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Intermediated attainment in OTC markets

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Abstract

We quantify the role of middlemen in the attainment of portfolio goals through trading in the fed funds market. To do so, we estimate the equivalent of a matching function for this prominent over-the-counter (OTC) market. Around 25 percent of attainment can be attributed to the service of middlemen. We deem this figure to be conservative for a measure employing discrete outcomes, though it drops to 11 percent when continuous outcomes are used. As a byproduct, we also provide estimates of the demand and supply elasticities and conclude that the fed funds market experiences either constant or decreasing returns.

Keywords: Intermediation, Search Friction

JEL Code: E43, E44, G21

Resumen

Cuantificamos el papel de los intermediarios en el logro de su cartera a través de préstamos interbancarios en el mercado de *Fed Funds*. Para hacerlo, estimamos el análogo de un *matching function* para este destacado mercado descentralizado. Alrededor del 25 por ciento de los logros en cartera se pueden atribuir al servicio de intermediarios. Como subproducto, también proporcionamos estimaciones de las elasticidades de la oferta y la demanda y concluimos que el mercado de préstamos interbancarios experimenta rendimientos constantes o decrecientes a escala

Palabras claves: intermediación, fricciones

Intermediated attainment in OTC markets

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Abstract

We quantify the role of middlemen in the attainment of portfolio goals through trading in the fed funds market. To do so, we estimate the equivalent of a matching function for this prominent over-the-counter (OTC) market. Around 25 percent of attainment can be attributed to the service of middlemen. We deem this figure to be conservative for a measure employing discrete outcomes, though it drops to 11 percent when continuous outcomes are used. As a byproduct, we also provide estimates of the demand and supply elasticities and conclude that the fed funds market experiences either constant or decreasing returns.

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1 Introduction

To what extend does the attainment of portfolio goals in an over-the-counter (OTC) market depend on intermediation? To answer this question, we estimate the equivalent of a matching function for the fed funds market, a prominent OTC market for short-term loans between banks. Matching functions are usually employed in labor economics to model search frictions between workers and firms, frictions which, in turn, can give rise to equilibrium unemployment and wage dispersion. Labor economists have created a large body of empirical work around matching functions. Other fields, such as monetary economics, financial economics, and real estate economics, also motivate key economic phenomena, such as the use of money, liquidity, and the stock of uninhabited houses, by employing search theory. Yet empirical estimates for their markets are largely lacking. Trading in OTC markets suffers from search frictions in a similar way, which is why a transfer of the matching function to the OTC environment is warranted; we hope to bridge a gap in this regard with this work. Some results mirror those in labor economics, while others are unique to the OTC environment. For example, a central feature of OTC markets is the presence of middlemen, and a salient feature of the fed funds market is that banks themselves offer intermediation services. Little is known on the extent to which intermediation facilitates trade in markets with search friction. We therefore highlight the role of intermediation in this study to determine whether it alleviates the search problem and, if so, to what extent.

Middlemen contribute positively and to a statistically significant degree to the attainment of portfolio goals. Estimates imply that a one percent increase in the number of middlemen leads to a 0.25 (0.23) percent rise in attainment between

1990Q1 and 1996Q4 (2002Q1 and 2006Q4). We refer to this time period as W1 (W2). Intermediation has a significantly greater impact on banks rebalancing their portfolios in W3 (2007Q1 and 2011Q4) than it does in the two other periods. W3 is marked by the financial crisis and the policy response known as quantitative easing, which pumped liquidity into the banking sector so that a majority of banks had excess funds. One possible explanation for this quantitative result may be that intermediation provides additional relief for a strong mismatch between the different sides of the market and the perceived higher default risk on uncollateralized loans. We perform a counterfactual calculation to assess the economic relevancy of intermediation to asset allocation in OTC markets in general, and in the fed funds market in particular, and find that around 25 percent of attainment can be attributed to middlemen. The estimates vary little between windows. This stability is at odds with the strong increase in the intermediation elasticity in W3 described above, but can be reconciled by the decrease in the number of middlemen in that period.

If we were to make an analogy with estimates in labor literature, we would say that the results show that the fed funds market observes constant and decreasing returns to scale to the number of participating banks in W1 and W2, respectively. Estimates for W3 are too noisy for any conclusive statements. The supply-demand ratio is the ratio of banks with excess funds to those with insufficient funds. The point estimates for the optimal supply-demand ratio are greater than and significantly different from one in W1 and W2. For those periods, the effective ratios are 1.8 and 2.7, and within 95 percent confidence intervals of their respective optimums. The market structure seems to favor many banks with excess funds and few banks with insufficient funds, which is precisely what occurred. Once again, estimates for W3 do not allow any conclusions to be drawn here, but quantitative easing tilted the effective ratio even higher, to above 12.

OTC and labor markets are subject to similar search frictions. In particular, the search frictions in an OTC market can be explained as follows: an individual aims for an optimal portfolio.[1] In the absence of a centralized clearing mechanism, all trade is bilateral and time consuming. Therefore, an individual with excess holdings of an asset prefers to trade with one that wishes to purchase that same asset in an equal amount. Search frictions arise as a result of the following information asymmetry: an individual does not publicly post her net demand, nor does she know the precise net demand of other market participants. Hence, she does not know with certainty which other market participants to contact. The search frictions in labor markets are similar: workers and firms need to match up, but they have no idea how good a match they are until they meet. Labor economists model the search outcomes with a matching function that maps aggregate market characteristics to the number of meetings that formed a lasting match. Hence, matching functions have a natural counterpart in OTC markets, one we refer to as an attainment function, since it explains the attainment of portfolio goals by market participants. The attainment function is explained in detail below, and we also explain why we choose to label it differently.

Intermediation is by no means a new topic, and certainly not one exclusive to OTC markets; middlemen are present in labor markets in the form of temp agencies that lend workers to firms for a limited amount of time. However, they play a more prominent role in OTC markets, which is why the fed funds market is a

[1]In case her liquid funds equal her reserve requirements after trading ceases she neither has to pay a punitive interest rate nor foregoes interest by holding cash.

good starting point. We exploit three facts to obtain data: first, fed funds trading centers largely around 24-hour loan contracts; second, reserve requirements display optimal portfolio levels for banks; and third, variables for both can either be taken directly from the quarterly call reports of the Chicago Fed for the reporting day or imputed from these.[2] Any bank that borrows and lends on the reporting day is de facto a middleman.

The results are tested for robustness, with various perturbations towards the end. The following points are worth highlighting: first, not accounting for intermediation overstates the economies of scale; second, banks that hold below US$300 million in total assets stop reporting mid-sample and including them leads to considerable noise in the estimates. Hence, in order to keep the sample consistent they are excluded from the main analysis (though we present their results for completeness); and third, to highlight the search friction and the coordination function of middlemen, we focus on binary outcomes at the bank level. However, we also extend the analysis to include continuous variables. Middlemen become less important and their contribution to attainment drops to 11 percent. The exercise—more than the result—highlights the fact that middlemen not only serve as coordination devices (i.e., by connecting banks that are interested in trading) but also as delegated monitors, who facilitate trading between parties that know about each other's trading needs but are unable to overcome asymmetric information problems.

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[2]The call reports are officially known as Reports of Condition and Income.

2 Institutional overview

The fed funds market is the primary transmission channel for U.S. monetary policy, which is conducted by the Federal Reserve (or "Fed" for short). The most prominent action of the Fed is its announcement of a target for the fed funds rate.[3] The term "fed funds rate" refers to a 24-hour overnight interbank lending rate for uncollateralized loans, or fed funds. The fed funds rate is a reference interest rate for short-term lending in the U.S..

The Fed does not set the fed funds rate directly but instead makes use of five tools to nudge it towards its stated target. The first of these, reserve requirements, determine the amount of liquid funds an individual bank must hold, and whether or not a bank satisfies this condition is verified at the end of any business day.[4] A bank with liquid funds below its reserve requirements at the end of a business day has insufficient funds. Banks with insufficient funds must obtain a loan directly from the Fed and are charged the discount window rate, which is set above the fed funds target level to encourage interbank lending. The discount window rate is the second tool available to the Fed to manipulate the fed funds rate. A bank that holds liquid funds above its reserve requirements at the end of a business day has excess funds; the Fed has paid interest on excess funds since October 9, 2008, which is the third tool used by the Fed. The interest on excess funds alleviates the pressure on banks when they hold interest-free liquid funds above their reserve requirements. The remaining two policy tools, overnight reverse repurchase agreements and open

[3]The Fed actually publishes a band for its target rate since December 16th 2008.

