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The Mechanics of a Graceful Exit: Interest on Reserves and Segmentation in the Federal Funds Market

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Abstract

To combat the financial crisis that intensified in the fall of 2008, the Federal Reserve injected a substantial amount of liquidity into the banking system. The resulting increase in reserve balances exerted downward price pressure in the federal funds market, and the effective federal funds rate began to deviate from the target rate set by the Federal Open Market Committee. In response, the Federal Reserve revised its operational framework for implementing monetary policy and began to pay interest on reserve balances in an attempt to provide a floor for the federal funds rate. Nevertheless, following the policy change, the effective federal funds rate remained below not only the target but also the rate paid on reserve balances. We develop a model to explain this phenomenon and use data from the federal funds market to evaluate it empirically. In turn, we show how successful the Federal Reserve may be in raising the federal funds rate even in an environment with substantial reserve balances.

Key words: federal funds, segmentation, interest on reserves, corridor system, exit strategy

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1 Introduction

The financial turmoil following the Lehman Brothers Inc. bankruptcy on September 15, 2008 necessitated unprecedented injections of liquidity into the financial system by the Federal Reserve. With the banking system awash in funds, the rate at which banks were willing to buy and sell these funds—the federal funds rate—dipped well below the intended policy target rate set by the Federal Open Market Committee (FOMC). As illustrated in figure 1(a), between September 16 and October 7, 2008, the average effective federal funds rate was 35 basis points below the 2 percent target rate set by the FOMC – in normal times, the effective rate is usually within 3 basis points of the target.

This situation created a tension for the Federal Reserve: while the increases in liquidity would prove to help improve market functioning, these increases were also exerting downward pressure on the federal funds rate. Following enactment of legislation that gave the Federal Reserve authority to pay interest on reserve balances beginning in October 2008, depository institutions (banks), for the first time, were able to earn overnight interest on funds held in accounts at the Federal Reserve, referred to as "reserve balances." The Federal Reserve essentially implemented a corridor (or channel) system similar to those operated by many other central banks such as the European Central Bank (ECB) and the Bank of England.[1] One feature of such a framework is that the interest rate paid on reserves normally provides a floor for the interbank interest rate that the central bank is seeking to control (Goodfriend 2002 and Ennis and Keister 2008, for example).

Even with the new framework in place, the effective federal funds rate continued to be not only below the target rate, but also below the interest rate paid on reserves, as shown in

[1] Refer to Berentsen and Monnet (2008) for a theoretical discussion of corridor systems.

figure 1(a). Between the October and December 2008 FOMC meetings the average effective federal funds rate was 32 basis points, while the target was 1 percent; the interest rate paid on reserves was 65 basis points or higher for the entire period. This deviation from the theoretical prediction was surprising for even the most astute observers of the federal funds market (Hamilton, 2008, for example). Why did interest on reserves provide an imperfect floor for the federal funds rate, even after the policy was changed so that the interest rate paid on reserves was set equal to the target rate?[2] Why would any financial institution lend out funds below the rate paid by the central bank? And even if that were the case, arbitrageurs would surely relish the opportunity of making a pure profit by borrowing cheaply in the market and placing the proceeds with the central bank, and by doing so, move the market rate toward the floor.

The explanation for the puzzling outcome is at least threefold. First, not all participants in the federal funds market are eligible to receive interest on their reserve balances.[3] Government-sponsored enterprises (GSEs) in particular, which are significant sellers of funds on a daily basis, are not legally eligible to receive interest on balances held with Reserve Banks. This heterogeneity across participants created a segmented market with different rate dynamics.[4] Second, banks' apparent general unwillingness or inability to engage in arbitrage has produced a market structure in which those banks that are willing and able to buy funds from the GSEs have

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[2] In particular, if the interest rate on reserves is set equal to the target rate, the price of reserves or interbank rate should become decoupled from the quantity if the supply of reserves is sufficiently large. Such a framework is known as a floor system and has been implemented in New Zealand. In the words of Keister, Martin and McAndrews (2008), "Money becomes divorced from monetary policy."

[3] Due to transactions costs for setting up accounts, not all banks have access to deposit facilities in other monetary policy areas; refer to Bindseil, Camba-Mendez, Hirsch, and Weller (2006) for more information.

[4] A segmented market is, however, not a sufficient condition for rate differences to emerge. For years, the overnight unsecured dollar market has been divided into the federal funds market and the market for Eurodollar deposits. But, as shown by Bartolini, Hilton, and Prati (2008), an overlap in participants resulted in the two markets being highly integrated as price differences were arbitraged away. McAndrews (2009) document that the reluctance of the big money center banks in New York to lend in the fall of 2007, led to a segmentation of the two markets and allowed the federal funds rate and overnight dollar Libor rates to diverge.

been able to exercise bargaining power and pay the GSEs rates below the interest rate paid on reserves. The lack of arbitrage possibly has been driven in part by banks seeking to control the size of their balance sheet more closely in part to avoid stressing regulatory capital and leverage ratios, as mentioned in Bernanke (2009a). Third, a combination of financial consolidation, credit losses, and changes to risk management practices has led at least some GSEs to limit their number of counterparties in the money market and to tighten credit lines. This trimming of potential trading partners has likely decreased bargaining power with the remaining counterparties.[5] In addition, the GSEs have become a larger share of the federal funds market in recent history and hence have pulled down the weighted average federal funds rate.

In this paper, we develop a simple framework for exploring the behavior of the effective federal funds rate in an environment with interest on reserves and a high level of reserve balances. The models we present incorporate the fact that certain participants are being paid interest on reserves (IOR) and others are not. In addition, as noted in Bernanke (2009a), we address the possibility that some IOR-eligible participants may be slower to adopt the new regime than others.

Based on our models, we are able to calibrate the bargaining power of the different participants to market data. This calibration allows us to investigate empirically the drivers of bargaining power in the federal funds market, and to use these estimated relationships to evaluate the impact on the federal funds rate of possible exit strategies from the Federal Reserve's accommodative monetary policy stance. In particular, we consider whether the rate paid on reserves balances can be used to shore up the federal funds rate in an environment in which

[5] Fannie Mae mentioned this pressure on p. 189 of its 2008 10K filing: "…the increasing consolidation of the financial services industry will increase our concentration risk to counterparties in this industry, and we will become more reliant on a smaller number of institutional counterparties, which both increases our risk exposure to any individual counterparty and decreases our negotiating leverage with these counterparties."

reserve balances are still high relative to normal levels as suggested by Dudley (2009). And, we also evaluate whether the Federal Reserve's

> "ability to pay interest on reserves will enable [it] to raise short-term interest rates even while the quantity of assets [held] is still quite elevated and while the reserve base of the banking system is extraordinarily high. The opportunity for banks to earn interest on a highly liquid risk-free deposit at the Federal Reserve should put a reasonably firm floor under short-term rates, including the federal funds rate" (Kohn 2009).

Using our estimated model, we find that in an environment of relatively normal market functioning, an effective federal funds rate of 2 percent or higher can likely be achieved even with $800 billion in reserve balances.[6] However, according to our model, the effective federal funds rate will likely be below the interest rate paid on reserves.

The paper is organized as follows. First, we briefly discuss the institutional details of the federal funds market. Second, we turn to the history and implementation of the interest-on-reserves regime. Third, we present our model of a bifurcated federal funds market with banks and GSEs. We also sketch out how the model can be extended to describe a trifurcated market in which some banks are slow to adopt the new policy regime. Fourth, we calibrate our model to federal funds market data and back out the relative bargaining power of the different market participants. Fifth, we explore the factors that affect our computed bargaining parameters. We show that the level and distribution of reserve balances, rates in other overnight funding markets, and the riskiness of the buyers all have significant predictive power in explaining the bargaining power of the different types of sellers. With this information, in our sixth section, we forecast the effective federal funds rate under a variety of exit scenarios from the current accommodative

[6] As of this writing, the interest rate paid on reserves is 25 basis points and reserve balances are over $1 trillion.

stance of monetary policy. The seventh section concludes and offers directions for further research.

2 Federal funds market

The Federal Open Market Committee (FOMC) implements its monetary policy goals of maximum employment, stable prices, and moderate long-term interest rates by affecting conditions in the federal funds market. For many years, the FOMC has employed a target for the interest rate at which depository institutions trade balances held at the Federal Reserve in the federal funds market; this rate is called the federal funds rate. The FOMC directs the Open Market Desk at the Federal Reserve Bank of New York to create conditions in the reserve market consistent with federal funds trading near the target (or within the target range).

Federal funds transactions are unsecured loans of balances at Federal Reserve Banks between depository institutions and certain other institutions including government-sponsored enterprises.[7] A borrower is said to *buy* funds whereas a lender is said to *sell* funds. The vast majority of trades are spot and the duration is typically overnight, but forward trades and trades for longer terms (called term federal funds) also take place.[8]

In general, there are two methods for trading federal funds. Buyers and sellers can either arrange trades directly--typically using an existing relationship--or employ the services of federal

[7] More specifically federal funds are deposit liabilities exempt from the reserve requirements under the Federal Reserve's Regulation D which include deposits of a domestic office of another depository institution, agencies of the U. S. government, Federal Home Loans Banks, and Edge Act or Agreement corporations.

[8] The market for term federal funds largely disappeared following August 9 2007, and has been slow to reemerge. Basically, creditors found they could not reliably determine the size of their counterparties' potential exposures and as a result, banks became much less willing to provide funding to other banks, especially for terms of more than a few days. Spreads of term federal funds rates and over rates on comparable-maturity overnight index swaps widened appreciably, and the liquidity in these markets diminished (see Board of Governors 2009, 31)

funds brokers. Like other brokers, federal funds brokers do not take positions themselves. Rather, for a fee, they bring buyers and sellers together on an ex-ante anonymous basis. That is, the broker will inform the seller about the identity of the buyer only after the seller's offer has been accepted. The repeated nature of the interactions ensures that a seller accepts the trade regardless of the buyer unless the seller does not have a specific credit line to the buyer or the line is already maxed out (Stigum and Crescenzi 2007). Based on summary reports from the brokers, every morning the Federal Reserve Bank of New York publishes the dollar weighted average rate of brokered trades--known as the effective federal funds rate--for the previous business day.

Trades are generally settled by the Federal Reserve's Fedwire Funds Service (Fedwire) which allows account holders to transfer funds in real time until the regular close of the system at 6:30 p.m. (6:00 p.m. for non-bank financial institutions). Unlike other parts of the money market, such as the repo market, the federal funds market tends to stay active throughout the day and according to Bartolini et al. (2005) about 40 percent of the trading occurs in the two hours before the close of Fedwire.

The federal funds market emerged in the 1920s as a method of adjusting reserve positions but over time the market acquired increased importance as an outlet for short-term investments and as a marginal source of funding (Willis 1972). The need for adjusting reserve positions arises from a combination of Federal Reserve regulations and the redistribution of balances that result from the daily flow of payments across accounts at the Federal Reserve. The Federal Reserve imposes penalties on account holders if they end a day overdrawn. In addition, depository institutions with reserve requirements are penalized if they hold an insufficient level of balances (and vault cash) relative to their requirement at the end of each reserve maintenance period. Reserve requirements are the amount of funds that a depository institution must hold in reserve against specified deposit liabilities.

As described by Stigum and Crescenzi (2007), in general, larger banks tend to be net buyers of federal funds, while smaller ones are often net sellers, because large corporate customers often borrow funds from the former and individuals often deposit funds at the latter. In addition, a few large custodial banks often buy substantial quantities of federal funds. Moreover, historically the GSEs have, because of their business models, been large net sellers of funds. For example, the Federal Home Loan Banks use the federal funds market to warehouse liquidity to meet unexpected borrowing demands from members, whereas Fannie Mae and Freddie Mac use the market as a short-term investment vehicle for incoming mortgage payments before passing the funds on in the form of principal and interest payments to investors.

The Federal Reserve usually kept excess balances in the banking system as a whole at a level that would ensure that the effective federal funds rate would stay close to the target rate. Lately, however, in an environment of heightened uncertainty in financial markets and highly accommodative monetary policy, many banks keep an elevated level of excess balances; few need to borrow to satisfy reserve requirements. In addition, the distribution of balances across Federal Reserve districts has become more concentrated. Indeed, as shown in table 1, as balances have increased markedly, the share held by the largest three Federal Reserve districts has jumped from 60 percent in July 2007 and July 2008 to 75 percent in July 2009, with the Second District's share climbing to nearly half of total balances. Furthermore, amid the recent financial turmoil and after the establishment of the conservatorship, Fannie Mae's and Freddie

Mac's current liquidity management procedures include a higher share of assets held as cash and cash equivalents, making federal funds a more prominent share of their balance sheet.[9]

[Table 1 about here.]

3 Interest on reserves

The expansion of the Federal Reserve's toolkit to include interest on reserves was a long time coming. Federal Reserve officials had for years requested that Congress provide the necessary legal authority to pay interest on reserve balances (Feinman 1993; Kohn 2004). Not remunerating reserves was seen as an implicit tax on banks that were subject to reserve requirements, as these institutions were obligated to hold balances overnight in their accounts and had to forego earnings elsewhere.[10] As a consequence, banks had an incentive to reduce their reserve balances to a minimum. To do so, they used tools such as sweep arrangements that move funds from deposits that were subject to reserve requirements to deposits and money market investments that were not. The Financial Services Regulatory Relief Act of 2006 gave the Federal Reserve authority, beginning October 2011, to pay interest on reserve balances (and to reduce reserve requirements to as low as zero). Importantly, the authorization only applied to depository institutions.[11]

The intensifying financial turmoil over the course of 2008 required larger and larger injections of liquidity into the financial system and made it infeasible for the Federal Reserve to

[9] For example, refer to Fannie Mae's 10K filing for 2008, release date February 26, 2009, p 125.
[10] Friedman (1959) also advocated this view, although only in conjunction with 100 percent reserve requirements.
[11] Institutions eligible to receive interest on reserves includes banks, savings associations, saving banks and credit unions, as well as trust companies, Edge and agreement corporations, and U.S. agencies and branches of foreign banks.

sterilize the resulting increases in reserve balances by redeeming or outright selling Treasury securities from the System Open Market Account (SOMA) portfolio, as illustrated in figure 1(b). The Federal Reserve asked Congress to move the October 2011 starting date for implementing interest on reserves forward to provide a floor for trading in the federal funds market (Bernanke 2008). Congress granted that authority as part of the Emergency Economic Stabilization Act of 2008, and the Reserve Banks began paying interest on reserve balances starting with the maintenance period beginning on October 9, 2008. The rules governing the payment of interest on reserves make a distinction between balances held to fulfill reserve requirements, referred to as "required reserve balances," and those paid on balances held in excess of required reserve balances and contractual clearing balances, referred to as "excess reserve balances."[12] The rates paid on required and excess balances evolved from the start of the program through December 2008 as shown in figure 2. Interest paid on required reserves was computed differently from that paid on excess reserves, and the rates applied differed. Initially, the rate paid on required reserve balances was 10 basis points below the *average* target federal funds rate for the maintenance period, while the rate paid on excess balances was 75 basis points below the *lowest* target for the period.

