities.

For the 28 quarters beginning January 1, 2005 and ending December 31, 2011, we begin with a sample of the 1,295 (1,920) BHCs with non-zero Y-9C borrowing (lending) and use the algorithm

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[14] http://www.federalreserve.gov/apps/reportforms/reportdetail.aspx?sOoYJ+5BzDal8cbqnRxZRg== accessed December, 2012.

to estimate fed funds transactions for these BHCs on the last day of each quarter. The algorithm produces 1,896 (1,937) quarter-end non-zero fed funds borrowing (lending) transactions observations, as shown in Table 1. We add up the estimated amount borrowed and the amount lent by each BHC on the last day of the quarter, creating an estimate of the total of fed funds that should be outstanding at quarter end.[15] Figure 1 shows the output of the Y-9C and the algorithm for three banks as an example. Generally, the algorithm output seems to move along with the Y-9C figures, although the measures sometimes diverge.

Table 3 summarizes the simple correlations between the Y-9C amounts and the amounts generated by the algorithm. The Y-9C amounts and the algorithm amounts are statistically significantly correlated, suggesting that the algorithm measures may be useful for researchers to understand fed funds activity, particularly borrowing. The overall correlation between the Y-9C amount borrowed (lent) and the algorithm estimates is 0.822 (0.516).

In Table 4 we replicate the correlation analysis with a simple regression analysis, using the Y-9C borrowing amount for each bank as the dependent variable and the algorithm amount as the explanatory variable for each of the BHCs that we observe in the algorithm.[16] We cluster standard errors at the BHC level to account for the fact that errors may not be independent across BHCs. We begin by evaluating the hypothesis that amounts produced by the algorithm are associated with the actual fed funds transactions of the bank. We begin with a sample of all banks which have a non-zero Y-9C and algorithm amount in the sample period and examine if there is any relationship between the algorithm amount and the actual amount on the Y-9C. We estimate a positive, statistically significant coefficient on the algorithm estimate (0.814), with a high adjusted r-squared of 0.71. We also estimate a positive number for the constant term, suggesting that the algorithm estimates are on average lower than the Y-9C amounts.

In the next two specifications, we split the sample between the pre- and post-IOER time periods, before and after October 8, 2008. The association between the algorithm estimates and the Y-9C amounts is lower after the third quarter of 2008. This may be a measure of the underlying noise in the algorithm, since with the large amounts of excess reserves, interbank fed funds activity falls to much lower amounts. If there is very low fed funds activity, and noise remains relatively stable, the proportion of noise relative to fed funds transactions identified by the algorithm increases.

In the fourth regression specification, we leave out quarters in which the total Y-9C amount borrowed is zero in order to understand whether the associations we document are driven by

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[15] We exclude transactions with Federal Home Loan banks (FHLBs), because these loans are specifically excluded from the Y-9C definition.
[16] We exclude the tri-party repo clearing banks from this analysis because we know they are likely to have transactions mischaracterized by the algorithm as fed funds.

the algorithm's accuracy at estimating actual activity or at estimating zeros. Results are similar to the initial specifications. Next we include the log of assets as a control and find that while the estimated coefficient falls slightly, correlations are not solely a function of size. In order to understand the impact of misidentifying potential tri-party repo related or other clearing bank transactions, in the sixth specification, we add the clearing banks to the sample and include a dummy variable for those two banks. The algorithm appears to perform less well for the clearing banks. The coefficient on the clearing bank dummy is a very large negative number and the estimated coefficient is statistically significantly lower (negative coefficient on the interaction of tri-party and the algorithm estimate), consistent with the algorithm misattributing transactions to the clearing banks. We explore alternative estimation methods in the next three specifications, and find qualitatively similar results if estimating without a constant, and using a median or tobit regression. When we narrow the sample to banks that borrow frequently in the algorithm data (more than 100 days), the estimated coefficient and adjusted r-squared increase, even though the number of observations is dramatically smaller.

Finally, we want to understand how well the algorithm captures fed funds activity in general. Therefore, we examine all 2,516 BHCs that file a Y-9C form, even those for which the algorithm never produces a non-zero fed funds number, and those which report no fed funds borrowing on the Y-9C. This analysis will help us understand if we are likely to correctly estimate that a bank never borrows, if the algorithm estimates zero borrowing for the bank. The result is 33,403 quarters of Y-9C observations. It appears that the algorithm is correctly estimating zero borrowing for many banks, because we again estimate a positive, statistically significant coefficient on the algorithm estimates (0.637), although the adjusted r-squared declines to 0.37.

In each of the twelve specifications we find a positive, statistically significant relationship between *Fed Funds Purchased* (borrowed) and the estimates produced by the algorithm, with the algorithm estimates explaining approximately 7 to 78 percent of the quarterly variation in *Fed Funds Purchased*. In the pre IOER period, the estimated coefficient from a regression of estimates on Y-9C actual is 0.887, with an adjusted r-squared of 0.78.

We repeat the analysis for *Fed Funds Sold* (lending) and summarize the results in Table 5. While in every specification we estimate a positive, statistically significant relationship between the Y-9C amount and the algorithm estimate, the coefficient and the adjusted r-squared are both smaller. We estimate an association between the Y-9C amount and the algorithm estimate with a coefficient of 0.302 in the pre-IOER period, with an adjusted R-squared of 0.25. Other than in the post-IOER period, in each of the specifications we find a positive, statistically significant relationship between *Fed Funds Sold* and the estimates produced by the algorithm, with the algorithm estimates explaining approximately 1 to 48 percent of the quarterly

variation in *Fed Funds Sold*. The difference between the association of the algorithm's estimates to the Y-9C figures for lending and borrowing warrants further investigation. Since the estimated constant is positive (on average Y-9C is higher than algorithm estimate), the results may be consistent with lenders in the sample lending to other banks (possibly not BHCs, but commercial banks "on-the-books"). It is also possible that some lending that we are attributing to a particular bank is actually lending done by that bank's clients.