[4]In order to give banks some leeway banks need to fulfill their reserve requirements "on average" over a period of two weeks which is called the maintenance period.

market operations, influence the flow of funds into and out of the system as a whole.

Reserve requirements and liquid funds determine what we refer to as regulatory demand and supply at the bank level. In particular, a bank satisfies its requirements with liquid funds comprised of its vault cash and electronic balances held on account at the Fed. If its liquid funds exceed its reserve requirements before trading, it will want to offload its excess reserves; hence, it has a regulatory supply of funds. If its liquid funds are shy of its reserve requirements, it has a regulatory demand for funds.

Individual balances at the Fed fluctuate throughout the day. For example, banks use Fed balances as a payment vehicle when trading interest-bearing assets among each other. Another reason balances fluctuate is because of payment orders issued by depositors. While the first operation is largely in the hands of the market participants, the second is not. In contrast, the aggregate balance of all Fed accounts only fluctuates when the Fed injects or withdraws funds.

The last couple of hours of each day are used to correct the liquid funds position through fed funds trading. In particular, banks with insufficient funds seek overnight loans from banks with excess funds and vice versa; hence trading activity is largely focused on moving a bank's liquid position towards its reserve requirements.

The fed funds market has no centralized clearing mechanism. In fact, banks and other participants in the fed funds market trade bilaterally (or "over the counter"). Consequently, interest rates paid on fed funds follow a non-degenerate distribution. The effective federal funds rate is an average of multiple surveyed quotes at which two large banks would trade with each other.

Fed funds trading primarily centers around 24-hour repayment vehicles, but there are also longer-term loans called term fed funds. As we exploit the term structure of reported items, we focus on overnight loans.

A major feature of the overnight loan market is the presence of intermediation. Intermediation can take many forms, though we will make a distinction between two of them: middlemen and brokers. The difference between these is that middlemen have a change in their balance sheet position, whereas brokers simply connect potential buyers and potential sellers for a fee. Ashcraft and Duffie (2007) claim that 74 percent of all transactions are non-brokered. In some markets, middleman are a distinct group of market participants,[5] while in others they emerge from the group of primary market participants, as is the case in the fed funds market (where banks themselves become middlemen).

3 Related work

Petrongolo and Pissarides (2001) survey estimations of the matching function employed in labor economics. The matching function represents the process whereby unemployed workers and vacancies come together. The estimations quantify how this process depends on aggregate market characteristics employed as regressors. For example, does the number of matches double when both vacancies and unemployed workers double? An affirmative answer would imply constant returns to scale, while a lower (higher) number of matches implies decreasing (increasing) returns. Pissarides (1986) and Layard et al. (2005) fail to reject constant returns to scale for the UK labor market. In contrast, Yashiv (2000) uses Israeli labour

[5]Temp work firms are examples of explicit intermediation services in labour markets.

market data, and rejects constant for increasing returns. There is also evidence of decreasing returns found by Burda (1993, Czech Republic and Slovakia), Burda and Wyplosz (1994, France, Germany, Spain and the UK) and Berman (1997, Israel). Therefore, the question of returns to scale in the matching function has yet to be settled. Our estimates for W1 and W2 point to decreasing returns, but we cannot reject the null of constant returns for the fed funds market in W1. One critical aspect is the inclusion of middlemen in the regression: incorrectly excluding middlemen increases the estimates. Another critical aspect is the focus on binary outcomes. Employing continuous outcomes suggests constant returns, though the interpretation changes slightly as we describe below.

Furfine (1999) finds that larger (smaller) banks are, on average, net borrowers (lenders) in the fed funds market, though frequently become lenders (borrowers). The fact that market participants can and do switch market sides certainly increases the search frictions over and above the benchmark setting in labor markets. However, there is some remedy. For example, Corbae and Ritter (2004) show that the persistent (and negative) correlation of liquidity needs between two banks can lead to long-term lending relationships, independent of any trust considerations. In the absence of repeated interaction, market participants constantly need to locate trading partners.

Bech and Atalay (2010) analyze bilateral intraday flows using network statistics. They find that only 5 percent of all banks inhabit what they refer to as an intermediating core.[6] This is a common feature in OTC markets: a small number

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[6]They define the core as a group of agents whose members form a *giant strongly connected component* in a network. In short, on a given day there is a set of banks who can reach each other following a set of directed links set out by transferred fed funds. Further, they state that 10 percent of all banks active on a given day populate the core. We would like to point out that

of agents serve as middlemen for a large number of market participants. For example, Li and Schürhoff (2014) study the municipal bond market and find that 10 to 30 dealers connect several hundred dealers. In contrast, around 27.8 percent of all bank-quarter observations in our sample show intermediating behavior. Afonso and Lagos (2012) find that the proportion of intermediated funds fell temporarily during the 2008 crisis. We observe a permanent decrease in the size of the middlemen group from 2008 onward. This begs the questions: how important is intermediation and what role did middlemen play during the financial crisis? We discuss our findings below.

There are several proposed explanations for the role of middlemen in markets. For example, intermediation may be a coordination device between buyers and sellers who are struggling to find each other easily, as described in Rubinstein and Wolinsky (1987). Middlemen may also take on the role of delegated monitors to overcome an asymmetric information problem between lenders and borrowers, as in Diamond (1984) and Li (1998) The fed funds market facilitates the exchange of uncollateralized loans without a centralized clearing mechanism so both roles, coordination and monitoring, can be essential in the sense that they expand the set of feasible outcomes. However, we focus on binary outcomes and consider whether banks can trade rather than how much they trade. While both roles, coordination and monitoring, are affected by search friction and default considerations, we suspect that binary outcomes highlight the coordination issue. We attribute 25 percent of the attainment to the services of middlemen. However, this number drops to about 11 percent when we employ continuous trading variables. Ulti-

non-participation is also a result of choice and since about half of all banks are inactive on any given day we quote the 5 percent.

mately, we can neither sharply identify nor assign weights of importance in this regard.

4 Data

All regulated financial institutions submit a Report of Condition and Income to the Fed each quarter. The Reports of Condition and Income are commonly referred to as 'call reports' and contain observations on balance sheet and income items. A panel data set of call reports was downloaded from the homepage of the Chicago Federal Reserve in March 2017.[7]

The period under investigation starts with the first quarter of 1990 and ends with the fourth quarter of 2011,[8] though the relevant time is the reporting day of each quarter (as the call reports contain trading data for that particular day). The object under investigation is the aggregate attainment of active commercial banks that are not owned by another entity and engaged in the fed funds market. We refer to these types of institutions simply as 'banks.' Ownership and entity type are determined directly by items in the call reports.[9] A bank i is active on reporting day t if it publishes a positive value for total assets held, $a_{i,t} > 0$.[10]

[7]Compare https://www.chicagofed.org/banking/financial-institution-reports/bhc-data.

[8]The data after Q4-11 shows gaps even for prominent variables such as assets held for the majority of banks. Hence, we drop later observations.

[9]Item 9331 is the entity type code, and item 9375 identifies the head office, and is 0 if this does not apply.

[10]Item 2170 in a call report is called "total assets".

Hence,

$$\widehat{N}_{i,t} = \begin{cases} 1 & if\, commercial\, bank_{it}\, \&\, not\, owned_{it}\, \&\, a_{i,t} > 0 \\ 0 & otherwise \end{cases}$$

Let $\widehat{N}_t = \sum_i \widehat{N}_{i,t}$ denote the aggregate number of banks on t that are not necessarily engaged in the fed funds market. The left panel of figure 1 shows how the number of banks decreased from 12.578 in 1990Q1 to 6.343 in 2011Q4.