The spreads were subsequently narrowed twice: first to zero for required balances and 35 basis points for excess balances, and then to zero for both by the maintenance period ending on November 19, 2008. Following the December 15-16, 2008 FOMC meeting the interest rates on required reserve balances and excess balances were both set at 25 basis points, that is, at the

[12] Contractual clearing balances are those balances held to satisfy a clearing balance requirement. A clearing balance requirement is an amount than an institution may contract to maintain with a Reserve Bank in addition to any reserve balance requirement in order to facilitate its payment clearing needs. Because clearing balances generate earnings credits redeemable for Reserve Bank payment and settlement services, these balances are not remunerated in the current interest-on-reserves regime.

upper bound of the newly established target range for the federal funds rate of 0 to 25 basis points.

Before December 16, the exact lower bound of the interest rate corridor was somewhat fuzzy to banks engaging in federal funds trading in maintenance periods with a scheduled FOMC meeting.[13] If market participants placed some weight on the probability of a rate change, they might be inclined to sell funds at rates closer to the expected remuneration rate for the period, rather than the contemporaneous one. Indeed, as shown in figure 2, there were clearly periods in which an anticipated change in the target rate may have been a factor in pushing down the expected excess reserves rate, and at the same time, the effective rate.

4 Model

We propose a simple framework for examining the effective federal funds rate in an environment with a segmented application of interest on reserves and a high level of excess reserves. The segmented market incorporates the current nature of the federal funds market in which certain participants are being paid interest on reserves (IOR) and others are not. In addition, in an extension of the model, we address the possibility that some IOR-eligible participants may be slower to adapt to the new regime than others when IOR is introduced. Both models take as given the existence of one or more frictions that constrain the ability of market participants to arbitrage away the difference between the federal funds rate and the interest on reserves.

[13] In principle, an unscheduled FOMC meeting could result in a lower or higher target rate as well. Thus, the rate paid on excess reserves was uncertain in all maintenance periods and varied with the probability of an FOMC meeting in conjunction with the probability of a change in the target rate.

4.1 A model of bargaining in a bifurcated federal funds market

The economy has a central bank and a set of profit-maximizing and risk-neutral agents that buy and sell overnight (federal) funds in an over-the-counter market. Agents clear and settle obligations through the central bank's large-value payment system. The central bank makes a distinction between two types of agents: institutions that are paid interest on overnight reserve balances with the central bank and those that are not. We use the shorthand "banks" to denote the former and "GSEs" to denote the latter. The interest rate paid by the central bank is denoted by r_{ior}. In line with the general description of the federal funds market above, we assume for simplicity that only banks buy (borrow) federal funds, while both banks and GSEs sell (lend) in the market. A business day consists of two periods: *intra-day* and *end-of-day*. Both banks and GSEs can trade (and settle) in the former, but only banks can settle and hence trade in the latter (see figure 3).

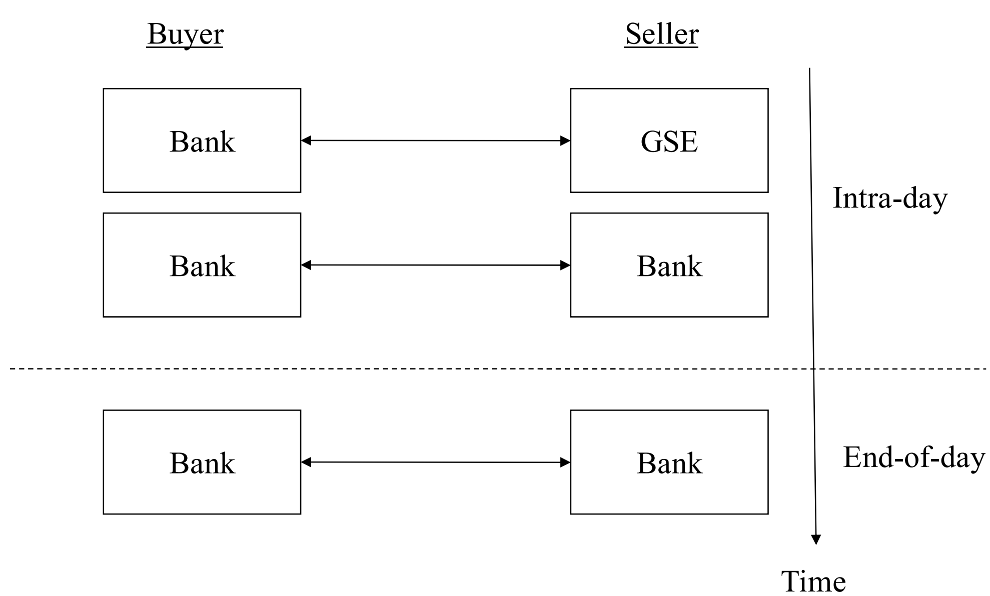

Figure 3: Market structure – agents, timing, and bargaining process

Furthermore, we assume that any agent can only trade with one counterpart per period and we abstract from possible size effects and take all transactions to have the same dollar value (scaled to one). The rate paid on a federal funds transaction between a GSE and a bank is denoted by r_{g2b}, while the rate on a transaction between two banks is given by r_{b2b}.[14] The effective federal funds rate is simply the weighted average rate paid on transactions between banks and GSEs and the rate paid on transactions between banks, that is

$$r_{eff} = pr_{g2b} + (1-p)r_{b2b} \tag{1}$$

where p can be thought of as the GSE market share for purposes of selling federal funds. If the GSEs can only command very low rates in the market and their market share is sufficiently large, then market segmentation will drive the effective federal funds rate below the IOR rate. Market segmentation, however, does not explain how market share and the different rates at which a bank can buy federal funds are determined.

4.1.1 Bank versus bank and GSE versus bank bargaining problems

In what follows, we assume that the GSE market share is exogenous while r_{g2b} and r_{b2b} are determined by bilateral bargaining. We do not specify the explicit bargaining processes but rather solve for *generalized Nash solutions* to the *bargaining problems* between a bank and a GSE as well as between two banks, respectively. In each case, the bargaining problem involves the two parties splitting the surplus between the rate at which a buyer can borrow funds and the rate at which a seller can place funds should the negotiation fail.[15] Buyers obviously seek the lowest rate possible and sellers the highest. Moreover, as shown below, the Nash solution

[14] As no new information arrives between the two periods and as there is no intraday discounting the bank to bank rate is the same in the two periods.

[15] The Nash solution ensures that the outcome is *Pareto efficient* and that it is *independent of irrelevant alternatives*, that is, it does not affect the outcome if the buyer is given another alternative borrowing option that charges a higher rate than the current alternative option.

implies that the seller gets paid its *alternative option* plus a share of the surplus reflecting its bargaining power, whereas the buyer has to pay its alternative option minus a rebate again reflecting its bargaining power.

Following Binmore (1992), for example, we formally define the bargaining problem as a pair $\langle A, d \rangle \in S$, where A is the set of feasible agreements, and $d = (d^{buyer}, d^{seller})$ is the *threat* or *disagreement* point that reflects the outcome if the parties fail to agree. A bargaining solution is a function $f : S \mapsto R^2$ that picks out a unique solution. In this context, with profit-maximizing risk-neutral agents, the utility of agents associated with a trade is simply equal to the interest income, and the generalized Nash solution can be written as

$$r^*(A,d) = \arg\max_{d \le a} (a^{buyer} - d^{buyer})^{1-\alpha} (a^{seller} - d^{seller})^{\alpha} \qquad (2)$$

where $a = (a^{buyer}, a^{seller}) \in A$ denotes an agreement and $\alpha \in [0, 1]$ denotes the bargaining power of the seller and $1 - \alpha$ the bargaining power of the buyer.[16] As trades in the federal funds market involve buyers paying sellers the interest r, any agreement is of the form $a = (-r, r) \in R_{-} \times R_{+}$, and assuming that there are gains from trade, the disagreement point satisfies $d^{buyer} \le a^{buyer} = -r$ and $d^{seller} \le a^{seller} = r$. Equation (2) simplifies to

$$r^* = \arg\max_{d^{seller} \le r \le -d^{buyer}} (-r - d^{buyer})^{1-\alpha} (r - d^{seller})^{\alpha}. \qquad (3)$$

Setting the first-order condition of the maximand (generalized Nash-product) equal to zero and solving for r yields the following solution:

[16] We could model the agents as risk-averse, but this would not change the overall implications. The only requirement for a Nash bargaining solution is that the feasible agreement set is convex.

$$\begin{aligned} r^* &= -\alpha d^{buyer} + (1-\alpha) d^{seller} \\ &= d^{seller} + \alpha(-d^{buyer} - d^{seller}) \\ &= -d^{buyer} - (1-\alpha)\underbrace{(-d^{buyer} - d^{seller})}_{Surplus} \end{aligned} \tag{4}$$

as shown in appendix A. If two banks meet then the minimum rate at which a seller bank will lend should theoretically be the excess reserves rate, that is, $d^{seller} = r_{ior}$. Moreover, the maximum rate at which a buyer bank would be willing to borrow money should be no higher than the all-in cost of going to the discount window, that is, $d^{buyer} = -r_{dw}$. Hence, the surplus to be divided is the difference between the all-in cost of the discount window and the interest paid on excess reserves, that is, $r_{dw} - r_{ior}$. From equation (4) it follows that

$$r^*_{b2b} = (1-\beta) r_{ior} + \beta r_{dw} = r_{ior} + \underbrace{\beta(r_{dw} - r_{ior})}_{mark-up} = r_{dw} - \underbrace{(1-\beta)(r_{dw} - r_{ior})}_{discount} \tag{5}$$

where β is the bargaining power of the banks selling funds.[17] From the seller's perspective, the agreed-upon rate is the rate at which funds could be placed at the central bank, plus a mark-up that depends on the seller's bargaining power and the surplus. From the buyer's perspective, the agreed-upon rate is all-in-cost of borrowing from the central bank, less a discount that depends on the buyer's bargaining power and the surplus.

In contrast, for a bank negotiating with a GSE, the alternative option is not the cost of going to the discount window but rather the "*bank versus bank*" bargaining solution, r^*_{bank}. We denote the alternative option for the GSEs as r_{alt}, but because GSEs cannot earn interest on funds

[17] For banks trading the in the first period the alternative option for both the buyer and the seller is the bank-to-bank rate in the second period, which is determined as in equation (5). Hence, as discussed in footnote 15, the rate between banks is the same in the intra-day and end-of-day periods.

placed at the Federal Reserve, we will in many places treat it as being zero.[18] Hence, the Nash solution to the bargaining between a bank and a GSE is given by

$$r_{g2b}^{*} = (1-\gamma)r_{alt} + \gamma r_{b2b}^{*} = r_{alt} + \gamma(r_{b2b}^{*} - r_{alt}) = r_{b2b}^{*} - (1-\gamma)(r_{b2b}^{*} - r_{alt}) \tag{6}$$

where γ denotes the bargaining power of a GSE. In appendix B, we provide a graphical illustration of the solution to the two bargaining problems. From equations (1), (4) and (5), we have

$$\begin{aligned} r_{eff}^{*} &= p((1-\gamma)r_{alt} + \gamma r_{b2b}^{*}) + (1-p)r_{b2b}^{*} \\ &= (1-p(1-\gamma))r_{b2b}^{*} + p(1-\gamma)r_{alt} \\ &= (1-p(1-\gamma))((1-\beta)r_{ior} + \beta r_{dw}) + p(1-\gamma)r_{alt} \end{aligned} \tag{7}$$

The effective federal funds rate is a weighted sum of the cost of going to the discount window, the interest on reserves rate, and the alternative rate available to the GSEs. The weights depend on the respective bargaining powers of banks and GSEs, as well as GSE market share. The relationship between the effective federal funds and the interest on reserves according to equation (7) is shown in figure 4, for a fixed width of the corridor (r_{dw} - r_{ior}) and an alternative option of the GSEs of zero.

[18] An alternative specification of the model would be to treat another overnight market as the alternative option of the GSEs. The secured, overnight repurchase agreement (repo) market is one of the most liquid and therefore would be a likely candidate. In addition, in terms of our model, the repo market usually trades at rates below federal funds, as federal funds transactions are generally unsecured. Empirically, however, on many days in our sample, rates in the repo market (or at least our measures of these rates) apparently traded at rates above those at which we observe the GSEs selling federal funds. If the repo market is, in fact, the GSEs' alternative option, then funds should not be sold at rates lower than repo. Because this is not the case, we let the repo market influence the federal funds market by allowing the repo rate to drive bargaining power, as presented in section 6.

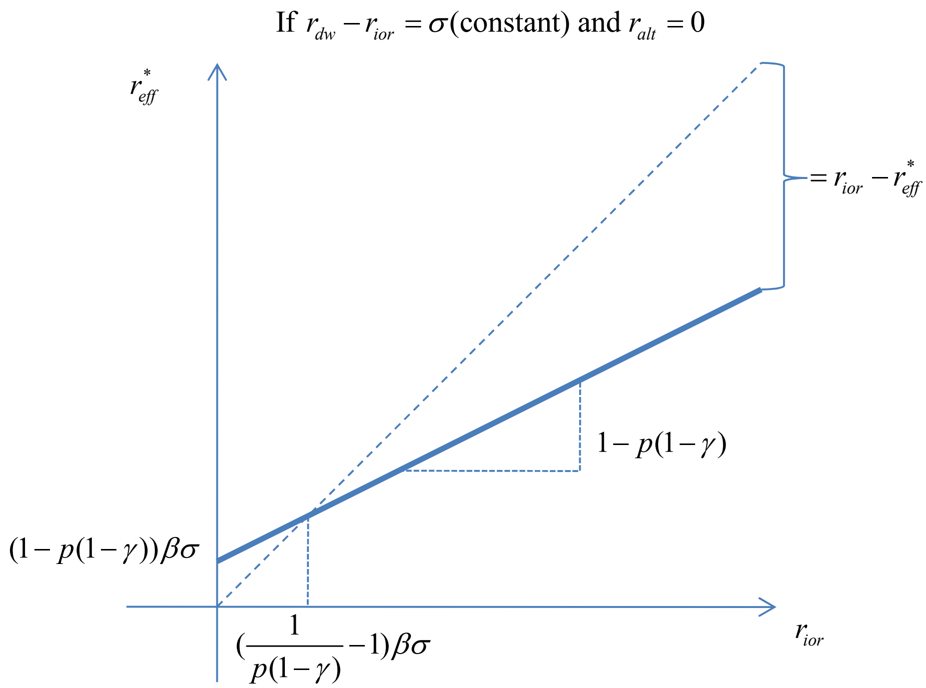

Figure 4: Relationship between the effective federal funds rate and the interest on reserves rate

In the model, increasing the interest on reserves rate raises the effective federal funds rate. For every basis point increase in r_{ior}, the effective federal funds rate increases by less than a basis point, $1-p(1-\gamma)$. Hence, the absolute difference between the interest on reserves rate and the effective federal funds rate widens as the interest rate paid on reserves is increased. As mentioned above, our model assumes the presence of frictions that limit market participants from arbitraging away these differences. Insofar as these frictions become less binding as the interest on reserves increases, our model defines a <u>*lower bound*</u> on the effective federal funds rate.[19]

[19] Moreover, the figure shows, that for low levels of the interest on reserves rate, the effective federal funds rate is the larger of the two. In the case of , r_{dw} - r_{ior} = 50 basis points, β = .25, γ = .5 and p = .8 (see appendix B) this occurs at 18.25 basis points.