We next look to see if changes in the amounts predicted by the algorithm are associated with changes in the Y-9C amounts, focusing on the subset of banks which have at least one non-zero Y-9C amount and one non-zero algorithm estimate over the sample period (approximately 355 banks). This analysis is particularly relevant since policy makers may be interested in understanding not just the levels of fed funds activity, but whether banks are increasing or decreasing their funding in this market. In Tables 6 and 7, we replicate much of the analysis from Tables 4 and 5, replacing as the dependent variable the change in borrowing or lending and controlling in each specification for the size of the BHC with the log of total assets. The change in borrowing (lending) fed funds reported by the algorithm is statistically significantly associated with the change in fed funds reported in the Y-9C. The coefficient is 0.211 (0.367) and the adjusted r-squared is 0.22 (0.06) for borrowing (lending). We analyze the same sub-samples and have similar results. We conclude that, on average, changes in fed funds activity identified by the algorithm will move together with changes in fed funds activity reported on the Y-9C. It is important, however, to note that this does not necessarily mean that in every quarter and for every bank, the two measures will move in the same direction at quarter end.

B. Are differences between Y-9C Regulatory Filings and estimates associated with bank characteristics?

Since we would expect that the algorithm estimates are measured with error, we are interested in understanding if this measurement error is biased. A better understanding of the measurement error will help us understand the extent to which we can make inferences about banks' fed funds. Thus at each quarter end, we estimate the difference between the amount borrowed and lent as per the BHC's regulatory filings and the amount estimated by the algorithm on the last date of each quarter. We begin by looking for bias across the panel of banks and run regressions to see if there is an association between bank characteristics and the difference between fed funds loans measured by the algorithm and those reported on banks' Y-9C. These results are summarized in Table 8 for borrowing and Table 9 for lending. In each regression specification, the dependent variable is the difference between the algorithm and the Y-9C amount. In each specification we include a different bank characteristic as the independent variable, including: Size (log of assets), level of the amount of fed funds activity (from the Y-9C), the total dollar volume of all Fedwire payments for that bank in the last day of

the quarter, capital (Tier 1 capital divided by assets from the latest quarter end), riskiness (the percentage of non-performing loans), and percent repo financing. After controlling for size, the difference appears to be lower for banks that are more active fed funds borrowers as proxied for by the previous period's Y-9C fed funds borrowing. Other than this, we find no statistically significant association between the difference in borrowing and bank characteristics, although we do see that the two clearing banks are significantly associated with higher differences. We do find a statistically significant association between the difference in lending and the volume of Fedwire payments. There was no significant explanatory power of geography – fixed effects for state and Fed district were not jointly statistically significant (not shown).

It appears that differences are serially correlated (the difference at time t is positively correlated with the difference at time $t-1$ and the explanatory power of the lagged difference is high). When we estimate bank fixed effects (specification 9), a joint test of significance of the fixed effects rejects the null that bank fixed effects are not statistically significant at the 1 percent level, and bank fixed effects explain approximately 30 percent of the variation in the difference. Interestingly, time fixed effects do not have significant explanatory power in explaining the difference between the Y-9C and algorithm estimated amount (Specification 10).

4. A comparison of the FRBNY estimates to other data sources

Armantier and Copeland (2012) propose a test of algorithm estimates of fed funds transactions in which they examine in detail the payments of two large banks. Their methodology makes use, for each of two particular banks, of a bank-provided code which serves to "identify unambiguously the receive leg of every fed funds transaction" for the two banks' payments over the Fedwire Funds Service. As discussed in Section 2B, comparisons based on payments data which identify particular transactions, such as described in A&C, and comparisons based on balance sheet data, such as done in this paper, may differ for a number of reasons. We are interested in understanding how the payments transactions flagged by two banks as fed funds payments examined in A&C compare to the aggregate measures of fed funds as reported in the Y-9C. To the extent that the "unique identifier" provided by the two banks to A&C captures all fed funds transactions recorded in the Y-9C, then the summation of transactions flagged by the identifier should be close to the Y-9C amount (see below). Therefore, we repeat the methodology described in Section 3, comparing estimates flagged by the two banks and used in the A&C test as fed funds transactions to the Y-9C fed funds amounts for the first quarter of each year, which are the quarter end dates included in the A&C study, for a total of 12 observations for lending and 14 for borrowing. We refer to the quarter-end total estimates for fed funds activity calculated from transactions flagged with the bank-provided code and used in A&C as the "A&C estimates."

Differences between the A&C estimates and the Y-9C amounts may arise from: i) transactions that are done on the banks' books (not cleared over the Fedwire Funds Service) and ii) term fed funds transactions (which are flagged with the same identifier). In addition, the Y-9C definition includes overnight loans secured by instruments other than securities, and thus differs from the Regulation D definition. Since the flag has been voluntarily provided by the banks, it is difficult to confirm the exact definition of fed funds these banks (and their counterparties) are applying and how it may differ from the fed funds definition in the Y-9C.

The following identity should roughly hold:

$$\text{A\&C flag}_{b,t} - \text{Y-9C}_{b,t} = \text{Term fed funds}_{b,t} - \text{On the books transactions}_{b,t} + \text{definitional diff}_{b,t}$$

where b indexes the two banks, t indexes quarters and *definitional diff* is any differences between the Y-9C definition and the definition of transactions that are flagged.

Panels B and C of Table 3 tabulate the correlations for each of the two banks between the bank's flagged estimate (A&C estimate), Y-9C amount purchased or sold and the algorithm estimate. If on-the-books transactions and definitional differences are roughly constant over 7 quarters for each bank, we would expect the correlations for the A&C estimate to be high, since it is based on flags provided by the banks and meant to be a comprehensive measure for fed funds activity. The correlation between the A&C estimate and Y-9C fed funds purchased is 0.366 for one bank and 0.717 for the other bank tested in A&C. The correlation between the A&C estimate and the Y-9C fed funds sold is -0.097 and 0.682. The comparable correlations for the FRBNY algorithm estimates with the Y-9C for the two banks are 0.281 and 0.806 for fed funds sold and 0.579 and 0.647 for fed funds borrowed. However, these correlation comparisons are based on 12 and 14 observations, respectively. As such, they are very sensitive to any one observation in each sample.

For both banks tested by A&C, in 1 out of 7 quarters, the flag identifies 0 fed funds purchased on the last day of the quarter while the Y-9C has non-zero amounts. For fed funds sold, in at least 2 out of 6 quarters, the flag identifies 0 fed funds sold while the Y-9C has non-zero amounts. This difference implies that in more than ten percent of all quarters these two banks' only fed funds transactions are on their own books (i.e. with banks with accounts at their banks) or that the difference between the Y-9C and the definition associated with the banks' identifiers used in A&C is very large.[17] In this same sample, there are no quarters in which the algorithm estimated zero amounts when the Y-9C has non-zero amounts.