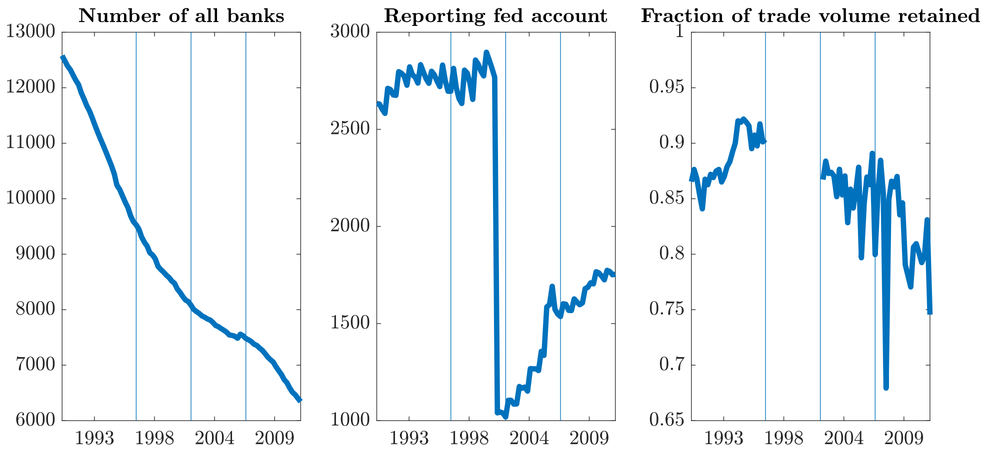

Figure 1: The number of banks, $\widehat{N}_t$ (left), the total number of banks reporting electronic balances held at the Fed, $f^{held}_{i,t}$, (center), and the value of trade retained in the sample (right) over time.

Three series that determine whether a bank is engaged in the fed funds market are affected by breaks. Both the amount of fed funds lent, $f^{lent}_{i,t}$, and borrowed, $f^{borrowed}_{i,t}$, are compositions of items that are not reported between 1997Q1 and 2001Q4.[11] Since March 2001, the value of electronic balances held in an account at the Fed, $f^{held}_{i,t}$, by banks with less than US\$300 million in total assets has

[11]The items producing $f^{lent}_{i,t}$ are 0276 and B987, and 0277 and B989 give us $f^{borrowed}_{i,t}$. Items 0276 and 0277 are reported before 1997 and items B987 and B989 are reported after 2001.

not been published.[12] The center panel of figure 1 displays the number of banks reporting $f_{i,t}^{held}$. It should be obvious from comparing the left panel and the center panel of figure 1 that a large percentage of banks did not report $f_{i,t}^{held}$ even before the 2001 change in reporting standards. Many smaller banks satisfy their reserve requirements because they hold sufficient vault cash to satisfy depositor demand. In order to keep the sample consistent, we exclude all observations related to banks reporting less than US$300 million in total assets, though we do ascertain their impact in a robustness check below. From here on, N_t refers to the number of banks subject to this requirement. The right panel of figure 1 shows the ratio of the total trading volume of banks in the sample to the total trading volume of all banks. Overall, only 13 percent of the total trading volume is lost over the entire sample period. The final sample contains 91,563 bank-quarter observations with 3,784 distinct banks over 68 reporting days.

Due to the data break between 1997Q1 and 2001Q4 and the monetary policy accompanying the Great Recession, the data is split into three windows: W1 contains the 28 reporting days between 1990Q1 and 1996Q4, W2 the 20 reporting days between 2002Q1 and 2006Q4, and, finally, W3 the 20 reporting days between 2007Q1 and 2011Q4 (which also covers the financial crisis).

The reader should bear in mind that the data set has no information on foreign central banks, international organizations or government-sponsored enterprises. These entities can and do participate in the fed funds market; however, due to their omission from the data set, their trading activity is omitted from the analysis below.

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[12] Item 0090. Compare www.federalreserve.gov/monetarypolicy/bst.htm.

5 Identification

Applying the idea of a matching function to the fed funds market requires some transfer. For example, the measure of success as regards the coordination issue in labor markets is an aggregate of individual success, i.e., the total number of jobs filled. An equivalent measure for the fed funds market is the extent to which all banks move their liquid position towards their optimal level. We refer to this measure as 'attainment,' as it reflects whether banks attain an optimal portfolio position.

There is one minor obstacle to directly transferring the matching function due to data availability. In particular, a match in a labor market leads to a single but permanent change for both parties: the unemployed person finds employment and a vacancy is filled. In contrast, balance sheets only reveal the total quantities traded over the entire day, not the quantity of trades. This data limitation suggests a focus on discrete over continuous variables at the bank level for the following two reasons: firstly, analyzing discrete outcomes yields a more accurate assertion regarding the coordination problem than employing traded quantities does (the latter adding a response to trading frictions along an intensive margin). Furthermore, the use of traded quantities should be qualified with a comment on the role of prices that are unavailable as well.[13] Secondly, both the available estimates in labor economics and theoretical results using search theory in monetary and financial economics focus on discrete outcomes;[14] hence the focus on discrete

[13] Both, quantities and prices, play a role in a bilateral exchange the same way they clear a centralized market.

[14] Compare Kiyotaki and Wright (1989), Rubinstein and Wolinsky (1987) or Duffie et al. (2005), and the large literature that followed those three papers as evidence for this claim.

outcomes ensures the estimates are comparable. Therefore, the measure of success is not an aggregate of how much a bank moved its liquid funds towards its reserve requirements but rather of whether or not it actually did. There is one obvious drawback: the measure of attainment chosen here does not fully encompass the general notion of attainment. After all, there is a difference in terms of welfare between a bank that moves 1 percent towards its optimal portfolio and one that moves 100 percent. For that reason, towards the end we use continuous bank-level variables in a robustness analysis. To avoid conflation with the matching function, we refer to the estimated function as an attainment function, regardless of whether we use discrete or continuous bank-level data.

The attainment function is defined by

$$Y_t = \Psi\left(F_t^{demand}, F_t^{supply}|\Phi_t\right) \tag{1}$$

where Y_t captures attainment on reporting day t which is defined below. Control variates Φ_t are employed to test various hypotheses below. The equivalent of unemployed workers and vacancies as regressors are aggregate demand for, F_t^{demand}, and supply of, F_t^{supply}, fed funds which are described next.

Identifying whether a market participant demands liquid funds or whether it would like to sell them requires knowledge of both its pre-trade and its optimal holding levels. A bank's pre-trade holding level can be deduced from its post-trade holding level and its intraday trading activity for the reporting day. A bank's post-trading holding level of liquid funds is a combination of published items, namely electronic balances held at the Fed, $f_{i,t}^{held}$, and vault cash, $v_{i,t}$.[15] As

[15]Item 0080.

changes in vault cash on the reporting day are not reported, we assume there are no systematic innovations between the beginning and the end of a reporting day. A bank's intraday trading quantities for the reporting day are revealed by the term structure of fed funds that are loans to be repaid the next day. Hence, $f_{i,t}^{lent}$ and $f_{i,t}^{borrowed}$ refer to trading activity on the reporting day only.

A bank's reserve requirements impose an optimal holding level for liquid funds, but this information is not publicly available. Documentation and items from the call reports allow us to impute an approximation of individual reserve requirements, $rr_{i,t}$.[16] The validity of this approximation is supported by publicly available aggregate data: figure 2 shows that the sum of the imputed individual reserve requirements of all banks in the call reports, $rr_t = \sum_i rr_{i,t}$, follows the official release in terms of both level and change.[17] In particular, rr_t accommodates the policy shift in the early 90s, where the factor for nontransaction savings deposits gradually decreases to zero in 1991Q1 . A simple OLS regression without intercept yields a coefficient of 1.0178 with a standard error of 0.0063 and an $R^2 = 0.94$.

[16] See appendix for details.

[17] The official release can be found in table 1 of the statistical release H.3. It can be downloaded from the St. Louis Fed. The particular item is REQRESNS. We employ all banks to compute rr_t, even the ones that do not report their Fed account.