4.1.2 Model implications

The expression for the effective federal funds rate in equation (7) permits some intuitive results in terms of comparative statics. The effective federal funds rate depends on the models' parameters in the following manner. First, an increase in GSE bargaining power pushes the effective rate up:

$$\frac{\partial r_{eff}^*}{\partial \gamma} = p(r_{b2b}^* - r_{alt}) > 0. \tag{8}$$

The magnitude of this effect depends on the market share of the GSEs and the relevant surplus to be divided; larger values of either magnify this effect. Simply put, if GSEs have higher bargaining power, the rate they can charge may increase.

Second, an increase in the GSEs market share of the federal funds market decreases the effective federal funds rate. The impact is smaller the larger the bargaining power of the GSE:

$$\frac{\partial r_{eff}^*}{\partial p} = (1-\gamma)(r_{alt} - r_{b2b}^*) < 0. \tag{9}$$

As explained above, the relevant bargaining range for the GSEs lies below that of the banks. Therefore, a higher percentage of funds sold by GSEs moves the effective rate down.

Third, an increase in the alternative option for the GSEs in terms of placement of funds drives up the federal funds rate:

$$\frac{\partial r_{eff}^*}{\partial r_{alt}} = p(1-\gamma) > 0. \tag{10}$$

An increase in the GSEs' alternative option moves up their disagreement point and hence their bargaining range, which necessarily causes the effective rate to increase. If the bargaining power of the GSE is already high, however, the effect of a change in the alternative option is diminished.

Fourth, an increase in the seller bargaining power in the bank-versus-bank interaction pushes up r_{b2b}^{*} and hence the effective federal funds rate. The upward pressure increases with the width of the corridor, that is, surplus, but is smaller if the GSE market share is large:

$$\frac{\partial r_{eff}^{*}}{\partial \beta} = \left(1 - p(1-\gamma)\right)(r_{dw} - r_{ior}) > 0. \tag{11}$$

Fifth, an increase in the borrowing cost at the discount window or the rate paid on reserves drives the effective federal funds rate up. The size of impact is smaller when the GSE market share is large:

$$\frac{\partial r_{eff}^{*}}{\partial r_{dw}} = \left(1 - p(1-\gamma)\right)\beta > 0; \text{ and} \tag{12}$$

$$\frac{\partial r_{eff}^{*}}{\partial r_{ior}} = \left(1 - p(1-\gamma)\right)(1-\beta) > 0. \tag{13}$$

Finally, if the discount window rate is raised, then the effective rate will rise, but if the IOR rate is lowered, then the effective rate will fall. Consequently, an increase in the width of the corridor that moves the discount window rate up but the IOR rate down will drive up the effective rate if $\beta > .5$, that is, if the selling banks have more bargaining power than the buying banks.

In sum, our model can explain the recent dynamics of the federal funds market in an environment where institutions appear to respond to their alternative options rationally. It seems, however, that some banks were selling funds below the IOR rate for a period of time, even though these institutions could leave the funds in their account at the Federal Reserve and earn a higher rate of interest. In what follows, we extend the model slightly to incorporate the behavior of these institutions into the market and offer an interpretation of their apparently aberrant behavior.

4.2 A model of bargaining in a trifurcated federal funds market

While the model above introduces heterogeneity across participants in the federal funds market, it is obviously a simplification. Nevertheless, the framework can easily be extended to allow for additional types of agents. In this section, we present an extended version of the model, where we allow banks to differ in how quickly they adjust to the new policy regime. As shown in figure 2, in the beginning days of IOR, there were frequent changes to the rules, which may have caused some banks to adapt to the regime slowly. We extend the model by dividing the bank seller category into two subcategories to reflect the possibility that some banks may have been slow to adjust to the new interest-on-reserves regime and could have been selling funds below the rate paid on (excess) reserves. We use the shorthand “old” regime and “new” regime to denote the two types. Specifically, we assume that the old regime banks tend to trade early and that the market share of old regime banks is q. The timing of the bargaining process in the case with slow adjusters to the interest on reserves policy is shown in figure 5.

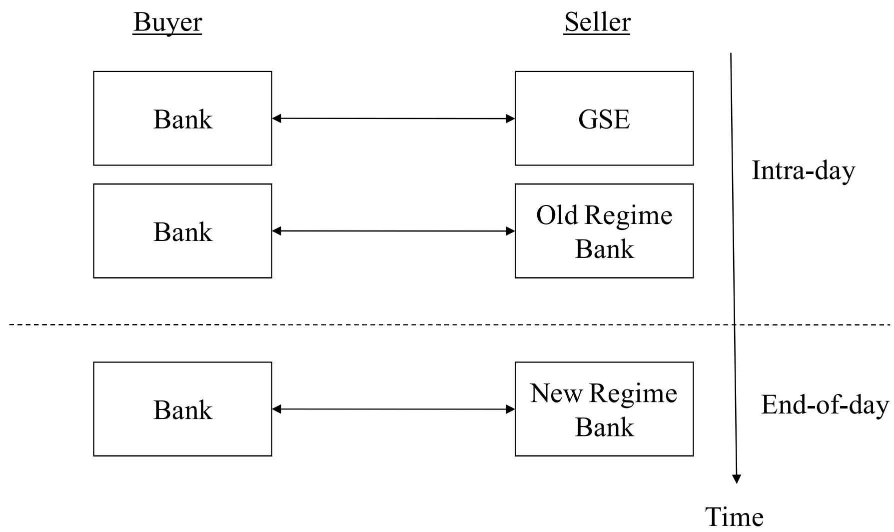

Figure 5: Market structure – agents, timing, and bargaining process with slow adjusters

The rates earned by old and new banks when selling funds are denoted r_{old} and r_{new} respectively. Hence, the effective federal funds rate can be decomposed as follows:

$$r_{eff} = pr_{g2b} + qr_{old} + (1-p-q)r_{new}. \tag{14}$$

The new-regime banks operate like the bank type in the previous model; that is, they treat the interest on reserves r_{ior} as their alternative option. In contrast, the old-regime banks suffer from inexperience with the new regime and are potentially willing to sell funds at lower rates.[20] We assume that they, like the GSEs, have zero as their alternative option, as these banks have not yet responded to the incentive of IOR and behave as if they receive no interest on balances held at the central bank. Again, we assume that outcomes are determined by Nash bargaining where the

[20]These trades may also be those done by a correspondent on behalf of a respondent. In this case, the correspondent may not fully receive the benefits of IOR from the respondent balances, and therefore, have no incentive to sell balances on behalf of the respondent at a rate greater than zero.

sellers' bargaining powers are denoted γ, ω, and β for a GSE, old-regime bank, and new-regime bank, respectively. The rate earned by new-regime banks can readily be determined as

$$r_{new}^{*} = (1-\beta)r_{ior} + \beta r_{dw} \tag{15}$$

whereas the rates paid to the GSEs and the old-regime banks are given by

$$\begin{aligned} r_{g2b}^{*} &= \gamma r_{new}^{*} = \gamma\left((1-\beta)r_{ior} + \beta r_{dw}\right) \text{ and} \\ r_{old}^{*} &= \omega r_{new}^{*} = \omega\left((1-\beta)r_{ior} + \beta r_{dw}\right). \end{aligned} \tag{16}$$

Substituting into equation (14) yields the effective federal funds with slow adopters. We have

$$\begin{aligned} r_{eff}^{*} &= p\gamma r_{new}^{*} + q\omega r_{new}^{*} + (1-p-q)r_{new}^{*} \\ &= \left(1 - p(1-\gamma) - q(1-\omega)\right)\left((1-\beta)r_{ior} + \beta r_{dw}\right) \end{aligned} \tag{17}$$

Note that for q = 0 and r_{alt} = 0, equation (17) is equivalent to the expression for the effective federal funds rate in equation (7). Comparative statics are shown in appendix C and have the same signs as in section 4.1.2, but now the magnitude may depend on ω and q. The effective federal funds rate depends on the two new parameters as follows: Increasing the bargaining power of the slow adjusters, that is, ω, increases the effective rate

$$\frac{\partial r_{eff}^{*}}{\partial \omega} = q r_{dw}^{*} > 0 \tag{18}$$

whereas increasing the share of slow adjusters moves the effective rate down, with the magnitude of the drop depending on the degree of their bargaining power.

$$\frac{\partial r_{eff}^{*}}{\partial q} = -(1-\omega) r_{new}^{*} < 0 \tag{19}$$

5 Calibration of bargaining power

In the remainder of the paper, we take our simple models to the data to estimate key parameters and to simulate the effective federal funds rate under different assumptions. A challenge is the fact that the bargaining power parameters are latent or unobserved. Our approach is to use information on the observed rates at which the different segments of the federal funds market trade to back out the bargaining-power parameters consistent with the model. In the following section, we then correlate these implied bargaining parameters with a set of variables and indicators that we a priori would expect to influence the relative bargaining power of buyers and sellers of federal funds. To the extent that the estimation exercises yield good fits and plausible marginal effects, they would provide a level of comfort in our framework and its implications.

5.1 Calibrating the bifurcated model

In our first calibration exercise, we use proprietary data on rates and volumes of brokered trades in the federal funds market that the Federal Reserve Bank of New York uses to construct the daily effective federal funds rate.[21] By doing so, we can take a close look at the data used to compile the official policy rate and attempt to identify movements in these data. One shortcoming of these data is that they provide information only on the aggregate dollar amounts traded at each rate and not the identity of either the buyer or the seller. As a result, we assume that trades at or above the interest rate paid on reserves are trades executed between banks and that trades below the IOR rate are executed between banks and GSEs.[22] Over the course of our sample, as shown in figure 6(a), p, the share of trades below the excess-reserves rate, was quite volatile in the early days of interest on reserves, ranging from 4 percent to 95 percent. It started

[21] Along with the value-weighted average (the effective federal funds rate), the Federal Reserve Bank of New York publishes the low and high rates as well as the value-weighted standard deviation of the data reported by the federal funds brokers.

[22] Note that this assumption biases the GSE and bank rates downward and, as such, if we instead assumed that trades at the IOR rate are attributable to the GSEs, the implied bargaining power of both the GSEs and the banks would move up. In our calibration exercises, then, these results reflect a lower bound on the bargaining power of each type of seller.

dropping from mid-December 2008 onward, and hovered around 80 percent for the months following.

Our identifying assumptions, in turn, allow us for each day to compute $\hat{r}_{g2b}(t)$ as the average interest rate on trades brokered below the excess rate, weighted by dollar volume; similarly, we compute $\hat{r}_{b2b}(t)$ as the weighted average rate for trades brokered at or above the excess reserves rate. The decomposition of the effective rate into these two rates is shown in figure 6(b). Our sample covers October 9, 2008, to July 1, 2009, with a total of 181 observations.

Using our calculated $\hat{r}_{b2b}(t)$ and $\hat{r}_{g2b}(t)$, we construct the implied bargaining powers. Rearranging equations (5) and (6), we have the following expressions for γ and β:

$$\hat{\beta}(t) = \frac{\hat{r}_{b2b}(t) - r_{ior}(t)}{r_{dw}(t) - r_{ior}(t)} \tag{20}$$

and

$$\hat{\gamma}(t) = \frac{\hat{r}_{g2b}(t) - r_{alt}(t)}{\hat{r}_{b2b}(t) - r_{alt}(t)} \tag{21}$$

for t greater than October 9, 2008. Note that these expressions are simply the share of the surplus that the seller captures from the bargaining. In our calibrations, we assume that the all-in cost of going to the discount window is 25 basis points above the primary credit rate and that the alternative rate for the GSEs is zero.[23] Before interest on reserves, we view the bank versus bank

[23] Little is known about the banks' perceived all-in cost of borrowing from the discount window. Our choice of level is to some extent arbitrary but changing level does not qualitatively affect our results, but it does quantitatively change the results of analysis. Nevertheless, regardless of the choice of the all-in cost of borrowing from the discount window banks trade close to the interest on reserves and hence in the bottom of their bargaining range.

and GSE versus bank markets as an integrated market and compute (for comparison) the bargaining power of a seller of funds as

$$\hat{\beta}(t) = \hat{\gamma}(t) = \hat{r}_{eff}(t) / r_{dw}(t) \tag{22}$$

for t less than October 9, 2008. Under these assumptions, our implied bargaining powers are plotted in figure 7(a). The implied bargaining power of sellers of funds hovered near 0.8, before the start of interest on reserves, as the intended target for the federal funds rate was at 2 percent, and the all-in cost of borrowing from the discount window is assumed to have been the primary credit rate of 2¼ percent plus 25 basis points. Following the Lehman bankruptcy, the supply of balances increased markedly and the estimated bargaining power of sellers of funds dropped precipitously. According to our calculations, in essence, the federal funds market became a buyer's market. After the implementation of interest on reserves, the alternative option for banks selling funds improved appreciably but we estimate that their bargaining power continued to fall—with buyers capturing all but a couple of basis points of the surplus. Our model suggests some improvement in bargaining power for banks selling funds around the end of the first quarter of 2009, but later in the sample, it apparently moved lower again, except for quarter-end 2009. Over the period as a whole, the bargaining power of bank sellers, $\hat{\beta}(t)$, averages about 0.12 and ranges from a low of 0.01 on June 8, 2009, to a high of 0.71 on June 30, 2009, where funds traded as high as 7 percent, probably due to some institutions' extreme reluctance to go to the discount window on a quarter-end statement date. In contrast, following the start of interest on reserves, the bargaining power of the GSEs (while volatile) is estimated to have moved down only slightly on balance. In early January 2009, the bargaining power rose significantly from 0.25 to over 0.50, likely reflecting the rise in repo rates surrounding a large settlement in

Treasury securities and the wind down of the Federal Reserve's term agency mortgage-backed securities (MBS) repurchase agreements.[24] Over our sample period the bargaining power of GSEs, $\hat{\gamma}(t)$, has an average of 0.48, although the range is about comparable with that for $\hat{\beta}(t)$.