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[17] One main definitional difference is that the Y-9C includes overnight loans secured by instruments other than securities, so for example, if a large amount of transactions are secured by instruments other than securities, that would be another explanation of the difference. Anecdotally, practitioners do not believe that a large amount of transactions are secured by instruments other than securities.

Since the Y-9C data is balance sheet data, rather than payments data, we cannot identify the source of the difference between the sum of the transactions flagged by the banks used in A&C on the last day of the quarter and the Y-9C amounts. Because the A&C estimates are lower than the Y-9C values, it is possible that there are payments transactions that meet the definition of Y-9C fed funds but are not flagged by the banks' identifiers. These payments may be those that the FRBNY algorithm flags as fed funds but A&C identify as "false positives."

5. Conclusions

Evaluating the quality of the estimates produced by the Furfine algorithm continues to be an important work in progress. In this paper, we propose an evaluation of the quality of the fed funds estimates based on regulatory filings. As noted in many research papers using these data, there are known shortcomings in the estimates produced by the algorithm, and researchers and readers should continue to highlight these issues. However, until such time as improved data are collected and disseminated to researchers, we conclude that the estimates produced by the FRBNY algorithm are useful measures of overnight fed funds activity, specifically in that they are correlated with one measure of such activity. This approach has some advantages relative to the test proposed by Armantier and Copeland (2012). First, it allows the evaluation of the algorithm on multiple banks over time. In addition, it allows for an understanding of the extent to which the known issues in the algorithm introduce bias. Unfortunately, there are several disadvantages of the approach described here as well—it does not allow for a quantification of Type I and Type II error and it relies on quarter end data, which may be substantially different from intra-quarter activity.

Evaluating the quality of an estimate is not straightforward. In the social sciences, where there is often no measure of the underlying object of interest, Carmines and Zeller (1979) define good estimates as those that are both reliable and valid. Reliability captures the notion that the estimates produce consistent results across repeated measurements, while validity concerns the relationship between the estimator and the concept being evaluated. The classic example is that of the 35 inch yardstick, which is completely reliable, but not valid. On the other hand, if you know that your yardstick is only 35 inches, you can still measure things. We conclude in this study that Furfine-based estimates are informative about the object of interest. However, as Carmines and Zeller note, "one does not assess the validity of the indicator, but rather the use to which it is being put." (p. 5). We echo the caution of Armantier and Copeland (2012) in emphasizing that these estimates are not precise measures and their validity in any particular project should be interpreted only with a careful understanding of the process by which they are extracted from payments data and with an eye towards understanding the known weaknesses of the methodology.

FIGURE 1: SAMPLE Y-9C and ALGORITHM OUTPUT

BHC #10
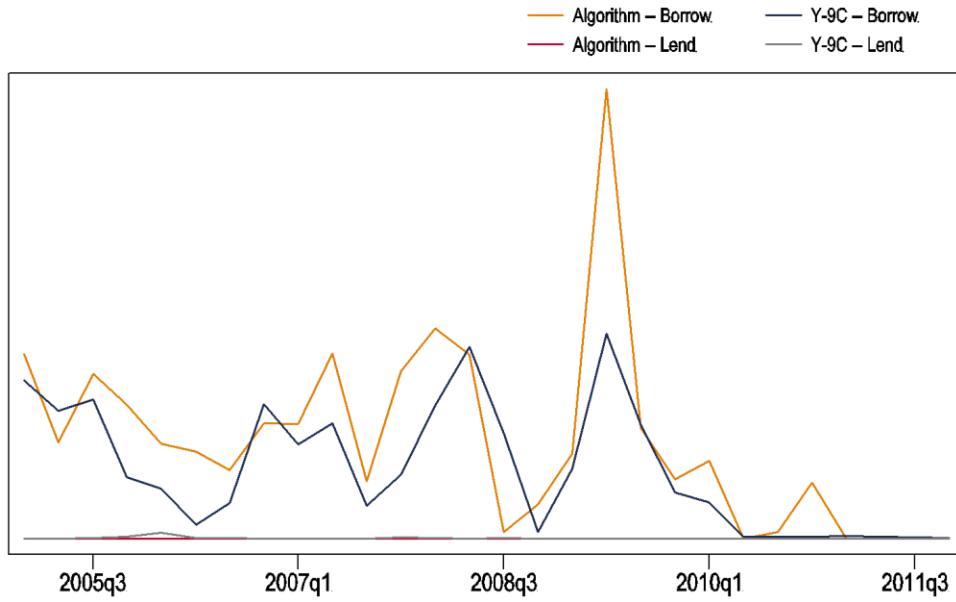
BHC #6
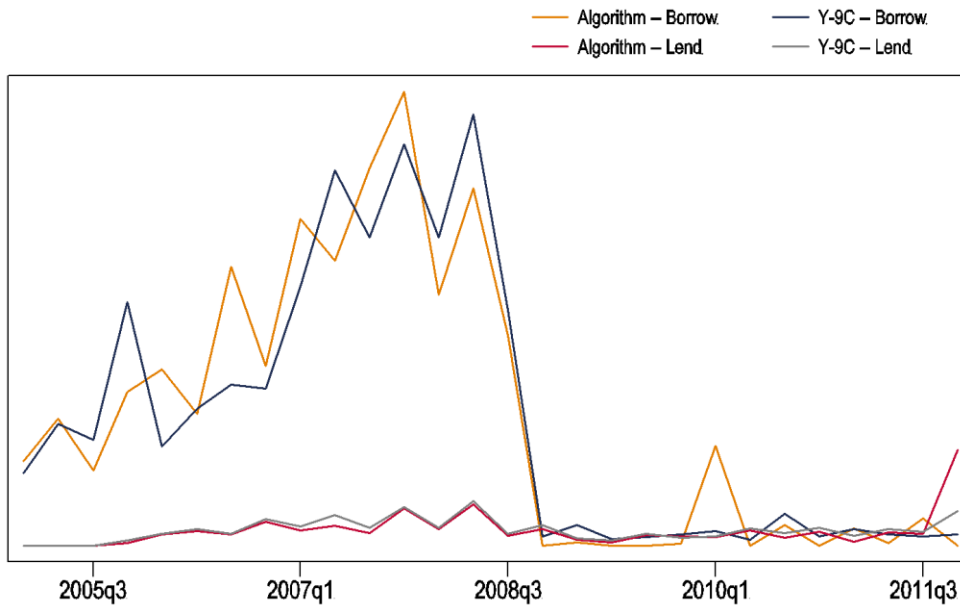
Note: Figures are presented without scales in order to maintain confidentiality of banks. Orange (red) line indicates fed funds borrowed (lent) at quarter end based on the algorithm while blue (grey) lines indicate fed funds borrowed (lent) based on the Y-9C.