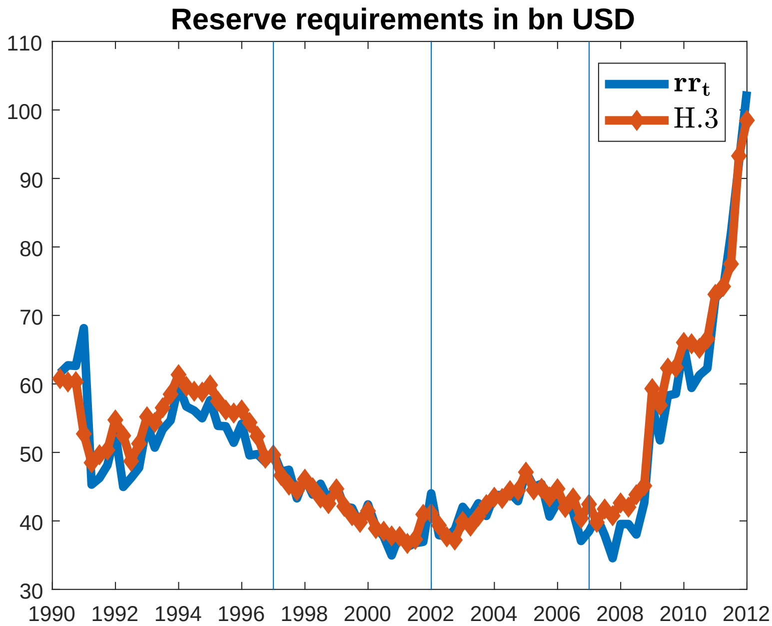

Figure 2: Aggregate reserve requirements over time. rr_t is imputed from call report data and H.3 refers to the official statistical releases.

Bank i has regulatory demand on reporting day t if its pre-trade holding level of liquid funds is below its imputed reserve requirements. Then

$$F_{i,t}^{demand} = \begin{cases} 1 & if\ v_{i,t} + f_{i,t}^{held} - f_{i,t}^{borrowed} + f_{i,t}^{lent} < rr_{i,t} \\ 0 & otherwise \end{cases}$$

Similarly, bank i has regulatory supply of fed funds on reporting day t if its pre-trade holding level of liquid funds is above its imputed reserve requirements, or

$$F_{i,t}^{supply} = \begin{cases} 1 & if\ v_{i,t} + f_{i,t}^{held} - f_{i,t}^{borrowed} + f_{i,t}^{lent} > rr_{i,t} \\ 0 & otherwise \end{cases}$$

Let us define the respective aggregates as $F_t^{demand} = \sum_i F_{i,t}^{demand}$ and $F_t^{supply} =$

$\sum_i F_{i,t}^{supply}$ from here on we refer to these measures simply as demand and supply. There is the possibility of a bank holding its exact reserve requirements, but we did not observe any case where $F_t^{demand} + F_t^{supply} = N_t$.

On average, banks only need to meet their individual reserve requirement over a two-week maintenance period. However, there is evidence that they avoid building up any surplus or deficit, as this would require a larger trading volume at the end of the maintenance period.[18] Therefore, individual success is defined as follows: first, a bank acquired fed funds due to the fact that it had regulatory demand, and second, a bank sold fed funds due to the fact that it had regulatory supply.

$$Y_{i,t} = \begin{cases} 1 & if\ f_{i,t}^{borrowed} > f_{i,t}^{lent} \wedge F_{i,t}^{demand} = 1 \\ 1 & if\ f_{i,t}^{borrowed} < f_{i,t}^{lent} \wedge F_{i,t}^{supply} = 1 \\ 0 & otherwise \end{cases} \tag{2}$$

Let us denote the aggregate of these two variables as $Y_t = \sum_i Y_{i,t}$, which reflects attainment (as described above). This requires one clarification: we implicitly count individual success twice: once for the borrower and once for the lender. In contrast, labor economists only count a match once. Given the parametric shape chosen below, this does not alter the interpretation of the estimated elasticities. Note that $Y_t \leq N_t$, and that we observe perfect attainment if $Y_t = N_t$.

A bank can borrow fed funds from banks with excess funds and lend fed funds to banks with insufficient reserves. The transactions affect its balance sheet and identify it as a middleman. Hence, bank i is a middleman on reporting day t if it

[18] Afonso and Lagos (2012) show that the distribution of $f_{i,t}^{held}$ contracts throughout the day.

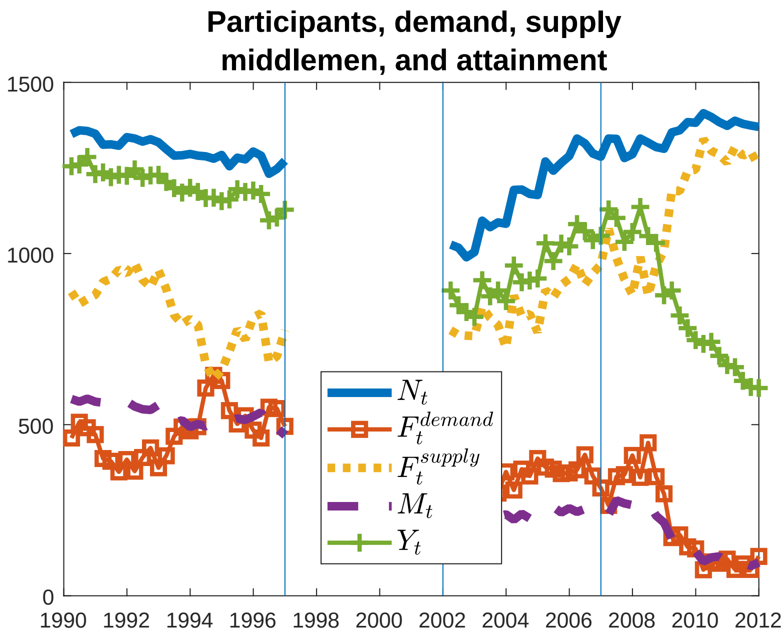

Figure 3: The total number of banks in the sample, N_t, demand, F_t^{demand}, supply, F_t^{supply}, middlemen, M_t, and attainment, Y_t, over time.

		Y_t	F_t^{demand}	F_t^{supply}	M_t
W_1	Mean	1196.9	478.18	824.68	529.43
	Median	1191.5	483	822.5	524
	Min	1097	362	633	460
	Max	1282	644	972	576
W_2	Mean	978.21	332.5	878.79	243.96
	Median	999.5	349	878.5	241
	Min	815	229	725	207
	Max	1136	447	1072	279
W_3	Mean	717.17	113.92	1265.8	117.42
	Median	718.5	103	1276	106
	Min	607	76	1182	87
	Max	892	178	1334	168

Table 1: Summary statistics for medium-sized and large banks employed for the main results.

borrows and lends

$$M_{i,t} = \begin{cases} 1 & if\, f_{i,t}^{borrowed} > 0 \wedge f_{i,t}^{lent} > 0 \\ 0 & otherwise \end{cases}$$

The total number of middlemen is $M_t = \sum_i M_{i,t}$. Figure 3 shows N_t, F_t^{demand}, F_t^{supply}, M_t, and Y_t for the sample period, while table 1 gives summary statistics for each variable and window.

We employ a parametric shape to gain efficiency and, without further guidance from theory, choose the familiar Cobb-Douglas function for equation 1. Therefore, the functional specification is given by

$$\log(Y_t) = \beta_{const} + \beta_{demand} \log\left(F_t^{demand}\right) + \beta_{supply} \log\left(F_t^{supply}\right) + \sum_k \gamma_k \phi_k + \epsilon_t \quad (3)$$

Additional factors using the variables ϕ_k are explained below. The Cobb-Douglas function also allows for a direct interpretation of the coefficients as elasticities. All estimations employ a weighting matrix that is robust to heteroscedasticity and autocorrelation (HAC).

6 Benchmark selection

The specification selection is guided by the Bayesian information criterium (BIC): integrating more regressors is penalized, thus avoiding an excess of explanatory variables in the benchmark specification.