5.2 Calibrating the trifurcated model

For our calibration of a three-type market, we use proprietary transaction-level data from the Fedwire funds transfer service that has been matched to form plausible overnight funding transactions, likely related to the federal funds market. Similar data were first used by Furfine (1999) and since then by Bartolini, Hilton, and McAndrews (forthcoming), Ashcraft and Duffie (2007), and Demiralp, Preslopsky, and Whitesell (2006) to mention a few.[25] Again, our sample is drawn from the universe of matched transactions from October 10, 2008, to July 1, 2009. The transaction data set contains basic transfer information, including the amount of the transaction, the implied interest rate of the identified transaction, and the seller and buyer in the trade. These last two pieces of information allow us to differentiate the rates earned by depository institutions and GSEs to evaluate the empirical implications described above.[26]

[24] On March 7, 2008, the Federal Reserve announced that it would initiate a series of 28-day term repurchase agreements (repos) in its open market operations (OMO) that eventually reached a level of $80 billion. As primary dealers could elect to deliver as collateral any of the types of securities that are eligible as collateral in its regular open market operations (Treasury, agency debt or agency MBS) only the least desirable type of collateral was used, that is, agency MBS. As funding conditions improved in early 2009, these term MBS repos were no longer rolled over by the Federal Reserve.

[25] The algorithm matches an outgoing Fedwire funds transfer sent from one account and received by another with a corresponding incoming transfer on the next business day sent by the previous day's receiver and received by the previous day's sender. This pair of transfers is considered a federal funds transaction if the amount of the incoming transfer is equal to the amount of the outgoing transfer plus interest at a rate consistent with the rates reported by major federal funds brokers. However, because we have no independent way to verify if these are actual federal funds transactions, our identified trades and characteristics of these trades are subject to error.

[26] One drawback of these data is that some portion of the transfers likely reflects Eurodollar transactions, which also go over Fedwire. Traditionally, Eurodollars traded at rates similar to federal funds; however, as of late, there has been a disconnect and a lack of arbitrage between the two markets. For a longer discussion on the apparent decoupling of the Eurodollar and federal funds market, refer to McAndrews (2009).

Turning to the estimated relative bargaining power of the trifurcated model, as shown in figure 7(b), the bargaining power of the new-regime banks averages 0.09—well below the implied bargaining power of the GSEs, which averages 0.57. Interestingly, the average bargaining power for the old-regime banks is 0.50, suggesting not only that it is lower than the GSEs, but also that these institutions divide evenly the implied surplus with their counterparties.[27] These calibrations also suggest that the GSEs usually capture relatively more of the available surplus from transactions than new regime banks do but, as their alternative options are worse, they still get a lower rate. In the Fedwire data, the bargaining power of bank sellers is in a much tighter range because of an estimated lower maximum bargaining power, but the averages of the brokered series and the Fedwire series are within one standard deviation of each other.

6 Determinants of bargaining power in the federal funds market

Although these bargaining-power dynamics are illustrative, they do not explain the factors that influence rate movements in the federal funds market. To address this issue more completely, we apply our theoretical model to data from the money market to identify the factors that significantly predict bargaining power.

The econometric specification is complicated by the fact that the bargaining power variables of interest are, by construction, positive proper fractions; that is, they take on values between zero and one. We based our analysis on the reduced-form fractional response (FR)

[27] One possible explanation of this phenomenon is that correspondent institutions (a subset of these old-regime banks) are selling funds cheaply to boost their leverage ratios and therefore are willing to accept a low rate when selling these funds.

model proposed by Papke and Wooldridge (1996). This model is based on a generalized linear framework

$$E\left[\alpha(t) \mid x(t)\right] = g^{-1}\left(\eta(t)\right) = g^{-1}\left(\theta x(t)\right) \tag{23}$$

where the conditional expectation of $\alpha(t) \in \{\beta(t), \gamma(t), \omega(t)\}$ is a function of the linear predictor $\eta(t)$--a combination of a vector of covariates $x(t)$ with a vector of parameters θ to be estimated--and the function g^{-1e} can be thought of as a distribution function.[28] The advantage of this construction is that while the linear prediction of the factors can take on any value, the predicted values of $\alpha(t)$ are necessarily constrained between zero and one. In these models, the function g (otherwise known as the "link" function) is a member of the exponential family of functions, and in our case g^{-1} is the logistic function.[29]

6.1 Covariates

Our hypothesis is that bargaining power in the federal funds market depends on selected covariates, including the quantity and distribution of reserve balances, conditions in related overnight funding markets, the policy environment, and exogenous factors affecting the demand for funds by different entity types. Table 2 presents summary statistics on our covariates. For the ease of exposition we group our covariates into four groups and as a result, we write $\eta(t)$ as

$$\eta(t) = \theta_0 + \theta_1 balances(t) + \theta_2 othermarkets(t) + \theta_3 policy(t) + \theta_4 calendar(t). \tag{24}$$

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[28] One can think of the dependent variable, $\alpha(t)$, as a probability of success for a particular experiment, where the distribution function associated with this probability is $g^{-1}()$. This mean value for this experiment depends on selected market factors denoted by $x(t)$ with weights corresponding to the vector of parameters θ.

[29] Selection of the particular form of g is made by examining the goodness of fit of the models under different distributional assumptions. Using the Akaike Information Criterion and the Bayesian information criterion, we determined that a logistic link function in general produced the best fit for most of the models; however, the fit was fairly similar regardless of the choice of g. We also examined the fit of the models using a logit, probit, log-log, or complementary log-log link function.

The group *balances* include the total level of reserve balances held at Reserve Banks (total fed balances) as well as a measure of the concentration of reserve balances.[30] Specifically, we compute a daily Herfindahl-Hirschman index (HHI) that measures the distribution of reserve balances among selected large institutions.[31] A higher level of reserve balances is, all else equal, expected to decrease sellers' bargaining power, whereas increased concentration is expected to help the GSEs as more banks would be looking to buy funds if the reserves in the system are in the hands of only a few participants.[32] Moreover, in the case of the trifurcated model, we also include a measure of the market share of certain money center and custodial banks in the federal funds market as these banks are more likely to exert a differential effect on the bargaining power of sellers of funds and, in addition, perhaps are more likely to engage in money market arbitrage.

The group *other markets* contains the spread of the Treasury general collateral (GC) repurchase agreement rate to the target rate and a credit default swap (CDS) index for investment-grade financial institutions.[33] The repo market and the federal funds market are closely related and many participants are active in both. Higher rates in the repo market may improve the bargaining power of sellers in the federal funds market by providing a price point. The CDS index captures capture broader market sentiment regarding the health of the banking sector. Many studies in banking--Berger and Udell (1995), for example--suggest that asymmetric information about credit quality affects bargaining power between banks and their customers and that the same may be true in the federal funds market. As such, increased

[30] Reflecting the dramatic change in the Federal Reserve's balance sheet, total balances ranges widely, from approximately $200 billion to $955 billion, with an average level of roughly $730 billion.
[31] We scaled this measure by 1000 in the reported summary statistics and estimation results.
[32] Alternatively, even if balances are concentrated in the set of depository institutions to which the GSEs are willing to sell, the GSEs may still be able to command a higher price, in that these market participants may have a relatively inelastic demand curve for balances.
[33] We use the rate on excess reserves as the "target" for the period after December 16, 2008. The CDS index is computed as the median credit default swap premium for a collection of investment-grade financial institutions.

counterparty risk may strengthen the hands of sellers as, on the one hand, they can plausibly demand higher rates. On the other hand, however, prudent risk management in response to a higher chance of default may reduce credit lines and limit eligible counterparties and hence lower the bargaining power of the seller who is now more constrained in how much and with whom it can trade.

The *policy* group includes indicator variables that control for the excess reserves regime and the policy environment. First, we include a dummy variable that equals 1 if the rate paid on excess reserve balances changes at a later date in the maintenance period. The anticipation of excess variable is an attempt to measure the degree to which banks were able to foresee future rate changes that would affect their remuneration on reserves held overnight on any given day. Second, we control for target rate changes. The announcement of the new target rate does not generally occur until later in the day (around 2:15 p.m.), so that on those days, trading in the first part of the day can be conducted in reference to a target rate different from that for trading later in the day.

Finally, the group *calendar* consists of a set of indicator variables to control for calendar effects. We include principal and interest (P&I) days when Fannie Mae and Freddie Mac pay out principal and interest on their debt obligations and mortgage-backed securities. All else equal, one would expect that the bargaining power of GSEs would be strengthened on those days as the need for Fannie Mae and Freddie Mac to sell funds is smaller. In addition, we include an indicator variable for quarter-end statement dates, when funds market behavior has in part been driven by reporting requirements.

6.2 Determinants of bargaining power in the bifurcated model

Table 3 presents results from estimating the relationship in equation (24) for both $\beta(t)$ and $\gamma(t)$ using the brokered data from the Federal Reserve Bank of New York. The first set of columns presents the results for estimating the determinants of bank sellers' implied bargaining power, β, and the second set of columns presents those for the GSEs, γ.

In the results for both banks and GSEs, the first column displays the estimated marginal effects from the fractional response model.[34] As a robustness check, the second and third columns show estimates from a simple linear specification and a linear specification with two autoregressive terms. All inference is based on Newey-West standard errors (shown in parentheses in the tables) that are corrected for heteroskedasticity and autocorrelation.

With the balances group factors, there are two points to note. First, the level of (log) balances has significant negative effects on seller bargaining power, as expected. However, the marginal effect for the GSEs is almost three times that for the banks. In the sample over which our parameters are estimated, banks are near the bottom of their bargaining range. Accordingly, additional balances do not cause their bargaining power to move very much. By contrast, GSEs usually capture about half the surplus from their trading interactions. Therefore, an increase in balances may push down their bargaining power more substantially.

Second, the distribution of balances also has some ability to predict the bargaining power of the GSEs. The coefficients on the HHI variable imply, in very rough terms, that an increase in the concentration of balances by one standard deviation implies an increase of bargaining power for the GSEs of about 0.08. One interpretation of the result is that increases in market

[34] For continuous variables, this is calculated at the means of the independent variables, while for indicator variables, it is calculated as the discrete change in the predicted value for an indicator variable going from zero to one. Actual parameter estimates are reported in appendix D.

concentration more generally push up the market power of sellers of funds, which include the GSEs.

The next set of coefficients focuses on the effects of broader market conditions on the bargaining power of these sellers. High repo rates tend to push down the bargaining power of banks, as evidenced by the negative coefficients on the spread to the target variable. By contrast, for the GSEs, bargaining power is positively correlated with the Treasury GC repo rate spread as expected. . These effects are even more pronounced after December 15, when the target range of zero to 25 basis points was introduced.

Continuing with the exploration of the effects of broader market conditions, we find that increased counterparty risk, as measured by the financial CDS index, increases the bargaining power of the banks, while it reduces the bargaining power of the GSEs. This result perhaps suggests that, as a result of smaller or fewer credit lines, fewer trading opportunities may dominate any increased risk premiums that the GSEs can collectively command.

As for the effect of the policy environment on bargaining power, the coefficient on the anticipation of the excess rate parameter suggests that cuts in the excess rate were not fully anticipated, otherwise, this coefficient would be equal to zero. As shown in figure 2, on multiple trading days the excess rate that would be applied at the end of the maintenance period was below that in effect at the beginning. Trading in the funds market adjusted down towards the new excess rate, but not all the way, implying an increase in the market power of banks selling above the excess rate. However, as is evident from the coefficient, the increase in market power was not one-to-one, and the marginal effect of being in an anticipation period was only about 0.02. In addition, the date of the FOMC has only limited effect on bargaining power.

The final set of coefficients control for various calendar effects. As is evident for the coefficients, the bargaining power of sellers increases on P&I days, likely because the GSEs are not as aggressively selling funds, given their need to keep the funds in their accounts to cover the large volume of outgoing payments. The positive and significant coefficient (for banks) on the quarter-end variable is consistent with a possible increased stigma of going to the discount window on reporting dates, thereby pushing up the bargaining power for sellers.

6.3 Determinants of bargaining power in the trifurcated model

As shown in table 4, the patterns in the trifurcated model and in the bifurcated model are the same. What is notable is that the magnitude of the effects of almost all factors is estimated to be greater for the GSEs than for the other types, particularly the old-regime banks. Increases in balances tend to push down the bargaining power of all types of institutions, but there is a much more marked effect estimated for the GSEs. As shown in figure 8(a), when balances rise, GSEs' bargaining power is estimated to fall considerably. Interestingly, the trifurcated model reveals that the effect of concentration on the below-IOR rate sellers that we saw in the brokered data is now estimated to be attributed to the old-regime banks. In fact, the bargaining power of the GSEs is not significantly affected by the concentration of balances according to our estimates. This points to further evidence of market segmentation, in that two types of institutions that are estimated to be selling below the excess rate have different interactions with potential buyers. Finally, while the concentration of balances at the largest institutions was positively correlated with the market power of both the old-regime banks and the GSEs with about the same magnitude, the share of the market attributed to custodial banks appears to have limited relevance.

We find that the repo rate spread has a relatively larger estimated effect on the GSEs than on the old-regime banks, although for both the effect is fairly sizable. As shown in figure 8(b), γ moves in step with the Treasury GC repo rate. As in the bifurcated model, bargaining power for the GSEs is more pronounced on the P&I dates, while bargaining power picks up substantially on quarter-end dates for new regime banks.

7 Exit Scenarios

Interest on reserves permits the Federal Reserve to change the stance of monetary policy and to raise or lower private interest rates by raising or lowering the rate paid on excess reserves. As noted by policy makers and pundits alike, this factor may prove to be an important part of the Federal Reserve's exit strategy going forward, should the FOMC choose to raise interest rates even when the balance sheet is still relatively large and excess reserve balances are elevated. In this section, we use the fractional model estimates calculated above to illustrate possible paths for the effective federal funds rate under different assumptions for the rate paid on excess reserve balances, the spread of the repo rate to the target rate, and the level of excess balances. In what follows, we assume that all other factors—including the distribution of reserve balances and the CDS financial index spread—revert back to their average pre-crisis levels. Table 5 shows our underlying assumptions for each of these exercises. We perform our forecasting exercises using the parameter estimates obtained from the brokered federal funds data. The results using the "Furfine" data are qualitatively similar.

In the first exercise, we calculate the implied effective rate for a range of excess reserves rates, assuming that reserve balances remain elevated at $800 billion. Furthermore, we posit that the excess reserves rate is set at the target rate, as is the case currently. We assume that the spread between the target federal funds rate and the overnight Treasury GC repo rate reverts to its historical level of 9 basis points. Figure 9 displays our results. The rates at which banks and GSEs sell federal funds are shown by the blue and red lines, respectively. The banks continue to sell at just above the excess rate, while GSEs sell below. The GSE rate, however, stays well above zero. In particular, all rates move up with the IOR rate. We also plot the implied effective federal funds rate with different assumptions for the market shares of the GSEs. In the "low" scenario, the GSEs have a 25 percent share of federal funds sales; in the "high" scenario, the GSE share is 75 percent. As we illustrated in figure 4, the effective federal funds rate rises with the rate paid on excess reserves, and the slope is steeper if the GSE share is low. As is evident from the figure, even though the effective rates may well be below the target, it is certainly possible to achieve an effective funds rate in the 2-3 percent range (or even higher) amid elevated balances. Again, it is worth noting that the analysis provides a lower bound for the effective rate as it is implicitly assumed that banks do not seek to arbitrage the difference between the IOR rate and where the market is trading.