TABLE 1: SUMMARY STATISTICS

$ MM	Obs.	Mean	StDev.	25%	50%	75%
All Observations						
Y-9C -- Borrow	20,714	100	790	0	0	5
Y-9C -- Lend	26,693	31	293	0	3	15
Algorithm -- Borrow	20,714	103	1,021	0	0	0
Algorithm -- Lend	26,693	39	538	0	0	0
Excluding 0's						
Y-9C -- Borrow	8,024	259	1,254	3	11	44
Y-9C -- Lend	18,180	46	354	3	9	25
Algorithm -- Borrow	1,896	1,123	3,200	23	91	602
Algorithm -- Lend	1,937	531	1,930	14	45	226
Fedkey -- All Observations						
Fedkey -- Borrow	14	1,942	2,587	163	592	4,575
Fedkey -- Lend	12	437	1,311	0	23	155
Y-9C -- Borrow	14	11,007	7,014	3,820	10,937	15,683
Y-9C -- Lend	12	3,170	5,375	154	340	3,995
Fedkey -- Excluding 0's						
Fedkey -- Borrow	12	2,266	2,667	372	856	4,680
Fedkey -- Lend	7	749	1,697	25	141	208
Y-9C -- Borrow	14	11,007	7,014	3,820	10,937	15,683
Y-9C -- Lend	12	3,170	5,375	154	340	3,995

Note: The data is quarterly and covers 1,295 borrowing (1,920 lending) BHCs from 1/1/2005 – 12/31/2011. All units are USD millions. *Y-9C* refers to the FR Y-9C form. *Algorithm* refers to the Furfine algorithm for fed funds inferences. *Fedkey* refers to the data used in A&C for two specific banks from 1/1/2005 – 3/31/2011. *All Observations* means those observations for which we have both Y-9C and algorithm data for a particular quarter-end date. *Excluding 0's* means leaving out observations for which Y-9C reported fed funds activity is zero on a particular quarter-end date.

Avg Daily Rate	(1)		(2)		(3)	
Effective FF Rate	0.997	***				
	0.001					
FF High			0.887	***		
			0.006			
FF Low					0.989	***
					0.008	
Constant	0.026	***	-0.100	***	0.441	***
	0.002		0.023		0.023	
Observations	1,760		1,760		1,760	
Adjusted R-squared	1.00		0.91		0.89	

Note: The data are daily and cover 1,295 borrowing (1,920 lending) BHCs from 1/1/2005 – 12/31/2011. *Avg Daily Rate* is the daily value-weighted fed funds rates calculated from the Furfine algorithm. *Effective FF Rate* is the effective rate published by the FRBNY Markets Group. *FF High* and *FF Low* are the high and low rates at which fed funds were transacted, also obtained from the FRBNY Markets Group.

TABLE 3: CORRELATIONS

Table #3a: All BHCs

	(1)	(2)	(3)
(1) Y-9C -- Borrow			
(2) Y-9C -- Lend	0.317 ***		
(3) Algorithm -- Borrow	0.822 ***	0.400 ***	
(4) Algorithm -- Lend	0.444 ***	0.516 ***	0.538 ***

Table #3c: Bank #1 - Borrow

	(1)	(2)
(1) Y-9C -- Borrow		
(2) Algorithm -- Borrow	0.579 ***	
(3) A&C -- Borrow	0.366	0.206

Table #3d: Bank #1 - Lend

	(1)	(2)
(1) Y-9C -- Lend		
(2) Algorithm -- Lend	0.281 **	
(3) A&C -- Lend	-0.097	-0.018

Table #3c: Bank #2 - Borrow

	(1)	(2)
(1) Y-9C -- Borrow		
(2) Algorithm -- Borrow	0.647 ***	
(3) A&C -- Borrow	0.717 ***	0.741 ***

Table #3d: Bank #2 - Lend

	(1)	(2)
(1) Y-9C -- Lend		
(2) Algorithm -- Lend	0.806 ***	
(3) A&C -- Lend	0.682 ***	0.423

Note: The data are quarterly and cover 1,295 borrowing (1,920 lending) BHCs from 1/1/2005 – 12/31/2011. *Y-9C* refers to the FR Y-9C form. *Algorithm* refers to the Furfine algorithm for fed funds inferences. *A&C* refers to the data used in A&C for two specific banks from 1/1/2005 – 3/31/2011.

TABLE 4: BORROWING

Y-9C -- Borrow		Algorithm -- Borrow		Log Assets		Triparty Repo	Triparty Repo x Algorithm		Constant		Observations	Adjusted R-squared
Sample	(1)	**0.814**	***						27.310	***	20,668	0.71
		0.060							*4.965*			
Pre-IOER	(2)	**0.887**	***						30.570	***	12,073	0.78
		0.076							*4.940*			
Post-IOER	(3)	**0.474**	***						26.280	***	8,595	0.36
		0.120							*7.509*			
No Zeros	(4)	**0.807**	***						72.300	***	7,978	0.70
		0.060							*12.630*			
Size controls	(5)	**0.770**	***	54.210	***				-354.700	***	20,668	0.72
		0.061		*12.300*					*86.190*			
Incl. TPR banks	(6)	**0.814**	***			-1270.000	-0.253	***	27.310	***	20,714	0.72
		0.060				*957.800*	*0.073*		*4.965*			
No constant	(7)	**0.818**	***								20,668	0.71
		0.060										
Median	(8)	**1.026**	***						0.000		20,668	0.50
		0.000							*0.001*			
Tobit	(9)	**0.875**	***						-373.467	***	20,668	0.07
		0.059							*89.030*			
Frequent	(10)	**0.852**	***						136.000	***	3,183	0.74
		0.048							*32.350*			
All Y-9C -- OLS	(11)	**0.635**	***						53.423	***	33,403	0.37
		0.072							*9.523*			
All Y-9C -- Probit	(12)	**2.637**	***						-0.688	***	33,403	0.11
		0.112							*0.023*			