Specification (1) of table 2 shows a vanilla estimation of (3) employing HAC-robust OLS. In particular, the estimation assumes there are no structural breaks

Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Method	OLS	GMM	OLS	OLS	OLS	GMM	OLS
Obs	68	62	68	68	68	62	68
$\log\left(F_t^{demand}\right)$	0.494*** (16.92)	0.581*** (11.38)	0.492*** (19.1)	0.424*** (4.42)	0.165* (1.84)	0.159 (1.41)	0.286*** (2.88)
$\log\left(F_t^{demand}\right) \times W_2$				−0.224** (2.28)	−0.045 (0.51)	−0.088 (0.82)	−0.136 (1.34)
$\log\left(F_t^{demand}\right) \times W_3$				0.016 (0.12)	−0.217* (1.95)	−0.323 * ** (2.87)	−0.486*** (3.08)
$\log\left(F_t^{supply}\right)$	0.579*** (7.5)	0.8*** (5.89)	0.560*** (8.06)	0.739*** (6.63)	0.212 (1.53)	0.159 (0.98)	0.479*** (3.01)
$\log\left(F_t^{supply}\right) \times W_2$				−0.066 (0.43)	0.326** (2.5)	0.315* (1.93)	0.174 (1.04)
$\log\left(F_t^{supply}\right) \times W_3$				−0.233 (0.63)	−0.194 (0.71)	−0.18 (0.92)	−0.606* (1.9)
const	0.127 (0.19)	−1.873** (1.55)	0.317 (0.53)	−0.443 (0.34)	1.187 (0.96)	0.607 (0.36)	0.594 (0.5)
$const \times W_2$				1.649 (1.14)	−1.676 (1.24)	−1.222 (0.71)	−0.247 (0.2)
$const \times W_3$				1.376 (0.43)	2.886 (1.19)	3.535* (1.8)	4.417* (1.76)
Q2			−0.062*** (2.97)	−0.045*** (2.72)	−0.043*** (3.67)	−0.041 * ** (3.28)	−0.035*** (3.36)
Q3			−0.049*** (2.67)	−0.038** (2.59)	−0.036*** (3.39)	−0.029 * ** (2.94)	−0.033*** (3.08)
Q4			−0.083*** (3.52)	−0.069*** (3.41)	−0.044*** (4.33)	−0.040 * ** (4.27)	−0.034*** (3.63)
$\log(M_t)$					0.557*** (5.71)	0.712 * ** (13.28)	0.246* (1.93)
$\log(M_t) \times W_2$							−0.016 (0.11)
$\log(M_t) \times W_3$							0.478** (2.64)
R^2	0.888	0.868	0.911	0.961	0.981	0.979	0.985
BIC	-161.358	-131.458	-164.163	-194.707	-240.302	-207.814	-245.51
* p<0.10, ** p<0.05, *** p<0.01, absolute t-statistics are in parenthesis							

Table 2: Estimates for (1).

in the parameters, no seasonal effects, and that $\log\left(F_t^{demand}\right)$ and $\log\left(F_t^{supply}\right)$ are both exogenous. We next check each of these assumptions.

We deem demand and supply to be exogenous for the following reasons: specification (2) estimates the same coefficients as specification (1) using HAC-robust GMM. Three lagged observations of the regressors are used as instruments. Similar to Berman (1997) we find the coefficients increase when we control for potential simultaneity. The Sargan–Hansen test with a p-value of 0.54 does not reject the null that some instruments are correlated with the structural error of the attainment function. A Hausman-style test with a p-value of 0.852 does not reject the null that $\log\left(F_t^{demand}\right)$ is exogenous at any reasonable level. Similarly, the p-value for the Hausman-style test for $\log\left(F_t^{supply}\right)$ is 0.545. Hence, we assess both regressors as exogenous.

An eyeball regression shows quarterly patterns in Y_t in figure (3) while in F_t^{demand} or F_t^{supply} they are absent. We are uncertain as to the economic interpretation, though this observation suggests different constant effects between quarters. Specification (3) introduces Q2, Q3, and Q4, which are set to one on the reporting day of the second, third, and fourth quarter of the year, respectively, and zero otherwise.[19] While their respective effect is not large, the BIC suggests integrating them into a benchmark specification.

Given the reporting issue and the financial crisis, we expect the coefficients of the attainment function (1) to change between windows. Let W_2 (W_3) be one between 2002Q1 (2007Q1) and 2006Q4 (2011Q4), and zero otherwise. Specification (4) introduces interaction terms between both window dummies, W_2 and W_3, and the constant, $\log\left(F_t^{demand}\right)$ and $\log\left(F_t^{supply}\right)$. Hence, W1 becomes a reference and the interaction terms show a change in the response to the economic variables in comparison to W1. Note that for efficiency's sake Q2, Q3, and Q4 do not have an interaction term. The BIC decreases further to -194.707 despite the introduction of six additional regressors.

The BIC suggests the model described in specification (4) as a benchmark for equation (1) before we introduce intermediation, despite the number of regressors.

[19]The first quarter is captured in the constant.

This implies that the coefficients changed significantly between windows. However, it is worth noting that all estimated specifications of (3) explain a sizable portion of the variation in log(Yt): the coefficient of variation is never below 0.868.

Next, we build on the benchmark specification and again employ the BIC to determine the right statistical model for when we want to introduce intermediation as an explanatory variable. Specifications (5) and (6) of table 2 introduce $\log(M_t)$ to the benchmark for 3 employing HAC-robust OLS and HAC-robust GMM, respectively. We reject the claim that $\log(M_t)$ is endogenous according to a Hausman test.[20] Hence, we treat $\log(M_t)$ as exogenous. Specification (5) also reveals a decrease in the BIC when we include $\log(M_t)$, which underlines the importance of intermediation in the fed funds market. Specification (7) allows for the interaction of $\log(M_t)$ with the window dummies. The BIC decreases once more, again highlighting the importance of intermediation and structural breaks in the estimation. Therefore, we next discuss the economic implications of the estimates in specification (7).

7 Results

The economic interpretation of the benchmark specification from specification (7) in table 2 requires certain transformations, which are contained in the first column of table 3. In particular, the elasticities correspond to the estimated coefficients from table 2 for W1, though require a summation for W2 and W3. The brackets below the point estimates contain the 95 percent confidence intervals.

[20] The p-value is 0.312.

Economic estimates and robustness results				
Specification	**(7)**	(4)	(S7)	(C7)
Intermediation elasticity				
W1	**0.246** **[−0.004,0.496]**		0.024 [−0.2,0.249]	0.396 [0.034,0.758]
W2	**0.23** **[0.105,0.355]**		0.243 [0.043,0.442]	0.456 [0.058,0.853]
W3	**0.724** **[0.481,0.967]**		0.643 [0.432,0.854]	0.447 [0.057,0.838]
Fraction of attainment due to intermediation in %				
All	**24.993** **[6.403,99.857]**		86.922 [24.565,315.283]	10.833 [1.608,77.665]
W1	**21.406** **[4.561,100.482]**		85.395 [20.057,363.608]	8.357 [0.896,77.95]
W2	**26.009** **[6.724,100.626]**		87.551 [25.966,295.281]	11.435 [1.636,80.045]
W3	**28.998** **[8.661,98.212]**		88.432 [29.476,267.63]	13.697 [2.576,74.887]
Demand elasticity				
W1	**0.286** **[0.091,0.481]**	0.424 [0.236,0.612]	0.082 [−0.015,0.179]	0.726 [0.65,0.802]
W2	**0.151** **[0.111,0.19]**	0.2 [0.127,0.272]	0.152 [0.104,0.2]	
W3	**−0.2** **[−0.442,0.043]**	0.44 [0.262,0.617]	−0.195 [−0.362,−0.028]	
Supply elasticity				
W1	**0.479** **[0.167,0.792]**	0.739 [0.52,0.957]	0.405 [0.166,0.644]	0.359 [0.212,0.507]
W2	**0.653** **[0.567,0.74]**	0.673 [0.488,0.857]	0.712 [0.616,0.809]	
W3	**−0.127** **[−0.668,0.414]**	0.506 [−0.177,1.189]	−0.248 [−0.815,0.319]	
Economies of scale				
W1	**0.765** **[0.264,1.267]**	1.163 [0.764,1.561]	0.487 [0.158,0.815]	1.086 [0.96,1.211]
W2	**0.804** **[0.717,0.891]**	0.872 [0.739,1.006]	0.864 [0.768,0.961]	
W3	**−0.327** **[−1.069,0.415]**	0.946 [0.09,1.802]	−0.443 [−1.115,0.229]	
Optimal supply-demand ratio				
W1	**1.673** **[1.321,2.025]**	1.742 [1.383,2.101]	4.95 [1.452,8.448]	0.495 [0.261,0.729]
W2	**4.339** **[2.946,5.733]**	3.367 [1.322,5.411]	4.681 [2.932,6.43]	
W3	**0.636** **[−1.549,2.82]**	1.151 [0.043,2.259]	1.272 [−1.223,3.766]	
Effective supply-demand ratio				
W1	1.797		3.2589	0.4078
W2	2.7132		2.82	1.4334
W3	12.172		12.802	49.271

Table 3: Point estimates with 95 percent confidence intervals in brackets corresponding to selected specifications from tables 2, 5, and 7.