We examine the effects of different levels of the repo-excess rate spread and total balances on the effective federal funds rate in figures 10 and 11, respectively. Both exercises assume a 2 percent rate paid on excess (and required) reserve balances, and $800 billion in excess balances. As shown in figure 10, the narrower the spread of the repo rate to the excess rate, the closer the effective rate is to the excess rate. Again a smaller GSE market share drives up the effective federal funds rate. The repo-excess rate spread has little effect on the predicted rate for banks (blue line) but for the GSEs (red line), however, rates march up as the spread between the repo rate and the target rate narrows. Even if the spread is particularly wide at 90 basis points, the GSE rate is still forecasted to be only 80 basis points below the excess rate.

The effect of balances on the effective rate is shown in figure 11. Higher balances suggest lower effective rates for a given level of the excess rate. But, the model predicts that even with $1 trillion in balances, the effective rate remains well above zero, but likely below the excess rate. Even more to the point, perhaps, the figure clearly shows that if balances revert to historical levels, the effective rate converges to the excess rate. In fact, at sufficiently low levels of balances and GSE market share, the effective rate rises above the interest on reserves rate. In other words, it moves within the corridor as posited by the standard theoretical models.

Going forward, should the FOMC choose to tighten its policy stance, the model suggests that that the Federal Reserve could use some combination of the IOR rate and tools to drain reserves—such as term deposits or reverse repurchase agreements—in order to achieve its monetary policy goals.[35] Figure 12 shows the effects of changing both the IOR rate and the level of balances simultaneously on the spread between the excess rate and the effective federal funds rate. As can be seen from the chart, our model suggests that raising the IOR rate in conjunction with draining reserve balances narrows the spread between the excess rate and the effective rate, all other things equal. Spreads are estimated to be particularly narrow when the GSEs have a relatively low market share. Indeed, our model estimates suggest that spreads are more sensitive to changes in the excess rate and changes in balances when the GSE share is high, but exhibit less sensitivity if this share is low.

[35] Refer to Bernanke (2009b) for more information on tools under consideration for draining reserve balances.

8 Conclusion

As borne out by international experience, a corridor or floor system for implementing monetary policy is a solid framework. However, certain structural aspects of the federal funds market in the United States (as well as the timing of the introduction of interest on reserves—during the height of the financial turmoil) have led to an average interbank rate below the floor rate. But, as we argue, this is a straightforward result of the market dynamics created by the fact that some participants in the federal funds market are paid interest on reserves and others are not. The deviation of the effective federal funds rate from the corridor—defined by the interest paid on excess reserves and the all-in cost of the discount window—has presumably been amplified by a combination of factors. These factors could include the general impairment of money markets, bank balance sheet pressures and the structure of the GSEs' conservatorship as well as their risk management practices. These may have left arbitrage opportunities unexploited. Moreover, the high level of excess reserves may have increased the market share of the participants with the less attractive alternative option, that is, the GSEs.

Nevertheless, the results in this paper suggest that a graceful exit is indeed possible. First, our estimates suggest that, even amid high balances, the Federal Reserve can raise the effective federal funds rate when conditions warrant. As shown above, if the Federal Reserve raises the rate paid on excess reserves, the effective rate would move up in tandem according to our model estimates, although the relationship will likely be less than one-to-one due to the segmented nature of the market. Second, if the deviation between the policy rate and the effective rate is deemed to be too large, then our model suggests that the Federal Reserve can raise the effective federal funds rate even further by draining reserve using tools such as reverse repurchase agreements or a term deposit facility. In particular, our comparative statics suggest that, if the Federal Reserve targets balances held by the GSEs directly, this approach would have a large impact because it would decrease the GSE market share in the federal funds market**,** improve the alternative option of the GSEs**,** and raise the bargaining power of sellers in general. As such, it would operate on all the three margins highlighted by our analysis to raise the effective federal funds rate and narrow the spread between the effective rate and the excess rate.

To conclude, our model is a simplification of current market conditions and only looks at a narrow, albeit important, part of the broader money market. Future research, could seek to incorporate the repo and Eurodollar markets in a more explicit manner.

Appendix A: Solving the generalized Nash bargaining problem

From equation (3) we have

$$r^* = \underset{d^{seller} \le r \le -d^{buyer}}{\arg\max} (-r - d^{buyer})^{1-\alpha} (r - d^{seller})^{\alpha}$$

Taking the first order conditions and setting it equal to zero yields,

$$\begin{aligned}
&-(1-\alpha)(-r-d^{buyer})^{-\alpha}(r-d^{seller})^{\alpha} + \alpha(-r-d^{buyer})^{1-\alpha}(r-d^{seller})^{\alpha-1} = 0 \Rightarrow \\
&\alpha(-r-d^{buyer})^{1-\alpha}(r-d^{seller})^{\alpha-1} = (-r-d^{buyer})^{-\alpha}(r-d^{seller})^{\alpha} \Rightarrow \\
&\alpha(-r-d^{buyer})^{1-\alpha}(-r-d^{buyer})^{\alpha} = (1-\alpha)(r-d^{seller})^{1-\alpha}(r-d^{seller})^{\alpha} \Rightarrow \\
&\alpha(-r-d^{buyer}) = (1-\alpha)(r-d^{seller}) \Rightarrow \\
&r^* = -\alpha d^{buyer} + (1-\alpha)d^{seller}
\end{aligned}$$

Appendix B: Illustrating generalized Nash bargaining in the federal funds market

The *bank versus bank* and the *GSE versus bank* bargaining problems and their solutions for different assumptions about bargaining power and alternative options are illustrated in panel (a) – (d) of figure B1. Interest rates are measured in basis points on the horizontal axis and the generalized Nash products from equation (3) are measured (also in basis points) on the vertical axis. In panel (a) – (c), the interest rate paid on excess reserves balances is assumed to be equal to 25 basis points (shown by the orange diamond marker), the all-in cost of going to the discount window is set at 75 basis points (shown by the purple asterisk marker), and the GSEs are assumed to have a market share of 80 percent.

The generalized Nash product in the *bank versus bank* bargaining is shown by the blue line. The rate that maximizes this function r^*_{b2b} is shown by the blue square. This rate constitutes the alternative option for a bank that is bargaining with a GSE. The generalized Nash product for the *bank versus GSE* bargaining is shown by the red line, and the rate at which this function reaches its maximum, r^*_{g2b}, is shown by the red triangle. The effective rate resulting from the nested bargaining problems is the market share weighted average of the *bank versus bank* and *bank versus GSE* rates (shown by the green circle). In the first figure, agents are assumed to split the surplus evenly in all negotiations, that is, the bargaining parameters are set at 0.5. This implies that the Nash products are symmetric around the mid-points of the bargaining ranges. Consequently, the *bank versus bank* rate is 50 basis points and hence the *bank versus GSE* rate is 25 basis points. This in turn implies that the effective rate is 0.8*25 + 0.2*50 = 30 basis points.

In figure 2, the bargaining power of a bank selling funds is decreased from 0.5 to 0.25 and the Nash product tilts to the left. The *bank versus bank* rate is now 37.5 basis points and the surplus to be split if a bank meets a GSE is now smaller by 12.5 basis points relative to before. An even split yields a *bank versus GSE* rate of 18.75 basis points. The effective rate is now at 22.3 basis points, and hence below the interest paid on reserves. In panel (c), the bargaining power of GSEs, γ, is reduced from 0.5 to 0.25 and the *bank versus GSE* Nash product tilts to the left, which further drives down the *bank versus GSE* rate to 9.5 basis points and the effective rate to 15 basis points, respectively. In the final figure, the interest rate on reserves is set at 200 basis points and the all-in cost of going to the discount window is at 250 basis points. The bargaining power of a selling bank is assumed to be .25 which drives the *bank versus bank* rate to 212.5 basis points and greatly expands the surplus to be shared between a bank and a GSE. Assuming an even split, that is, $\gamma = .5$ the effective rate is 127 basis points with a GSE market share of 0.8. In other words, the increase in the interest rate paid on reserves raised the effective federal funds rate significantly but it still sits well below the interest paid on reserves.

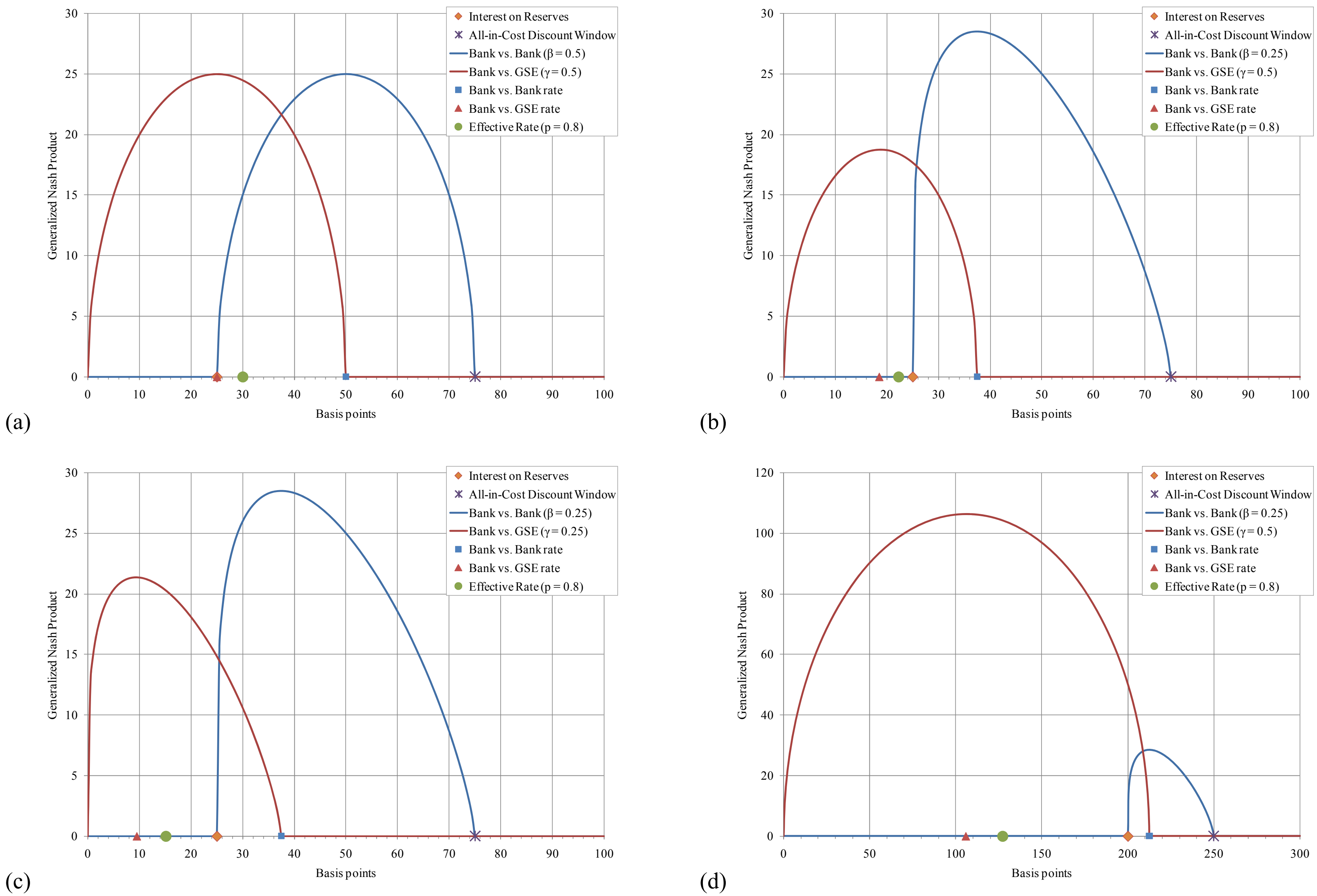

Figure B1: Bargaining Problems

Appendix C: Comparative statics in the trifurcated model

From equations (7) and (17) it follows that

	Bifurcated model	Trifurcated model
$\partial r_{eff}^* / \partial p$	$(1-\gamma)(r_{alt} - r_{b2b}^*) < 0$	$-(1-\gamma) r_{new}^* < 0$
$\partial r_{eff}^* / \partial \gamma$	$p(r_{b2b}^* - r_{alt}) > 0$	$p r_{new}^* > 0$
$\partial r_{eff}^* / \partial \beta$	$(1-p(1-\gamma))(r_{dw} - r_{ior}) > 0$	$(1-p(1-\gamma)+q(1-\omega))(r_{dw} - r_{ior}) > 0$
$\partial r_{eff}^* / \partial r_{alt}$	$p(1-\gamma) > 0$	NA
$\partial r_{eff}^* / \partial r_{dw}$	$(1-p(1-\gamma)\beta > 0$	$(1-p(1-\gamma)-q(1-\omega))\beta > 0$
$\partial r_{eff}^* / \partial r_{ior}$	$(1-p(1-\gamma))(1-\beta) > 0$	$(1-p(1-\gamma)+q(1-\omega))(1-\beta) > 0$

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Table 1: Reserve balances by Federal Reserve district
($ millions)

District	July 4, 2007 Level	July 4, 2007 Percent of total	July 2, 2008 Level	July 2, 2008 Percent of total	July 1, 2009 Level	July 1, 2009 Percent of total
Boston	644	4	874	5	30,025	4
New York	5,104	30	3,216	20	333,833	46
Philadelphia	597	4	952	6	15,153	2
Cleveland	1,397	8	552	3	28,096	4
Richmond	2,928	17	4,686	29	151,292	21
Atlanta	1,511	9	1,026	6	25,131	3
Chicago	1,090	7	920	6	28,251	4
St. Louis	310	2	316	2	4,833	1
Minneapolis	252	2	265	2	2,866	0
Kansas City	439	3	475	3	22,719	3
Dallas	667	4	730	4	16,521	2
San Francisco	1,817	11	2,222	14	67,541	9
Total	16,755	100	16,232	100	726,260	100

Source: Federal Reserve Statistical Release H.4.1, various dates.