Note: The data are quarterly and cover 1,295 borrowing BHCs from 1/1/2005 – 12/31/2011. *Y-9C* refers to the FR Y-9C form. *Algorithm* refers to the Furfine algorithm for fed funds inferences. *Log Assets* is the logarithm of assets. *Triparty Repo* is a dummy variable equal to one if the BHC is a tri-party repo clearing bank or an entity which, by mergers, will become a tri-party repo clearing bank. Specifications (1) through (10) are run using all observations for which we have both Y-9C and algorithm data for a particular quarter-end date. Specification (2) is run on the subset of observations taking place in the pre-IOER period (prior to 10/3/2008). Specification (3) is run on the subset of observations taking place in the post-IOER period. Specification (4) is run on the subset of observations for which the Y-9C reported fed funds borrowing is nonzero. Specification (5) controls for BHC size using log of assets. Specification (6) incorporates the tri-party repo dummy and the interaction term and is run on the whole time period. Specification (7) is a repeat of (1), now with no constant. Specifications (8) and (9) are median and tobit regressions, respectively. Specification (10) is run on only frequent borrowers, where frequent is defined as borrowing on 100 or more days in the interbank market from 7/1/2005 through 7/31/2008. Specifications (11) and (12) are run using all observations for which we have Y-9C data, regardless of the transactions identified by the Furfine algorithm. All errors are clustered at the BHC level.

TABLE 5: LENDING

Y-9C -- Lend		Algorithm -- Lend		Log Assets		Triparty Repo		Triparty Repo x Algorithm		Constant		Observations	Adjusted R-squared
Sample	(1)	0.125	**							22.390	***	26,647	0.10
		0.063								2.473			
Pre-IOER	(2)	0.302	**							25.700	***	15,879	0.25
		0.131								3.590			
Post-IOER	(3)	0.004								11.490	***	10,768	0.00
		0.004								0.942			
No Zeros	(4)	0.268	**							28.690	***	18,134	0.22
		0.127								3.311			
Size controls	(5)	0.108	*	28.850	***					-177.900	***	26,647	0.15
		0.059		6.311						41.840			
Incl. TPR banks	(6)	0.125	**			-2447	***	0.783	***	22.390	***	26,693	0.48
		0.063				447		0.097		2.473			
No constant	(7)	0.128	**									26,647	0.11
		0.064											
Median	(8)	0.141	***							2.600	***	26,647	0.02
		0.000								0.083			
Tobit	(9)	0.132	***							-34.542	***	26,647	0.01
		0.021								8.198			
Frequent	(10)	0.079	**							83.540	***	3,634	0.06
		0.033								15.570			
All Y-9C -- OLS	(11)	0.281	**							24.068	***	33,403	0.20
		0.140								3.491			
All Y-9C -- Probit	(12)	1.478	***							0.317	***	33,403	0.03
		0.155								0.023			

Note: The data are quarterly and cover 1,920 lending BHCs from 1/1/2005 – 12/31/2011. *Y-9C* refers to the FR Y-9C form. *Algorithm* refers to the Furfine algorithm for fed funds inferences. *Log Assets* is the logarithm of assets. *Triparty Repo* is a dummy variable equal to one if the BHC is a triparty repo clearing bank or an entity which, by mergers, will become a triparty repo clearing bank. Specifications (1) through (10) are run using all observations for which we have both Y-9C and algorithm data for a particular quarter-end date. Specification (2) is run on the subset of observations taking place in the pre-IOER period (prior to 10/3/2008). Specification (3) is run on the subset of observations taking place in the post-IOER period. Specification (4) is run on the subset of observations for which the Y-9C reported fed funds borrowing is nonzero. Specification (5) controls for BHC size using log of assets. Specification (6) incorporates the triparty repo dummy and the interaction term and is run on the whole time period. Specification (7) is a repeat of (1), now with no constant. Specifications (8) and (9) are median and tobit regressions, respectively. Specification (10) is run on only frequent lenders, where frequent is defined as lending on 100 or more days in the interbank market from 7/1/2005 through 7/31/2008. Specifications (11) and (12) are run using all observations for which we have Y-9C data, regardless of the transactions identified by the Furfine algorithm. All errors are clustered at the BHC level.

TABLE 6: CHANGES IN BORROWING

Change in Y-9C	Sample		Pre-IOER		Post-IOER	No Zeros		Incl. TPR banks		No constant		Tobit		Frequent		All Y-9C OLS	
	(1)		(2)		(3)	(4)		(5)		(6)		(7)		(8)		(9)	
Change in Algorithm	0.211	***	0.252	***	0.144	0.211	***	0.211	***	0.210	***	0.274	***	0.218	***	0.210	***
	0.068		0.050		0.142	0.068		0.068		0.068		0.087		0.077		0.068	
Log Assets	-0.002		0.005		0.034	-0.002		-0.003		0.006	*	0.065		(0.025)		(0.001)	
	0.018		0.019		0.035	0.018		0.018		0.003		0.061		0.022		0.016	
Triparty Repo								0.118									
								0.173									
Triparty Repo x Change Alg								-0.110									
								0.180									
Constant	0.078		0.050		-0.415	0.078		0.089				-2.924	**	0.324		0.070	
	0.177		0.192		0.415	0.177		0.176				1.269		0.219		0.163	
Observations	1,761		1,359		402	1,761		1,805		1,761		1,761		1,512		1,805	
Adjusted R-squared	0.22		0.46		0.07	0.22		0.22		0.23		0.05		0.22		0.22	

Note: The data is quarterly and covers 1,295 borrowing BHCs from 1/1/2005 – 12/31/2011. *Change in Y-9C* is the percent change in amount according to the FR Y-9C form. *Change in Algorithm* is the percent change in amount according to the Furfine algorithm for fed funds inferences. *Log Assets* is the logarithm of assets. *Triparty Repo* is a dummy variable equal to one if the BHC is a triparty repo clearing bank or an entity which, by mergers, will become a triparty repo clearing bank. Specifications (1) through (8) are run using all observations for which we have both Y-9C and algorithm data for a particular quarter-end date. Specification (2) is run on the subset of observations taking place in the pre-IOER period (prior to 10/3/2008). Specification (3) is run on the subset of observations taking place in the post-IOER period. Specification (4) is run on the subset of observations for which the Y-9C reported fed funds borrowing is nonzero. Specification (5) incorporates the triparty repo dummy and the interaction term and is run on the whole time period. Specifications (6) and (7) are repeats of (1), with no constant and as a tobit regression, respectively. Specification (8) is run on only frequent borrowers, where frequent is defined as borrowing on 100 or more days in the interbank market from 7/1/2005 through 7/31/2008. Specifications (9) and (10) are run using all observations for which we have Y-9C data, regardless of the transactions identified by the Furfine algorithm. All errors are clustered at the BHC level.