The first block of table 3 deals with the effect of intermediation, while the top highlights the marginal effect; the intermediation elasticity of attainment in the fed funds market in W1 is 0.246. In other words, increasing the number of intermediaries by 1 percent increases attainment by 0.246 percent. This value corresponds to the estimate for the coefficient of $\log(M_t)$ in specification (7) of table 2, and, therefore, is significant at the 1 percent level but not at the 10 percent level (as indicated by the negative lower confidence bound). However, the point estimate is close to the intermediation elasticity in W2, i.e., 0.23. The latter value corresponds to the summation of the estimated coefficients of $\log(M_t)$ and $\log(M_t) \times W_2$ in specification (7) of table 2. The confidence intervals are much sharper in W2. The intermediation elasticity increases threefold for W3 with a point estimate at 0.724. Once again, the confidence intervals become larger compared to W2, though given the level increase we are certain intermediation was a contributing factor in the attainment of portfolio goals during the Great Recession. Overall, the estimates are all positive and of a reasonable size.

The bottom of the first block of table 3 highlights the aggregate importance of intermediation to the fed funds market. Let us denote the expected attainment employing (3) by

$$\widehat{Y}_t = \mathbb{E}[Y_t]$$

and let the expected attainment when the number of middlemen is zero be

$$\widehat{Y}_t^0 = \mathbb{E}[Y_t | M_t = 0]$$

The ratio $m_t = \widehat{Y}_t^0 / \widehat{Y}_t$ quantifies the contribution of intermediation services on reporting day t. Our preferred specification predicts an average contribution of around 25 percent over the whole sample period. Employing 95 percent confidence intervals for the predictions of $\widehat{Y}_t^0$ and $\widehat{Y}_t$ yields lower and upper bounds for $\mathbb{E}[m_t]$ of around 6.4 percent and 99.9 percent, respectively. The averages for the point predictions and confidence intervals for each window are also reported in table 3. The point predictions range from around 21.4 percent to 29 percent, despite the threefold increase in the intermediation elasticity in W3. This stability reflects a relative decrease in the number of middlemen in W3.[21]

The first column of the second block of table 3 shows a byproduct of our estimation of demand and supply elasticities and the economies of scale for attainment in the fed funds market. In particular, table 3 suggests that the demand elasticity in W1 is around 0.286. This value corresponds to the estimate for the coefficient of $\log\left(F_t^{demand}\right)$ in specification (7) of table 2, and, therefore, is also significant at the one percent level. The confidence interval implies that the true demand elasticity is below 0.091 or above 0.481 with a 10 percent probability only. The demand elasticity in W2 is 0.151, with a much sharper confidence interval. The demand elasticity decreases to -0.2 for W3, but uncertainty about the estimate increases, so we cannot conclude that an additional bank with insufficient funds would actually lower attainment. Note that this is not implausible given that congestion can occur in search markets. The supply elasticity is 0.479, 0.653, and -0.127 for W1, W2, and W3, respectively. The negative estimate arises when the Fed pumped liquidity into the system under the policy of quantitative easing. In plain English,

[21] We can only speculate around our estimates, but we believe that the decrease of middlemen lead to a higher concentration of intermediation services among fewer middlemen in W3. This is in line with the relatively high intermediation elasticity in W3.

a large proportion of banks held excess funds and an additional bank supplying funds was not what the market needed. However, as with the demand elasticity, the estimate is rather imprecise and we attribute this to the turbulent state of financial affairs and the one-sidedness of the fed funds market in W3.

The second block of table 3 also evaluates the hypothesis regarding the economies of scale. The point estimates are the summed elasticities of demand and supply. The estimated economies of scale for W1 and W2 are close to one, but the stricter bounds allow us to reject constant returns to scale in W2 in favor of decreasing returns. Due to the negative estimates for demand and supply elasticities in W3, the prediction for the economies of scale is also negative, though again rather imprecise.

The first column of the next block in table 3 contrasts the effective supply-demand ratio with an optimal one. How is the optimal supply-demand ratio determined? Let us suppose that the fed funds market works exactly as the attainment function describes; thus, attainment is maximized by a social planner when

$$\max_{\left\{F^{supply},F^{demand}\right\}} \left\{ {F^{supply}}^{\beta_{supply}} \; {F^{demand}}^{\beta_{demand}} \right\}$$

subject to $N = F^{supply} + F^{demand}$. The solution can be expressed as a ratio

$$\frac{{F^{supply}}^{*}}{{F^{demand}}^{*}} = \frac{\beta_{supply}}{\beta_{demand}}$$

Note that this computation is not always possible for labor markets, as the number of vacancies posted is endogenously determined. Hence, an answer for labor markets crucially depends on constant returns. Here the total number of banks per reporting day is fixed and the constraint arises because no bank has liquid funds that exactly match its reserve requirements. The effective supply-demand ratios in W1, W2, and W3 are 1.8, 2.71, and 12.17, respectively, while the benchmark specification implies an optimal ratio of 1.67, 4.34, and 0.64, respectively. Only the last value is significantly different from the observed value, but it is also the only one less than one and derives from the problematic W3 window. Therefore, we are inclined to disregard this estimate. The first two windows suggest an optimal supply-demand ratio of greater than one. In other words, a well-functioning fed funds market requires an abundance of banks with excess funds over banks with insufficient funds, which was the case in W1 and W2.[22] But why? One might point to trading friction and the information friction involved with uncollateralized loans: banks in need of an overnight loan might spread their default risk by borrowing from more banks. Another explanation derives from the size heterogeneity in the banking industry. Furfine (1999) documents that the fed funds market is actually quite asymmetric because a small number of large banks are effectively net liquidity-absorbing, while a large number of small banks supply liquidity. This would explain the asymmetry.

Overall, we find reasonable estimates for the effect of intermediation in all windows, as well as for the demand and supply elasticities and their derivative predictions in W1 and W2. The reason we have confidence in the estimate for intermediation in W3 stems not only from the expected sign and the relatively small confidence intervals but also from the fact that functions that make intermediation essential become more crucial in W3: the extreme one-sidedness of the fed funds

[22]Pissarides (1986) finds that the maximum number of matches in labor markets is achieved when the unemployed outnumber vacancies 2.3 to 1.

market requires coordination and the perceived increase in default risk intensified the need for delegated monitoring from specialized intermediaries.

8 Robustness

We extend the analysis in the previous section along three dimensions. First, we evaluate the estimates for demand and supply elasticities and their derivative predictions without considering intermediation. To do so, we employ the specification in specification (4) found in table 2. Second, we exclude small banks so that the sample consists of similar banks between windows. We subsequently reintroduce small banks to evaluate their impact. Third, we discretize the positions and outcomes. We employ continuous bank-level variables below.

8.1 No intermediation

We convert the estimated coefficients from specification 2 in a similar fashion to above. Overall, the differences between specifications (4) and (7) are small and can be accounted for as described below.