Table 2: Summary statistics				
	Mean	Standard deviation	Minimum	Maximum
Market shares				
Brokered data				
Bank (above excess rate)	0.25	0.22	0.04	0.96
GSE (below excess rate)	0.75	0.22	0.04	0.96
Fedwire data				
New regime bank (above excess rate)	0.16	0.12	0.02	0.55
Old regime bank (below excess rate)	0.41	0.14	0.05	0.63
GSE (below excess rate)	0.42	0.06	0.25	0.63
Bargaining power				
Bifurcated model, brokered data				
Beta (above or equal to excess rate)	0.12	0.10	0.01	0.71
Gamma (below excess rate)	0.48	0.18	0.10	0.81
Trifurcated model, Fedwire data				
Beta (bank, above or equal to excess rate)	0.09	0.08	0.01	0.41
Omega (bank, below excess rate)	0.50	0.18	0.10	0.81
Gamma (GSE)	0.57	0.23	0.13	0.97
Memo: Bifurcated model, Fedwire data				
Beta (above or equal to excess rate)	0.08	0.08	0.01	0.41
Gamma (below excess rate)	0.50	0.18	0.10	0.82
Independent variables				
Log of total balances	6.55	0.30	5.30	6.86
HHI	1.09	0.28	0.57	1.89
Custodial bank share	0.24	0.06	0.06	0.39
Spread of Treasury GC repo rate to target rate	-0.16	0.41	-1.40	0.21
Post December 15, 2008	0.05	0.07	-0.15	0.21
CDS financial index	2.99	0.53	2.02	4.45
Anticipation of excess rate	0.07	0.25	0	1
FOMC	0.03	0.18	0	1
Principal and interest payment date	0.10	0.30	0	1
Quarter end	0.02	0.13	0	1

Date range: October 10, 2008 to July 1, 2009

Number of observations: 180 (excludes Good Friday, 2009)

Table 3: Factors affecting seller market power, October 10, 2008 to July 1, 2009

Dependent variable: Seller's bargaining power (Brokered data)

	Banks (beta)			GSEs (gamma)		
	FR marginal effect	Regression	AR(2)	FR marginal effect	Regression	AR(2)
Log of total balances	-0.054**	-0.063**	-0.076+	-0.090**	-0.065*	-0.159*
	(0.01)	(0.02)	(0.04)	-0.026	-0.025	-0.064
HHI	-0.028	-0.015	-0.021	0.166**	0.166**	0.091**
	(0.02)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)
Spread of repo rate to target rate	-0.111**	-0.127**	-0.116**	0.404**	0.364**	0.185**
	(0.02)	(0.02)	(0.04)	(0.04)	(0.03)	(0.03)
Post December 15, 2008	-0.373**	-0.371**	-0.416**	1.036**	0.985**	0.607**
	(0.14)	(0.12)	(0.14)	(0.13)	(0.15)	(0.12)
CDS financial index	0.061**	0.051**	0.048*	-0.114**	-0.107**	0.036
	(0.01)	(0.01)	(0.02)	(0.03)	(0.01)	(0.04)
Anticipation of excess rate	0.036**	0.054**	0.052	-0.095**	-0.060*	-0.045+
	(0.00)	(0.02)	(0.03)	(0.01)	(0.03)	(0.02)
FOMC	0.05	0.04	0.042+	0.02	0.02	0.01
	(0.03)	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)
P & I date	0.001	0.002	0.003	0.036**	0.031	0.018+
	(0.00)	(0.01)	(0.02)	(0.00)	(0.02)	(0.01)
Quarter end	0.193*	0.243+	0.220**	-0.095*	-0.082	-0.117**
	(0.08)	(0.15)	(0.01)	(0.04)	(0.07)	(0.01)
Constant		0.338**	0.44		1.187**	1.399**
		(0.11)	(0.29)		(0.17)	(0.43)
AR(1)			0.143**			0.593**
			(0.07)			(0.06)
AR(2)			0.212**			0.349**
			(0.06)			(0.06)
R-squared/Pseudo R-squared	0.53	0.57	0.63	0.80	0.80	0.91
Observations	180	180	180	180	180	180

Newey-West heteroskedasticity-autocorrelation robust errors in parentheses for fractional response; robust standard errors for regression.

+ significant at 10% * significant at 5%; ** significant at 1%

Table 4: Factors affecting seller market power, October 10, 2008 to July 1, 2009

Dependent variable: Seller's bargaining power, Fedwire data

	Banks						Gamma (GSE)		
	Beta (new regime)			Omega (old regime)					
	FR Marginal effect	Regression	AR(2)	FR Marginal effect	Regression	AR(2)	FR Marginal effect	Regression	AR(2)
Log of total balances	-0.076**	-0.136**	-0.141**	-0.037	-0.02	-0.159**	-0.431**	-0.337**	-0.317**
	(0.00)	(0.02)	(0.03)	(0.03)	(0.03)	(0.06)	(0.02)	(0.04)	(0.06)
HHI	-0.033*	-0.03	-0.03	0.200**	0.194**	0.093**	0.159+	0.166**	-0.059+
	(0.02)	(0.02)	(0.03)	(0.04)	(0.04)	(0.02)	(0.09)	(0.04)	(0.03)
Custodial bank market share (buy)	0	0	-0.001	0.001	0.001	0.001	0.007*	0.007**	0.004**
	0.00	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Spread of repo rate to target rate	-0.062**	-0.076**	-0.060*	0.356**	0.320**	0.134**	0.474**	0.399**	0.329**
	(0.00)	(0.02)	(0.02)	(0.04)	(0.03)	(0.03)	(0.10)	(0.06)	(0.02)
Post December 15, 2008	-0.153**	-0.214**	-0.200*	0.875**	0.833**	0.332**	1.206**	1.075**	1.271**
	(0.04)	(0.07)	(0.09)	(0.15)	(0.16)	(0.09)	(0.29)	(0.16)	(0.13)
CDS financial index	0.028**	0.021**	0.016	-0.076**	-0.071**	0.048	-0.086*	-0.080**	0.033
	(0.00)	(0.01)	(0.02)	(0.03)	(0.01)	(0.03)	(0.04)	(0.01)	(0.05)
Anticipation of excess rate	0.037**	0.067**	0.038+	-0.098**	-0.072**	-0.03	0.00	0.00	0.092**
	(0.01)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.02)	(0.04)	(0.02)
FOMC	0.075*	0.07	0.058**	0.00	0.00	-0.01	-0.051+	-0.04	-0.03
	(0.03)	(0.04)	(0.01)	(0.02)	(0.04)	(0.02)	(0.03)	(0.04)	(0.02)
P & I date	0.008*	0.013	0.011	0.024**	0.021	0.003	0.069**	0.062*	0.024+
	(0.00)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)	(0.03)	(0.01)
Quarter end	0.143**	0.158**	0.160**	-0.097**	-0.087	-0.170**	0.015	0.008	-0.048+
	(0.03)	(0.06)	(0.01)	(0.02)	(0.05)	(0.01)	(0.02)	(0.06)	(0.03)
Constant		0.898**	0.980**		0.736**	1.322**		2.829**	2.706**
		(0.11)	(0.19)		(0.18)	(0.37)		(0.29)	(0.37)
AR(1)			0.448**			0.758**		0.734**	0.661**
			(0.07)			(0.07)		(0.06)	(0.06)
AR(2)			0.075			0.203**		0.204**	0.254**
			(0.07)			(0.07)		0.07	(0.07)
R-squared/Pseudo R-squared	0.54	0.69	0.73	0.78	0.77	0.91	0.81	0.79	0.93
Observations	180	180	180	180	180	180	180	180	180

Newey-West heteroskedasticity-autocorrelation robust errors in parentheses for fractional response; robust standard errors for regression.
+ significant at 10% * significant at 5%; ** significant at 1%

Table 5: Forecasting values

	Value
GSE share (percent)	25.6
Total balances ($ billions)	800
HHI (divided by 1000)	1.26
Custodial bank share (percent)	17.39
Spread of Treasury GC repo rate to excess rate (percent)	-0.09
CDS financial index	0.27
Anticipation of excess rate	0
FOMC	0
Principal and interest payment date	0
Month end	0
Quarter end	0

Date range: January 2, 2007 to August 1, 2007

Appendix D: Parameter estimates for fractional response model

Dependent variable: Seller's bargaining power

	Brokered data		Fedwire data		
	Beta	Gamma	Beta	Omega	Gamma
Log of total balances	-0.585**	-0.363**	-1.119**	-0.15	-1.778**
	(0.07)	-0.104	(0.06)	(0.12)	-0.076
HHI	-0.298	0.667**	-0.480*	0.798**	0.657+
	(0.22)	(0.16)	(0.24)	(0.17)	-0.362
Custodial bank market share (buy)			-0.004	0.003	0.031*
			(0.00)	(0.01)	(0.01)
Spread of repo rate to target rate	-1.199**	1.620**	-0.904**	1.422**	1.957**
	(0.21)	(0.14)	(0.10)	(0.16)	(0.45)
Post December 15, 2008	-4.026*	4.154**	-2.245**	3.500**	4.981**
	(1.57)	(0.52)	(0.57)	(0.62)	(1.26)
CDS financial index	0.657**	-0.459**	0.408**	-0.303**	-0.355*
	(0.12)	(0.10)	(0.07)	(0.11)	(0.15)
Anticipation of excess rate	0.341**	-0.388**	0.457**	-0.398**	(0.01)
	(0.04)	(0.06)	(0.08)	(0.07)	(0.10)
FOMC	0.413+	0.08	0.802**	0.01	-0.206+
	(0.25)	(0.09)	(0.24)	(0.09)	(0.12)
P & I date	0.014	0.144**	0.111**	0.095**	0.292**
	(0.05)	(0.02)	(0.04)	(0.02)	(0.09)
Quarter end	1.309**	-0.389*	1.261**	-0.394**	0.061
	(0.41)	(0.17)	(0.18)	(0.09)	(0.08)
Constant	(0.52)	3.543**	3.771**	1.497**	12.321**
	(0.81)	(0.29)	(0.36)	(0.33)	(1.15)
Observations	180	180	180	180	180

Newey-West heteroskedasticity-autocorrelation robust errors in parentheses .

+ significant at 10% * significant at 5%; ** significant at 1%

Figure 1(a): Federal funds rate

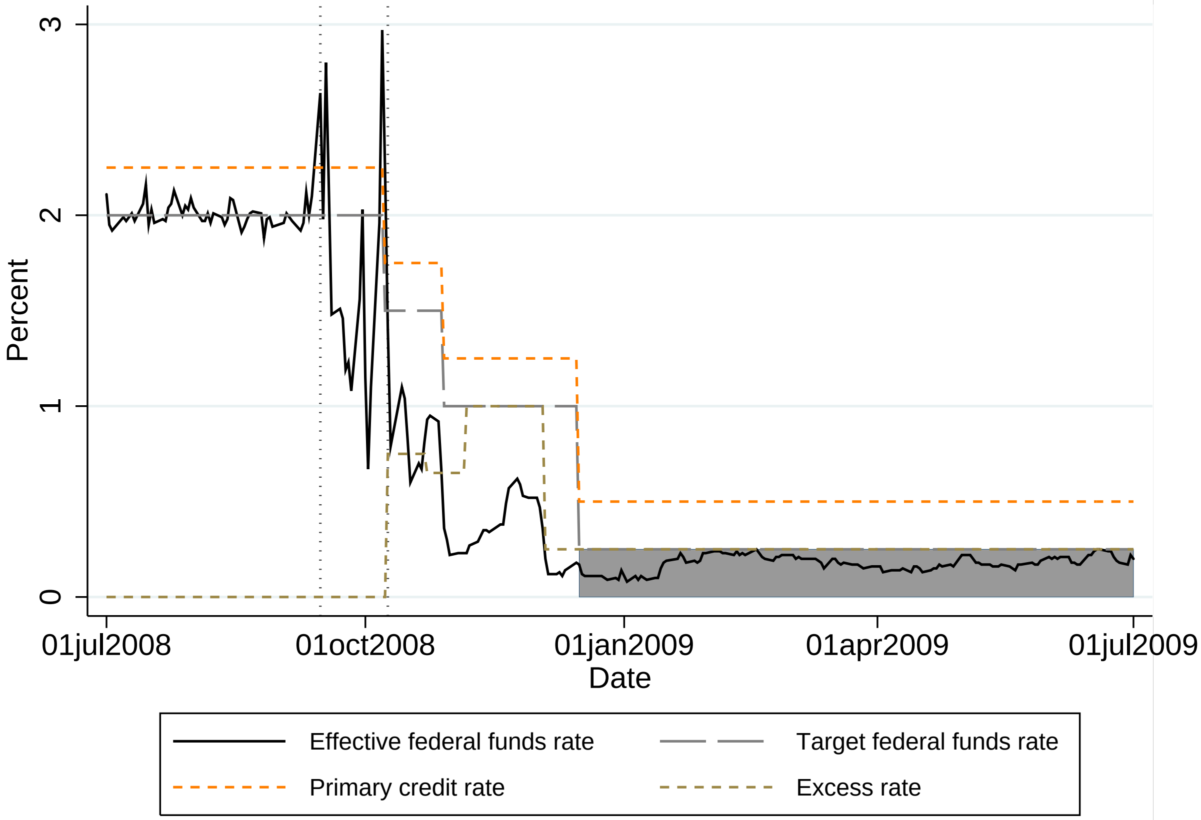
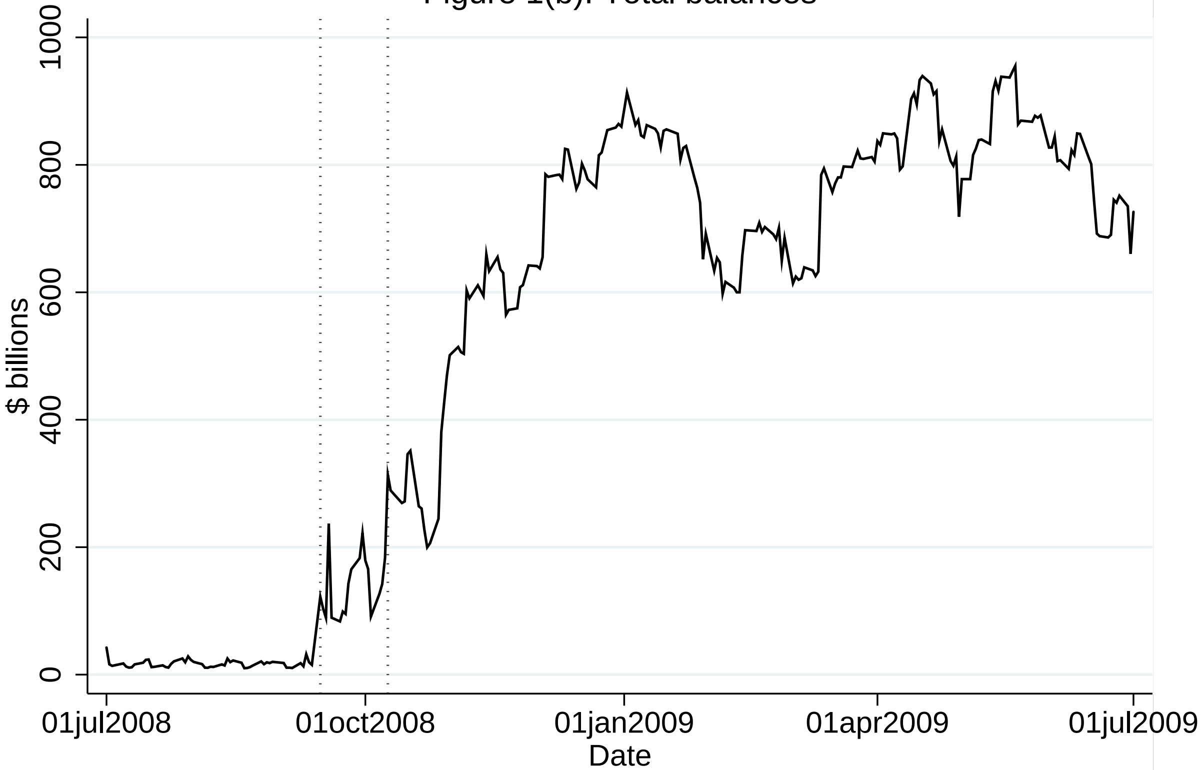
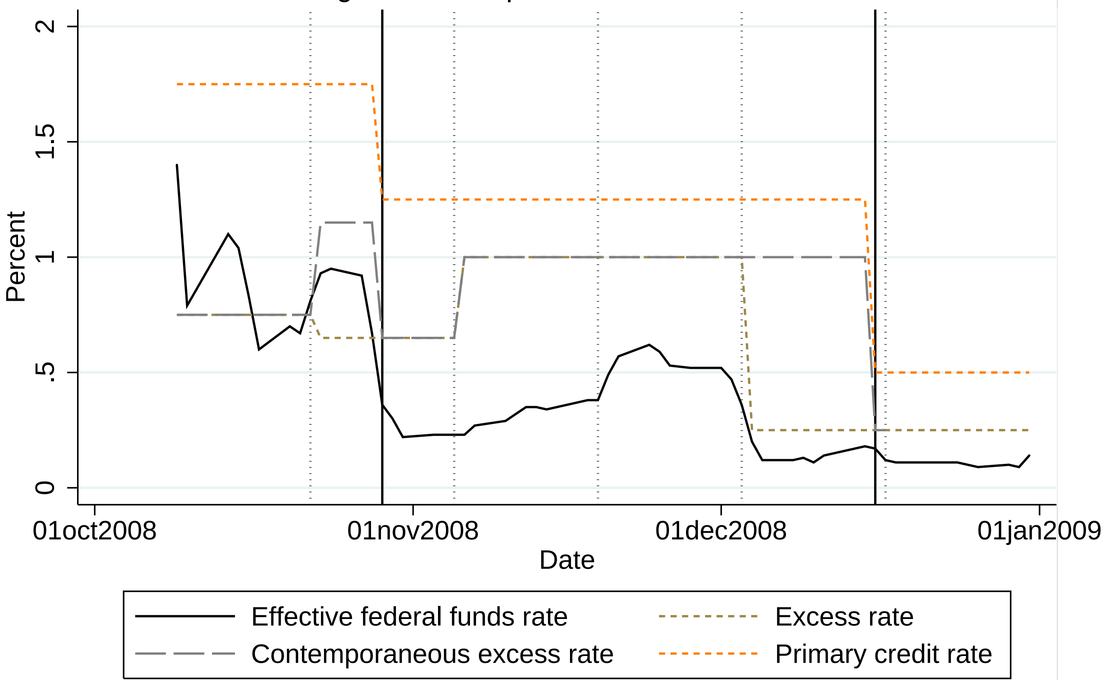