TABLE 7: CHANGES IN LENDING

Change in Y-9C	Sample		Pre-IOER		Post-IOER	No Zeros		Incl. TPR banks		No constant		Tobit		Frequent		All Y-9C OLS	
	(1)		(2)		(3)	(4)		(5)		(6)		(7)		(8)		(9)	
Change in Algorithm	0.367	**	0.370	**	0.272	0.367	**	0.368	**	0.376	**	0.697	***	0.382	**	0.368	**
	0.156		0.159		0.233	0.156		0.156		0.155		0.237		0.172		0.155	
Log Assets	0.262	**	0.274	**	0.219	0.262	**	0.256	**	0.090	***	0.405	**	0.235	*	0.231	**
	0.119		0.134		0.138	0.119		0.119		0.025		0.172		0.132		0.107	
Triparty Repo								-0.957									
								1.017									
Triparty Repo x Change Alg								-0.368									
								0.262									
Constant	-1.543	*	-1.683	*	-1.005	-1.543	*	-1.498	*			-9.477	***	-1.328		-1.310	
	0.900		1.018		1.070	0.900		0.900				2.467		1.030		0.816	
Observations	1,764		1,460		304	1,764		1,808		1,764		1,764		1,400		1,808	
Adjusted R-squared	0.06		0.08		0.01	0.06		0.06		0.07		0.02		0.07		0.06	

Note: The data is quarterly and covers 1,920 lending BHCs from 1/1/2005 – 12/31/2011. *Change in Y-9C* is the percent change in amount according to the FR Y-9C form. *Change in Algorithm* is the percent change in amount according to the Furfine algorithm for fed funds inferences. *Log Assets* is the logarithm of assets. *Triparty Repo* is a dummy variable equal to one if the BHC is a triparty repo clearing bank or an entity which, by mergers, will become a triparty repo clearing bank. Specifications (1) through (8) are run using all observations for which we have both Y-9C and algorithm data for a particular quarter-end date. Specification (2) is run on the subset of observations taking place in the pre-IOER period (prior to 10/3/2008). Specification (3) is run on the subset of observations taking place in the post-IOER period. Specification (4) is run on the subset of observations for which the Y-9C reported fed funds borrowing is nonzero. Specification (5) incorporates the triparty repo dummy and the interaction term and is run on the whole time period. Specifications (6) and (7) are repeats of (1), with no constant and as a tobit regression, respectively. Specification (8) is run on only frequent lenders, where frequent is defined as lending on 100 or more days in the interbank market from 7/1/2005 through 7/31/2008. Specifications (9) and (10) are run using all observations for which we have Y-9C data, regardless of the transactions identified by the Furfine algorithm. All errors are clustered at the BHC level.

TABLE 8: DIFFERENCES IN BORROWING

Difference in Borrowing	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Log Assets	-5.404	17.940	-30.130 **	-5.482	-5.568	-7.736	-5.503	3.469	50.350	-6.442	24.338
	19.070	*17.870*	*13.800*	*19.000*	*19.130*	*18.620*	*19.050*	*9.109*	*41.620*	*19.540*	*45.792*
Lag Log Y-9C		-27.280 ***									-12.998 ***
		7.335									*4.321*
Fedwire Payments			0.003								0.007
			0.003								*0.007*
% Tier 1 Equity				-0.257							2.575
				0.489							*2.178*
% NPL					2.577						2.908
					1.941						*2.445*
% Repo						2.192					7.032
						3.431					*11.434*
Triparty Repo							7,441.000 ***				
							228.600				
Lag Difference								0.675 ***			
								0.081			
Constant	24.460	-111.70	191.700 **	26.930	21.720	35.240	25.150	-28.150	-371.70	79.870	-190.687
	129.400	*125.300*	*93.580*	*127.300*	*128.600*	*126.400*	*129.300*	*62.570*	*295.700*	*124.700*	*337.644*
BHC FE	N	N	N	N	N	N	N	N	Y	N	Y
Quarter FE	N	N	N	N	N	N	N	N	N	Y	Y
Observations	20,668	19,200	20,668	20,668	20,668	20,668	20,714	19,200	20,668	20,668	19,200
Adjusted R-squared	0.00	0.01	0.07	0.00	0.00	0.00	0.36	0.41	0.29	0.00	0.31

Note: The data are quarterly and cover 1,295 borrowing BHCs from 1/1/2005 – 12/31/2011. *Difference in Borrowing* is calculated as the amount borrowed as reported by the algorithm less that reported by the Y-9C. *Log assets* is the logarithm of assets. *Fedwire Payments* is the total amount borrowed by each bank over the Fedwire Funds Service on each day. *% Tier 1 Equity* is Tier 1 Equity as a percentage of total assets. *% NPL* is total NPL as a percentage of total assets. *% Repo* is repo as a percentage of total assets. *Triparty Repo* is a dummy variable equal to one if the BHC is a tri-party repo clearing bank or an entity which, by mergers, will become a tri-party repo clearing bank. *Lag Difference* is the lag of *Difference in Borrowing*. All specifications are run using all observations for which we have both Y-9C and algorithm data for a particular quarter-end date. Specification (9) includes BHC fixed effects. Specification (10) includes quarter fixed effects. Specification (11) includes both BHC and quarter fixed effects. All errors are clustered at the BHC level.