Naturally, we are unable to make any predictions regarding intermediation, but the second column of table 3 shows the demand and supply elasticities, economies of scale, and optimal supply-demand ratios for specification (4). Note that all demand and supply elasticities are larger in specification (4) compared to the equivalent estimates in specification (7). Intuitively, demand and supply of fed funds ought to increase attainment and estimates of their average effect should be non-negative but below one. However, the essential role of intermediation is to facilitate allocation in markets subject to frictions. Hence, not accounting for intermediation appears to attribute a more important role to the fundamental market sides. Consequently, the economies of scale are larger in specification (4) and we cannot reject constant returns in W2. In other words, not accounting for intermediation leads to an increased estimate for the economies of scale. The optimal supply-demand ratio is greater than one for all windows and significantly larger than one in W1 and W2. There is an increase in the optimal ratio from W1 to W2, similar to specification (7) but smaller.

8.2 Including small banks

Next, we include all banks with an account at the fed, which increases the number of small banks in the first window. Summarizing, we can state the following: the estimates become noisier in W1 but remain robust in W2 and W3 when compared to our benchmark estimates. This is unsurprising because small banks do not report outright in W2 and W3, so the estimates are largely unaffected. In particular, the point estimates for the intermediation and demand elasticities in W1 become smaller and insignificant, while the average contribution of intermediation to attainment more than triples, hovering around 87 percent. While we cannot reject this number outright, we believe it to be excessive and instead classify the benchmark results as conservative estimates. Numerous things change in the estimation when we include small banks: the discharge of fed funds by small banks with excess funds becomes a more prominent subcategory for attainment, while supply and intermediation observations increase substantially in W1. Therefore, we speculate that the effect of intermediation by small banks on attainment may not be significant, so their inclusion creates a lot of statistical noise.

Similar to table 1 above, table 4 in the appendix presents summary statistics solely for small banks entering the sample. The numerical changes are largest in the first window: when we include small banks in the estimation, average attainment more than doubles and average supply increases by a factor of 2.4. Again, it is important to highlight that these banks may still participate in W2 and W3, but they do not report their fed funds holding, which is crucial for the identification of demand and supply positions.

We add the prefix 'S-' to the specifications where small banks are included. The regression analysis described in table 5 in the appendix pans out in a similar way to that without small banks: a vanilla version estimate shows a slightly larger coefficient for $\log\left(F_t^{supply}\right)$ in specification (S1) compared to the same estimate from table 2. Neither demand nor supply are endogenous in specification (S2) using HAC-robust GMM,[23] seasonal effects matter in specification (S3) according to a Wald-test and the BIC, and so do the structural breaks in the coefficients between windows in specification (S4). Hence, the benchmark specification without intermediation is the same as above, again chosen by the BIC. Introducing intermediation lowers the BIC further in specification (S5). Middlemen are also not endogenous, as indicated by a Hausman-like test with a p-value of 0.233 in specification (S6). Accounting for a structural break lowers the BIC even further in specification (S7). Table 3 shows the economic estimates for specification (S7) in the third column, which support what we mentioned already in the first paragraph of this subsection.

[23] The p-values for the Hausman statistics are 0.864 and 0.147, respectively.

8.3 Continuous bank-level information

Here we change variable definitions and employ continuous positions and outcomes. We define demand and supply for bank i on reporting day t along the intensive margin at the bank-level by

$$\bar{F}_{i,t}^{demand} = \begin{cases} rr_{i,t} - v_{i,t} - f_{i,t}^{pretrade} & if\; v_{i,t} + f_{i,t}^{pretrade} < rr_{i,t} \\ 0 & otherwise \end{cases}$$

where $f_{i,t}^{pretrade} = f_{i,t}^{held} - f_{i,t}^{borrowed} + f_{i,t}^{lent}$, and

$$\bar{F}_{i,t}^{supply} = \begin{cases} v_{i,t} + f_{i,t}^{pretrade} - rr_{i,t} & if\; v_{i,t} + f_{i,t}^{pretrade} > rr_{i,t} \\ 0 & otherwise \end{cases}$$

Individual attainment of bank i on reporting day t is then given by

$$\bar{Y}_{i,t} = \begin{cases} f_{i,t}^{borrowed} - f_{i,t}^{lent} & if\; f_{i,t}^{borrowed} > f_{i,t}^{lent} \wedge F_{i,t}^{demand} = 1 \\ f_{i,t}^{lent} - f_{i,t}^{borrowed} & if\; f_{i,t}^{borrowed} < f_{i,t}^{lent} \wedge F_{i,t}^{supply} = 1 \\ 0 & otherwise \end{cases}$$

Aggregation is straightforward and variables are marked by a bar. Note that we still employ the number of middlemen as our measure of intermediation.[24] Table 7 in the appendix provides summary statistics.

We proceed as before, though obtain slightly different results. Specification

[24]This keeps estimates comparable. We are also not sure what the appropriate continuous measure for intermediation would be. Several candidates are used in the literature, compare Afonso and Lagos (2012), for example.

(C1) shows an estimation of 3 without bells and whistles. We detect no endogeneity issues with $log\left(\bar{F}_t^{demand}\right)$ and $log\left(\bar{F}_t^{supply}\right)$ in specification (C2).[25] We reject the inclusion of seasonal dummies in specification (C3) and the idea of structural breaks in specification (C4). Hence, we take specification (C1) as our benchmark for continuous variables before we consider intermediation based on the BIC. Specification (C5) introduces $\log(M_t)$, and we observe that the BIC does not decrease. Testing for endogeneity yields a p-value of 0.36 for the Hausman test in specification (C6). Specification (C7) allows for structural breaks in the coefficient of $\log(M_t)$ between windows and, alas, the coefficients change notably, and the BIC suggests the parameters account for the break. This is therefore our benchmark when we employ continuous variables at the bank-level. The fourth column in table 3 reports the economic estimates.

Given these modifications, we observe the following changes: intermediation elasticities vary between 0.396 and 0.456 but do not spike in W3, while the average contribution of intermediation to attainment is now 10.8 percent for the whole sample period and varies little for the sub-periods. The demand and supply elasticities are 0.726 and 0.359 for the entire sample period, while the economies of scale are almost on point for constant returns. In fact, estimates become so precise that we can now even reject the notion that the optimal supply-demand ratio is above 0.729 with a 2.5 percent probability of a type I error.

[25] The Hausman p-values are 0.232 and 0.834, respectively.

9 Conclusion

Search frictions have implications for how markets perform and the similarities between labor and OTC markets warrant transfer and comparison. We selected a benchmark specification of the attainment function to serve as the equivalent of the matching function in labor economics. A prominent feature of OTC markets in general—and the fed funds market in particular—is the presence of middlemen, who we find play a considerable role in the fed funds market. The elasticity of attainment attributable to the middleman group is significant, positive, and sizable: a one percent increase in the number of banks providing intermediation services increases attainment by 0.23 to 0.72 percent, while the total contribution can be as high as 29 percent.

The fed funds market displays decreasing or constant returns to scale with respect to the number of market participants. Furthermore, an optimal fed funds market has more banks with excess funds than it does banks with insufficient funds. We attribute this to the well-documented fact that a few larger banks in the fed funds market are net liquidity-absorbing, with many smaller banks providing that liquidity. Search frictions initially played a significant role, but their effect became noisier. Overall, the explanatory power is negligible, at least according to our measure.

Empirically, the attainment function explains a sizable fraction of the overall variation. Hence, it could adopt a role like that of the Taylor rule for the fed funds rate, as well as serve as a background model against which to test related hypotheses.

Future research should focus on the panel structure of the data set. It might also be interesting to determine what dictates whether a bank chooses to serve as an intermediator.

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Appendix

Additional tables for robustness results

		$Y_{t,small}$	$F^{demand}_{t,small}$	$F^{supply}_{t,small}$	$M_{t,small}$
W_1	Mean	1261.1	184.57	1207.9	152.14
	Median	1266.5	166.5	1219	152.5
	Min	1140	83	1088	131
	Max	1372	341	1334	169
W_2	Mean	76.036	13.571	74.357	4.4643
	Median	58.5	10.5	60.5	3.5
	Min	8	0	9	0
	Max	218	46	218	15
W_3	Mean	89	7.1667	152.92	2.5833
	Median	87	8	145	2
	Min	80	3	118	1
	Max	103	10	192	5

Table 4: Summary statistics for banks that held less than US$ 300 million in total assets.