Figure 1(b): Total balances



Vertical line at September 15, 2008 marks the Lehman bankruptcy.
Vertical line at October 9, 2008 marks the start of IOR.

Figure 2: Rate paid on excess reserves



Dotted vertical lines mark maintenance period end dates.
Solid vertical lines indicate FOMC meetings with changes in the target federal funds rate.

Figure 6(a): Share brokered below excess rate

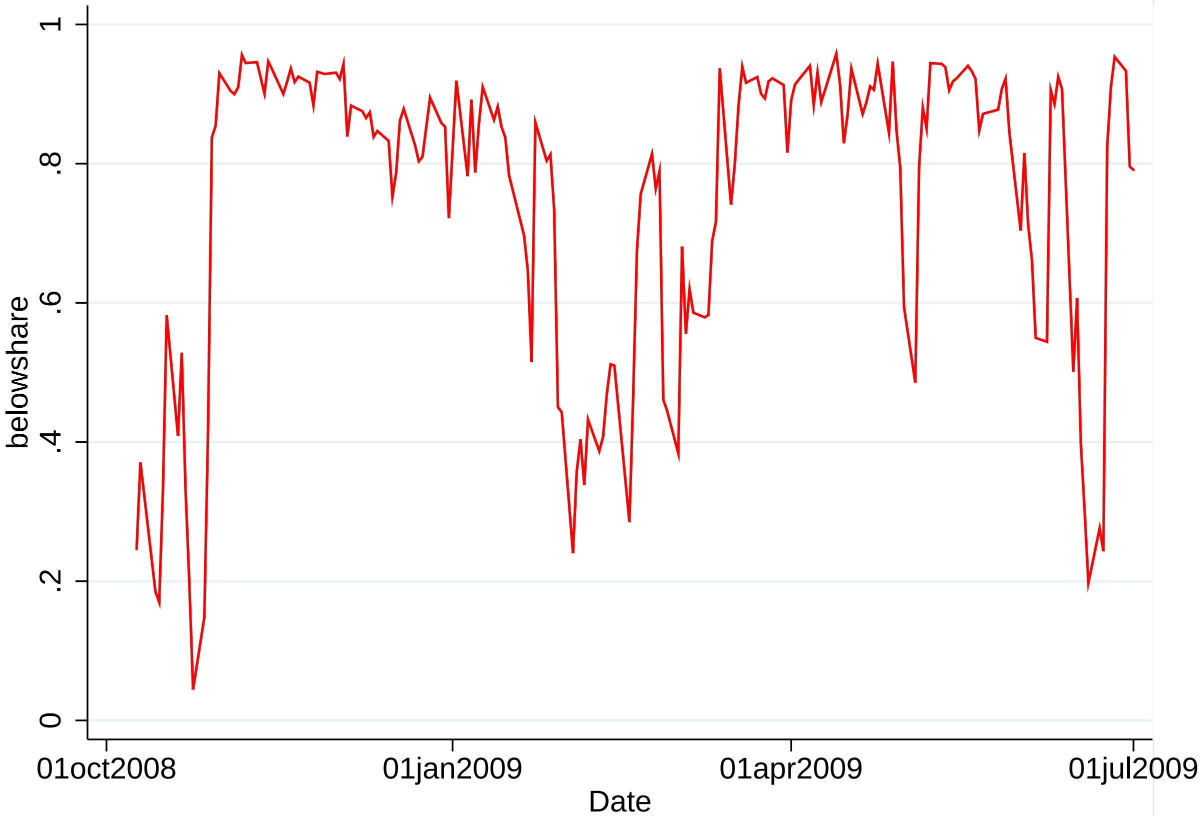
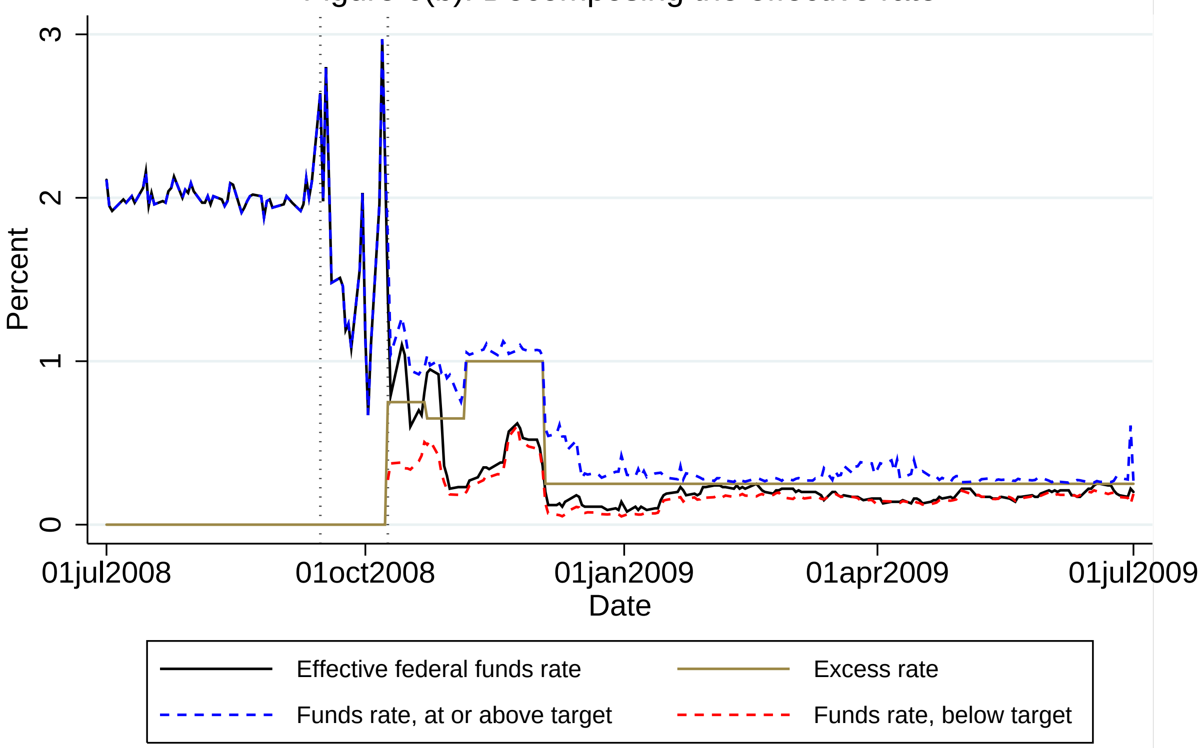
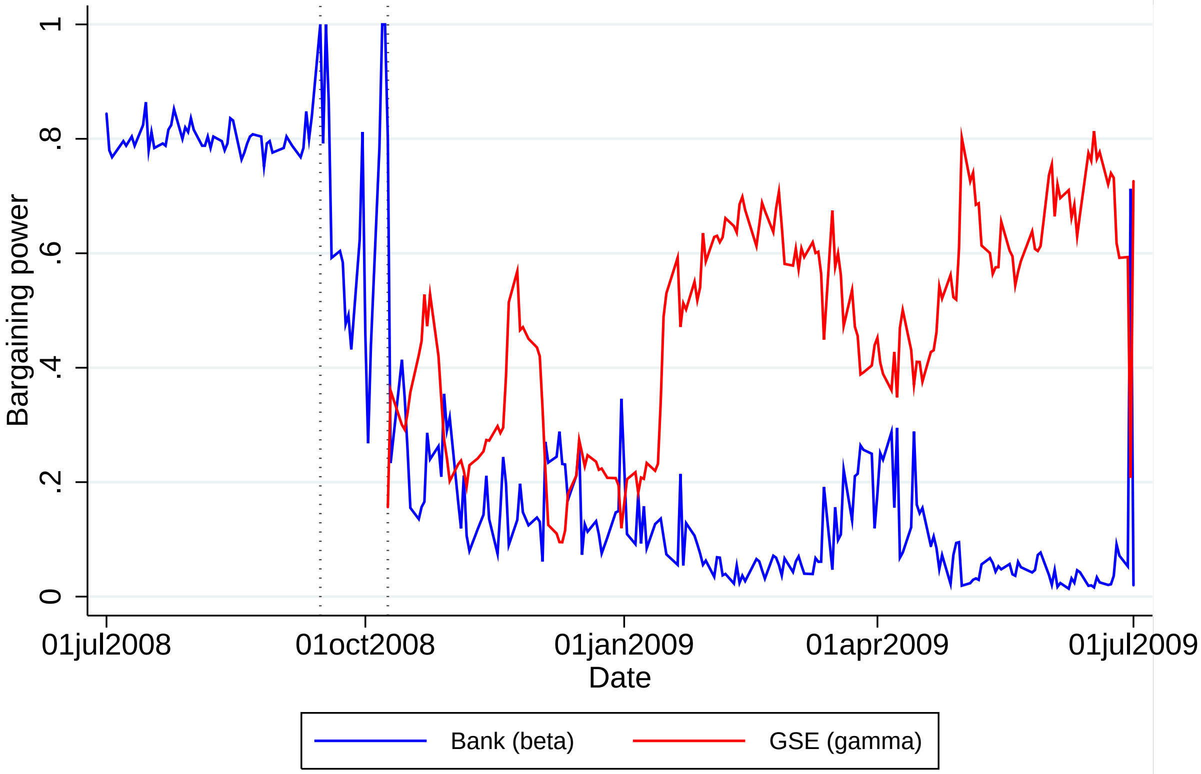


Figure 6(b): Decomposing the effective rate



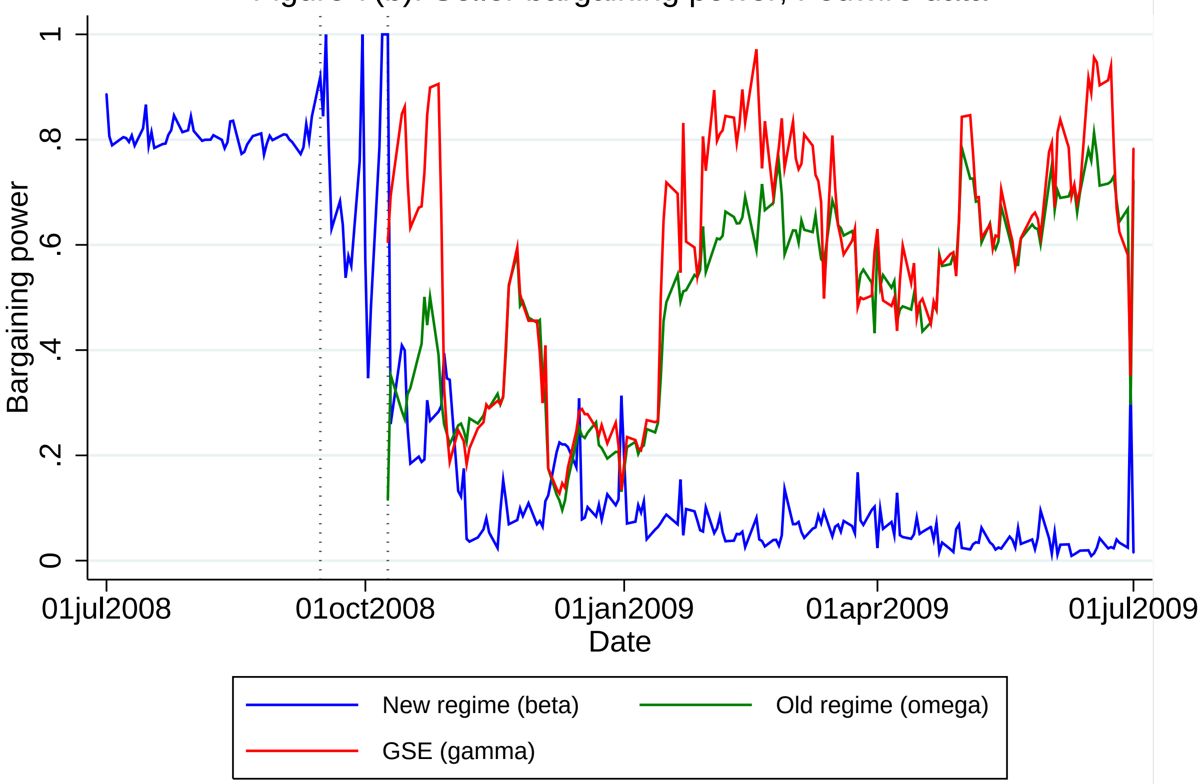
Vertical line at September 15, 2008 marks the Lehman bankruptcy.
Vertical line at October 9, 2008 marks the start of IOR.
Rates weighted by dollar volume.