TABLE 9: DIFFERENCES IN LENDING

Difference in Lending	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Log Assets	33.600	38.700	-14.480	33.360	33.940	23.830	33.700	11.290	32.930	36.720	49.505
	31.170	*32.940*	*9.251*	*31.030*	*31.390*	*25.080*	*31.140*	*6.908*	*38.110*	*33.900*	*60.037*
Lag Log Y-9C		-7.198									7.797 ***
		6.106									*2.465*
Fedwire Payments			0.008 ***								-0.003
			0.002								*0.012*
% Tier 1 Equity				-0.626							-0.888
				0.787							*1.018*
% NPL					-3.098						-2.594
					2.410						*3.091*
% Repo						7.846					-16.491
						5.854					*19.260*
Triparty Repo							2,759.000 ***				
							217.100				
Lag Difference								0.862 ***			
								0.099			
Constant	-231.50	-257.40	87.960	-225.10	-229.40	-183.000	-232.300	-77.160 *	-226.90	-195.10	-224.24
	209.200	*224.500*	*61.810*	*205.500*	*207.600*	*177.300*	*209.000*	*46.120*	*265.200*	*218.900*	*306.817*
BHC FE	N	N	N	N	N	N	N	N	Y	N	Y
Quarter FE	N	N	N	N	N	N	N	N	N	Y	Y
Observations	26,647	24,476	26,647	26,647	26,647	26,647	26,693	24,476	26,647	26,647	24,476
Adjusted R-squared	0.01	0.01	0.23	0.01	0.01	0.02	0.08	0.36	0.33	0.01	0.33

Note: The data are quarterly and cover 1,920 lending BHCs from 1/1/2005 – 12/31/2011. *Difference in Lending* is calculated as the amount lent as reported by the algorithm less that reported by the Y-9C. *Log assets* is the logarithm of assets. *Fedwire Payments* is the total amount lent by each bank over the Fedwire Funds Service on each day. *% Tier 1 Equity* is Tier 1 Equity as a percentage of total assets. *% NPL* is total NPL as a percentage of total assets. *% Repo* is repo as a percentage of total assets. *Triparty Repo* is a dummy variable equal to one if the BHC is a tri-party repo clearing bank or an entity which, by mergers, will become a tri-party repo clearing bank. *Lag Difference* is the lag of *Difference in Lending*. All specifications are run using all observations for which we have both Y-9C and algorithm data for a particular quarter-end date. Specification (9) includes BHC fixed effects. Specification (10) includes quarter fixed effects. Specification (11) includes both BHC and quarter fixed effects. All errors are clustered at the BHC level.

Y-9C	Borrowing		Lending	
	(1)	(2)	(3)	(4)
Fedkey	1.305 ***	1.305 ***	2.914 ***	2.914 ***
	0.447	*0.447*	*0.445*	*0.445*
Constant	8472.000 ***	8472.000 ***	1,897.000	1,897.000
	1857.000	*1857.000*	*2,021.000*	*2,021.000*
Observations	14	14	12	12
Adjusted R-squared	0.17	0.17	0.46	0.46

Note: *Fedkey* is self-reported fed funds activity by two BHCs as used in A&C and covers 1/1/2005 − 3/31/2011. *Algorithm* is the amount borrowed (lent) as reported by the Furfine algorithm. Specifications (1) and (3) are run using all observations for which we have both Y-9C and Fedkey data for a particular quarter-end date. Specifications (2) and (4) are run on the subset of observations for which the Y-9C reported fed funds borrowing (lending) is nonzero. All errors are clustered at the BHC level.

Appendix A: The Furfine Algorithm (Source: Afonso et al 2011)

The algorithm used to identify fed funds loans is similar to the one proposed by Furfine (1999). This technique has been used to identify uncollaterized loans in the U.S. settled over the Fedwire Funds Service in Furfine (2001, 2002), Demiralp, Preslopsky, and Whitesell (2004), Ashcraft and Bleakley (2006), Ashcraft and Duffie (2007), Bech and Atalay (2008), and Bartolini, Hilton, and McAndrews (2010), among others. Modified versions of this methodology are also employed by Millard and Polenghi (2004) and Acharya and Merrouche (2010) to identify overnight lending activity in the U.K. CHAPS Sterling and by Hendry and Kamhi (2007) in Canada's Large Value Transfer System (LVTS).

The algorithm identifies fed funds loans from payments as follows:

- Step 1: Screen out settlement institutions from pool of transactions transferred over the Fedwire Funds Service.

  The algorithm excludes transactions for which the sending institution is not involved in fed funds activity such as transfers originating from the Clearing House Interbank Payments System (CHIPS, a private and large-value U.S. dollar payments system owned and operated by the Clearing House Payments Company), Continuous Linked Settlement (CLS, a payment-versus-payment settlement system that settles foreign exchange transactions), or the Depository Trust Company (DTC, a securities settlement system).

- Step 2: Identify overnight loans.

  We identify all transfers from one institution to another in amounts equal to or greater than $1 million and ending in five zeros when there is a payment of a slightly higher amount in the opposite direction on the following day. The difference between the two payments is interpreted as the interest rate on the loan. These transfers are selected because federal funds loans are usually made in round lots of over $1 million (Stigum and Crescenzi (2007), Furfine (1999)).

  Next, we refine this set of potential fed funds loans by limiting the range of possible loan rates. "Reasonable" interest rates for uncollaterized loans may vary daily depending on market conditions. To take the variation in rates into account, we narrow the pool of overnight loans to include only loans with (positive) rates within a window of 50 basis points below the minimum brokered fed funds rate (low) and 50 basis points above the maximum brokered fed funds rate (high) published by the Markets Group of the Federal Reserve Bank of New York from a daily survey of the four largest federal funds brokers.

- Step 3: Identify a unique rate per fed funds loan.

  When on the following day multiple repayments match one outgoing payment, the algorithm identifies the median rate as the rate of the loan.

- Step 4: Separate fed funds from Eurodollar activity.

  The U.S. market for unsecured loans consists of federal funds and Eurodollar[18] trades. An important difference between these two types of trades is that while fed funds can be settled directly between a domestic borrower and lender with reserve accounts at the Federal Reserve, Eurodollars require an intermediary, correspondent bank, or offshore account to complete the transaction (McAndrews (2009)). Step 4 incorporates the customer code that a sending bank enters on the return payment-leg message indicating the payment is made on behalf of a customer as a proxy for a Eurodollar loan to distinguish whether an overnight loan is fed funds or Eurodollar.[19]

As noted by Furfine (1999) and Bech and Atalay (2008), among others, this methodology presents some weaknesses. First, only fed funds loans settled through the Fedwire Funds Service are identified. However, fed funds loans settle almost exclusively on the Fedwire Funds Service (McAndrews (2009)). Second, term fed funds loans are not included. The term funds market is considerably smaller than the overnight market. The amount of term fed funds appears to be on the order of one-tenth (Meulendyke (1998)) to one-half (Kuo, Skeie, Vickery, and Youle (2013)) of the amount of overnight funds arranged on a given day. The number of term transactions per day is much smaller than the outstanding amount in direct proportion to the maturity of the term loan. Third, loans made on behalf of client banks and firms may be misattributed to the correspondent bank.[20] Similarly, transfers between banks that pay an opportunity cost of capital for specific purposes such as settlement will be included as fed funds loans. However, as Furfine (1999) pointed out, correspondent lending mainly represents loans made by very small institutions with little or no direct contact with major financial markets. Fourth, rates outside the specified window are missed. Increasing the size of the window is unlikely to add additional fed funds transactions (Furfine (1999)). Fifth, other overnight loans settled through the Fedwire Funds Service, such as Eurodollars or tri-party repos, could be misidentified as fed funds. Refinements of the algorithm such as the use of the customer code as a proxy for Eurodollar loans lessen the relevance of this concern.