Specification	(S1)	(S2)	(S3)	(S4)	(S5)	(S6)	(S7)
Method	OLS	GMM	OLS	OLS	OLS	GMM	OLS
Obs	68	62	68	68	68	62	68
$\log\left(F_t^{demand}\right)$	0.467*** (25.02)	0.473*** (49.08)	0.472*** (29.92)	0.023 (0.44)	−0.107 (1.49)	0.233*** (4.11)	−0.175** (2.14)
$\log\left(F_t^{demand}\right) \times W_2$				0.176** (2.43)	0.217** (2.54)	−0.147** (2.08)	0.321*** (3.52)
$\log\left(F_t^{demand}\right) \times W_3$				0.276* (1.75)	0.013 (0.09)	−0.388*** (4.15)	−0.039 (0.29)
$\log\left(F_t^{supply}\right)$	0.728*** (26.58)	0.731*** (19.59)	0.719*** (27.53)	0.219 (1.33)	−0.322 (1.59)	0.570*** (3.71)	−0.367* (1.81)
$\log\left(F_t^{supply}\right) \times W_2$				0.538*** (3.25)	0.559** (2.66)	0.041 (0.26)	0.716*** (3.47)
$\log\left(F_t^{supply}\right) \times W_3$				−0.263 (0.42)	0.204 (0.52)	−0.706** (2.32)	0.196 (0.55)
const	−0.767*** (4.35)	−0.83*** (2.85)	−0.686*** (3.89)	6.038*** (3.82)	6.535*** (2.98)	−2.105 (1.2)	9.236*** (3.13)
$const \times W_2$				−5.379*** (3.43)	−5.036** (2.42)	0.943 (0.57)	−6.641** (2.26)
$const \times W_3$				−0.396 (0.07)	−1.348 (0.37)	7.561*** (2.85)	−3.835 (1)
Q2			−0.068*** (2.98)	−0.049*** (2.93)	−0.043*** (3.4)	−0.036*** (3.64)	−0.035*** (3.14)
Q3			−0.055** (2.56)	−0.045*** (3.14)	−0.040*** (3.53)	−0.021* (1.85)	−0.039*** (3.49)
Q4			−0.081*** (3.02)	−0.076*** (3.81)	−0.049*** (3.68)	−0.032*** (3.03)	−0.043*** (3.51)
$\log(M_t)$					0.571*** (6.08)	0.627*** (11.37)	0.277 (1.32)
$\log(M_t) \times W_2$							−0.083 (0.36)
$\log(M_t) \times W_3$							0.449* (1.95)
R^2	0.976	0.976	0.98	0.994	0.978	0.996	0.982
BIC	-148.727	-138.917	-148.959	-205.077	-230.522	-210.171	-234.594

* p<0.10, ** p<0.05, *** p<0.01, absolute t-statistics are in parenthesis

Table 5: Estimates for (1) including banks that held less than US$ 300 million in total assets.

		$\bar{Y}_t$	$\bar{F}_t^{demand}$	$\bar{F}_t^{supply}$
W_1	Mean	30.632	5.7576	28.019
	Median	30.118	5.4312	28.109
	Min	22.654	3.0298	16.806
	Max	39.316	9.0674	36.379
W_2	Mean	13.307	2.6032	12.842
	Median	13.201	2.6534	12.735
	Min	9.4634	1.4427	9.6335
	Max	17.799	3.9905	17.77
W_3	Mean	6.7673	0.8264	28.56
	Median	6.6898	0.85495	29.97
	Min	4.4653	0.24395	20.637
	Max	10.762	1.3966	33.621

Table 6: Summary statistics for variables that employ continuous observations at the bank level in trillion 2009 US$.

Specification	(C1)	(C2)	(C3)	(C4)	(C5)	(C6)	(C7)
Method	OLS	GMM	OLS	OLS	OLS	GMM	OLS
Obs	68	62	68	68	68	62	68
$\log\left(\bar{F}_t^{demand}\right)$	0.841*** (22.27)	0.868*** (33.53)	0.840*** (22.36)	0.740*** (29.66)	0.847*** (24.16)	0.865*** (51.67)	0.726*** (18.72)
$\log\left(\bar{F}_t^{demand}\right) \times W_2$				−0.169*** (5.73)			
$\log\left(\bar{F}_t^{demand}\right) \times W_3$				0.161*** (3.44)			
$\log\left(\bar{F}_t^{supply}\right)$	0.318*** (8.47)	0.341*** (13.13)	0.316*** (8.37)	0.274*** (6.92)	0.295*** (3.86)	0.299*** (6.62)	0.359*** (4.79)
$\log\left(\bar{F}_t^{supply}\right) \times W_2$				0.103* (1.9)			
$\log\left(\bar{F}_t^{supply}\right) \times W_3$				0.014 (0.16)			
const	−2.349* (1.85)	−3.262** (3.49)	−2.286* (1.78)	0.323 (0.3)	−1.79 (0.84)	−2.197** (1.68)	−3.435 (1.63)
$const \times W_2$				0.221 (0.19)			
$const \times W_3$				−2.131 (0.86)			
Q2			−0.023 (0.91)				
Q3			−0.038 (1.35)				
Q4			−0.003 (0.06)				
$\log(M_t)$					−0.044 (0.56)	−0.044 (0.59)	0.396** (2.15)
$\log(M_t) \times W_2$							0.060*** (3.19)
$\log(M_t) \times W_3$							0.052*** (3.26)
R^2	0.968	0.968	0.969	0.974	0.969	0.968	0.976
BIC	-92.533	-77.549	-81.211	-80.479	-88.905	-74.213	-97.922
* p<0.10, ** p<0.05, *** p<0.01, absolute t-statistics are in parenthesis							

Table 7: Estimates for (1) explaining $\log\left(\bar{Y}_t\right)$ employing variables that are continuous at the bank-level.

Information regarding the calculation of the required reserves

Compare www.federalreserve.gov/monetarypolicy/reservereq.htm for a review and documentation of historical tranche sizes and rates, and http://www.federalreserve.gov/releases/h3/hist/annualreview.htm documents breaks and adjustments. The computation is straightforward. In short, the reserve requirements $rr_{i,t}$ are calculated using the total of the net transaction accounts and the total of the of nonpersonal time deposits a bank manages. The total of the net transaction accounts is effectively item 2215 (total transaction accounts) minus item 0085 (balances due from other banks in the U.S. (including their ibfs')) minus item 0020 (cash items in process of collection and unposted debits) plus item 0030 (unposted debits). The total of the net transaction accounts has an exempted amount. Above a first threshold a factor of 0.03 is applied and above a second threshold the factor becomes 0.1. These thresholds are changed each year and are documented in the appendix. Since Q1 of 1991 the effective factor for nonpersonal time deposits is zero. The appendix documents the historical rates. Note that borrowed fed funds are bank liabilities. They are exempted from the reserve requirements.

Low-Reserve Tranche Amounts and Exemption Amounts since 1982

Effective date (beginning of maintenance period)	Low-reserve tranche amount (millions of U.S. dollars)	Exemption amount (millions of U.S. dollars)
28-Dec-89	40.4	3.4
27-Dec-90	41.1	3.4
26-Dec-91	42.2	3.6
24-Dec-92	46.8	3.8
23-Dec-93	51.9	4
22-Dec-94	54	4.2
21-Dec-95	52	4.3
31-Dec-96	49.3	4.4
1-Jan-98	47.8	4.7
31-Dec-98	46.5	4.9
30-Dec-99	44.3	5
28-Dec-00	42.8	5.5
27-Dec-01	41.3	5.7
26-Dec-02	42.1	6
25-Dec-03	45.4	6.6
23-Dec-04	47.6	7
22-Dec-05	48.3	7.8
21-Dec-06	45.8	8.5
20-Dec-07	43.9	9.3
1-Jan-09	44.4	10.3
31-Dec-09	55.2	10.7
30-Dec-10	58.8	10.7
29-Dec-11	71	11.5
27-Dec-12	79.5	12.4

Table 8: Historical thresholds for exemption and low-reserve tranches from the homepage of the Federal Reserve.