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[18] Loosely speaking, Eurodollars are dollar-denominated deposits held outside the U.S. For a more precise definition and discussion of the fed funds and Eurodollar markets, see Bartolini, Hilton, and Prati (2008).

[19] McAndrews (2009) tests the predictive power of the costumer code as a proxy for a Eurodollar loan by matching brokered trades provided by BGC Brokers with Fedwire settlement data. By using the absence of a costumer code as a proxy for fed funds, the probability of correctly identifying fed funds loans is 89%, with an 11% chance of counting Eurodollars as fed funds (type I error) and a 4% chance of incorrectly excluding fed funds (type II error).

[20] Small banks and institutions that do not have a reserve account at the Federal Reserve can settle fed funds transactions through the account of correspondent banks. They can also lend to correspondent banks using correspondent re-booking. Deposits these institutions hold at correspondent banks can be reclassified as overnight federal funds loans. Next day, the correspondent bank credits the account of the lending institution with the nominal of the loan plus the negotiated interest. Rebooking does not require transfers between reserve accounts at the Federal Reserve and hence these uncollateralized interbank loans would not be identified as fed funds by the algorithm.

Appendix B: Y-9C definitions

Definition of fed funds from FR Y-9C

For purposes of the FR Y- 9C, federal funds transactions involve the lending (federal funds sold) or borrowing (federal funds purchased) in domestic offices of *immediately available funds* under agreements or contracts that *have an original maturity of one business day or roll over under a continuing contract*. However, funds lent or borrowed in the form of securities resale or repurchase agreements, due bills, borrowings from the Discount and Credit Department of a Federal Reserve Bank, deposits with and advances from a Federal Home Loan Bank, and overnight loans for commercial and industrial purposes are excluded from federal funds. Transactions that are to be reported as federal funds transactions may be secured or unsecured or may involve an agreement to resell loans or other instruments that are not securities. *Immediately available funds* are funds that the purchasing bank holding company can either use or dispose of on the same business day that the transaction giving rise to the receipt or disposal of the funds is executed. The borrowing and lending of immediately available funds *have an original maturity of one business day* if the funds borrowed on one business day are to be repaid or the transaction reversed on the next business day, that is, if immediately available funds borrowed today are to be repaid tomorrow (in tomorrow's immediately available funds). Such transactions include those made on a Friday to mature or be reversed the following Monday and those made on the last business day prior to a holiday (for either or both of the parties to the transaction) to mature or be reversed on the first business day following the holiday. A *continuing contract* is a contract or agreement that remains in effect for more than one business day but has no specified maturity and does not require advance notice of either party to terminate. Such contracts may also be known as rollovers or as open-ended agreements. Federal funds may take the form of the following two types of transactions in domestic offices provided that the transactions meet the above criteria (i.e., immediately available funds with an original maturity of one business day or under a continuing contract): (1) Unsecured loans (federal funds sold) or borrowings (federal funds purchased). (In some market usage, the term ''fed funds'' or ''pure fed funds'' is confined to unsecured loans of immediately available balances.) (2) Purchases (sales) of financial assets (other than securities) under agreements to resell (repurchase) that have original maturities of one business day (or are under continuing contracts) *and* are in immediately available funds. Any borrowing or lending of immediately available funds in domestic offices that has an original maturity of more than one business day, other than security repurchase or resale agreements, is to be treated as a borrowing or as a loan, *not* as federal funds. Such transactions are sometimes referred to as ''term federal funds.''

Definition of fed funds from FR Y-9C glossary

Report the outstanding amount of federal funds sold, i.e., immediately available funds lent (in domestic offices) under agreements or contracts that *have an original maturity of one business day or roll over under a continuing contract*, excluding such funds lent in the form of securities purchased under agreements to resell (which should be reported in Schedule HC, item 3(b)) and overnight lending for commercial and industrial purposes (which generally should be reported in Schedule HC, item 4(b)). Transactions that are to be reported as federal funds sold may be secured or unsecured or may involve an agreement to resell loans or other instruments that are not securities. Immediately available funds are funds that the purchasing bank holding company can either use or dispose of on the same business day that the transaction giving rise to the receipt or disposal of the funds is executed. A continuing contract, regardless of the terminology used, is an agreement that remains in effect for more than one business day, but has no specified maturity and does not require advance notice of the lender or the borrower to terminate. Report federal funds sold on a gross basis, i.e., do *not* net them against federal funds purchased, except to the extent permitted under ASC Subtopic 210-20, Balance Sheet – Offsetting (formerly FASB Interpretation No. 39, *Offsetting of Amounts Related to Certain Contracts*). *Also exclude* from federal funds sold (1) Sales of so-called ''term federal funds'' (as defined in the Glossary entry for ''federal funds transactions'') (report in Schedule HC, item 4(b), ''Loans and leases, net of unearned income''). (2) Securities resale agreements that *have an original maturity of one business day or roll over under a continuing contract*, if the agreement requires the bank holding company to resell the identical security purchased or a security that meets the definition of substantially the same in the case of a dollar roll (report in Schedule HC, item 3(b), ''Securities purchased under agreements to resell''). (3) Deposit balances due from a Federal Home Loan Bank (report as balances due from depository institutions in Schedule HC, item 1(a) or 1(b), as appropriate). (4) Lending transactions in foreign offices involving immediately available funds with an original maturity of one business day or under a continuing contract that are not securities resale agreements (report in Schedule RC, item 4(b), ''Loans and leases, net of unearned income'').

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