Figure 7(a): Seller bargaining power, brokered data



Vertical line at September 15, 2008 marks the Lehman bankruptcy; vertical line at October 9, 2008 marks the start of IOR.
Selected betas have been truncated at 1 between these two dates.

Figure 7(b): Seller bargaining power, Fedwire data



Vertical line at September 15, 2008 marks the Lehman bankruptcy; vertical line at October 9, 2008 marks the start of IOR.
Selected betas have been truncated at 1 between these two dates.

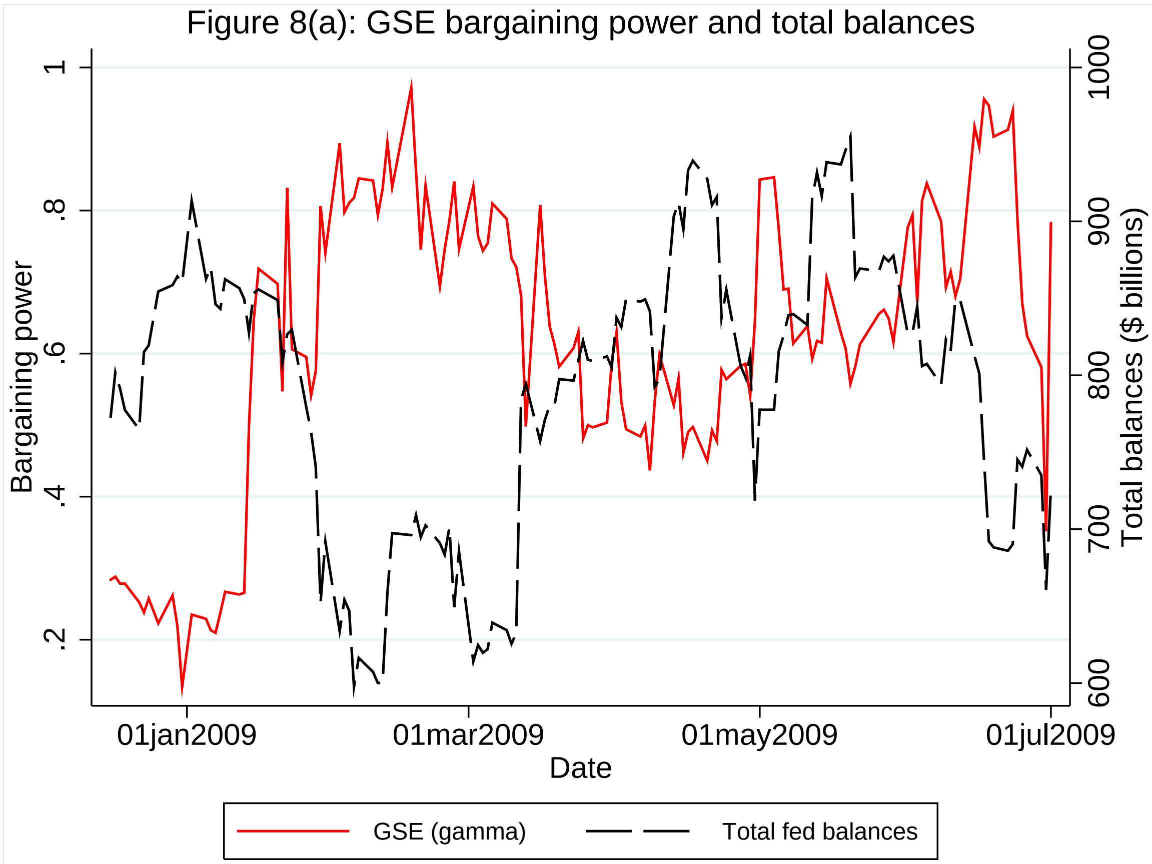


Figure 8(a): GSE bargaining power and total balances
Bargaining power
.2
.4
.6
.8
1
Total balances ($ billions)
600
700
800
900
1000
01jan2009
01mar2009
01may2009
01jul2009
Date
GSE (gamma)
Total fed balances

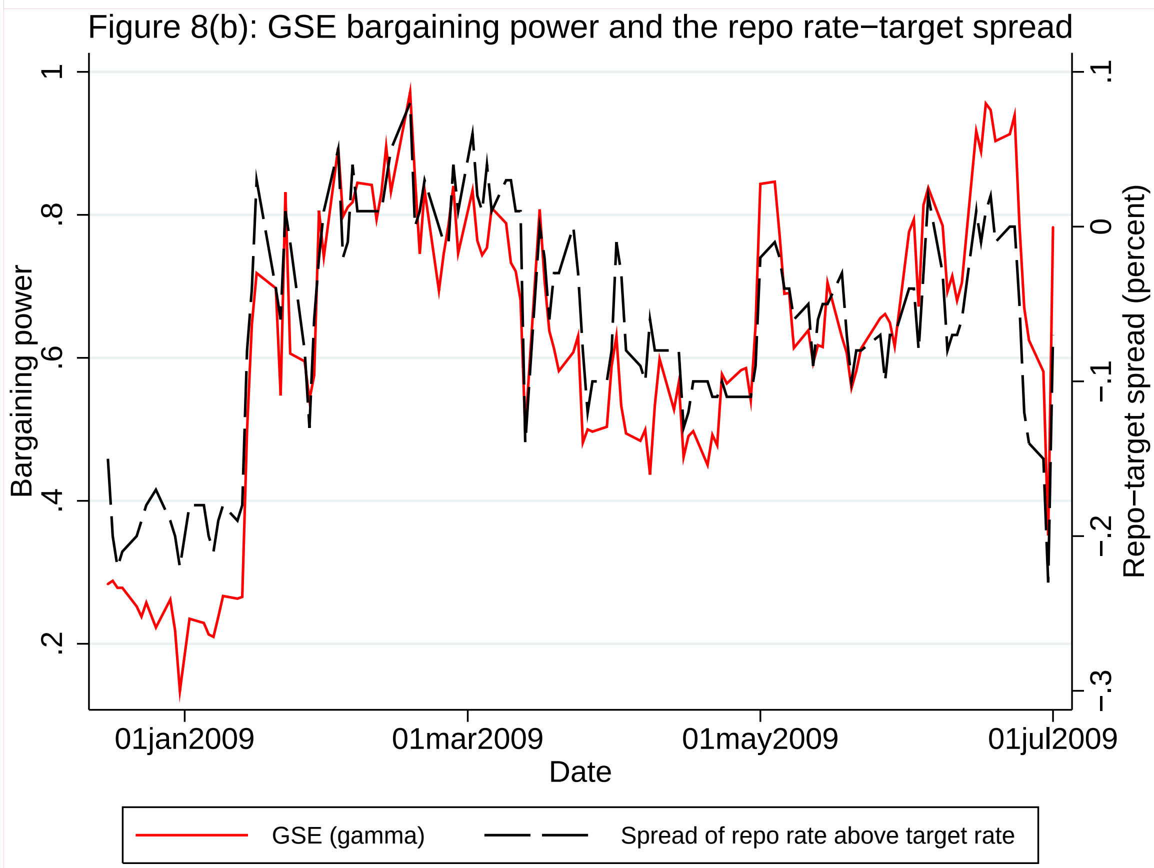


Figure 8(b): GSE bargaining power and the repo rate−target spread
Bargaining power
.2
.4
.6
.8
1
Repo−target spread (percent)
−.3
−.2
−.1
0
.1
01jan2009
01mar2009
01may2009
01jul2009
Date
GSE (gamma)
Spread of repo rate above target rate

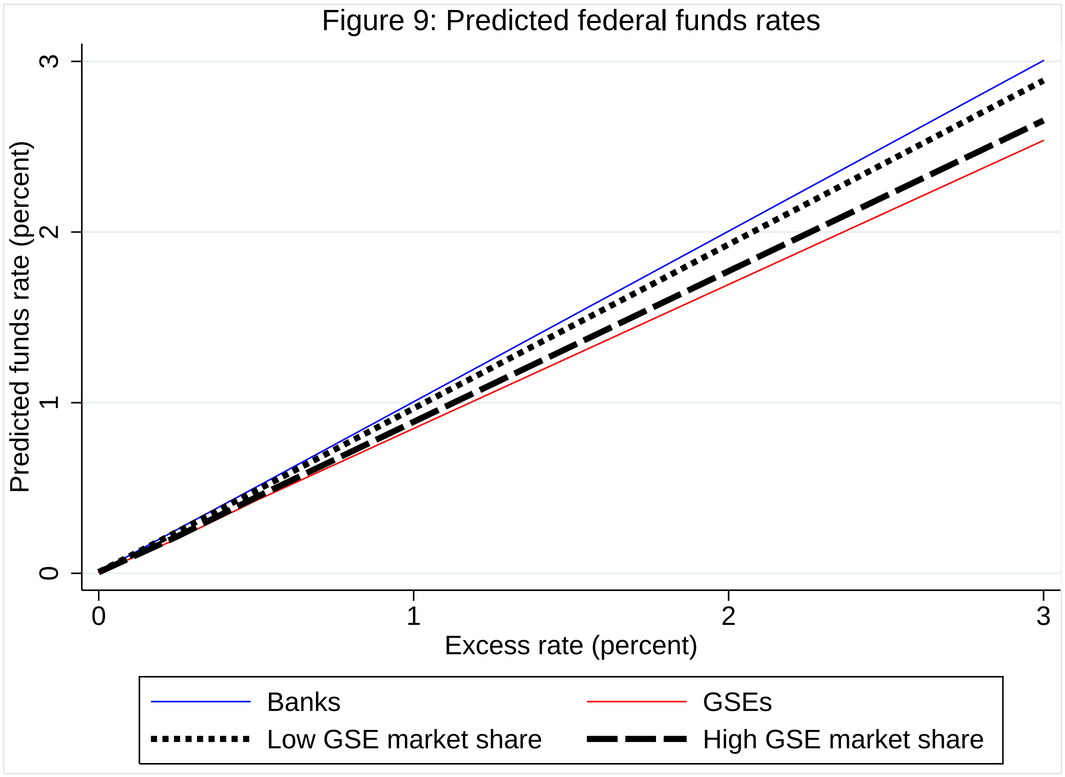


Figure 9: Predicted federal funds rates
Predicted funds rate (percent)
0
1
2
3
0
1
2
3
Excess rate (percent)
Banks
GSEs
Low GSE market share
High GSE market share

Figure 10: Predicted funds rates −− Repo−excess rate spread

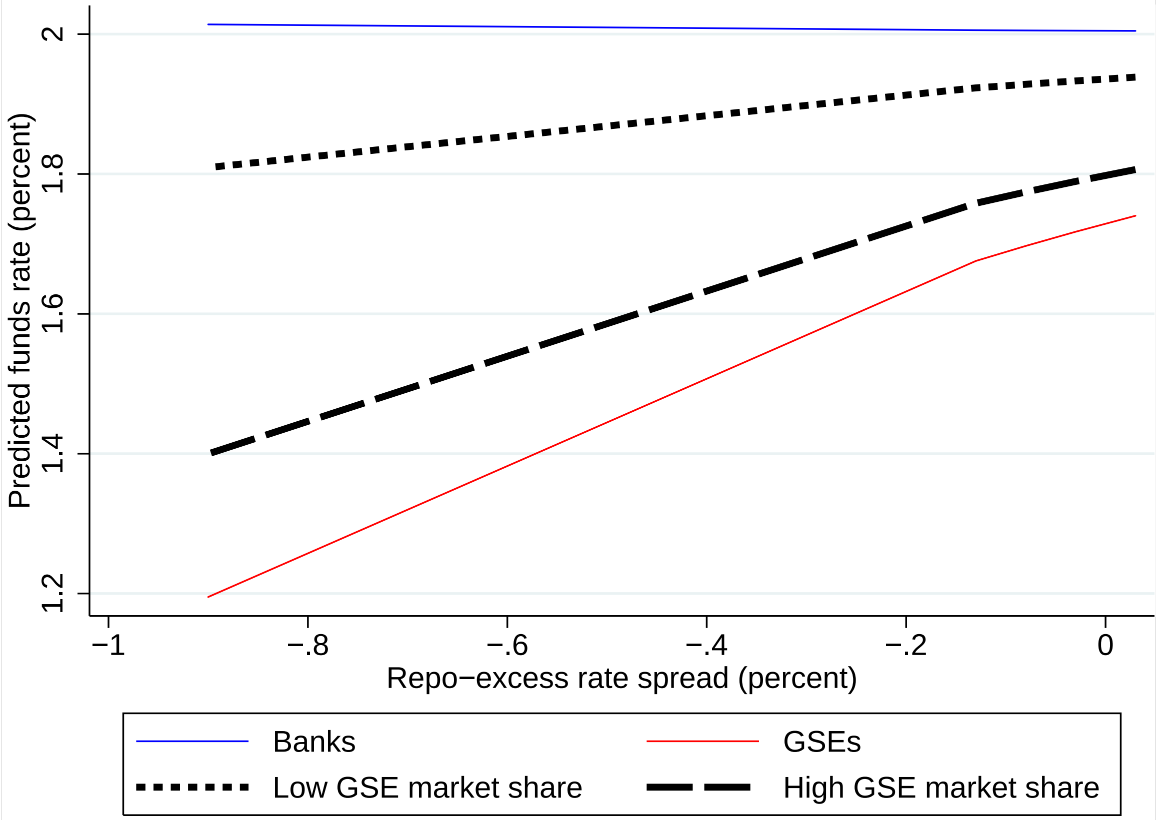


Figure 11: Predicted federal funds rates −− Total balances

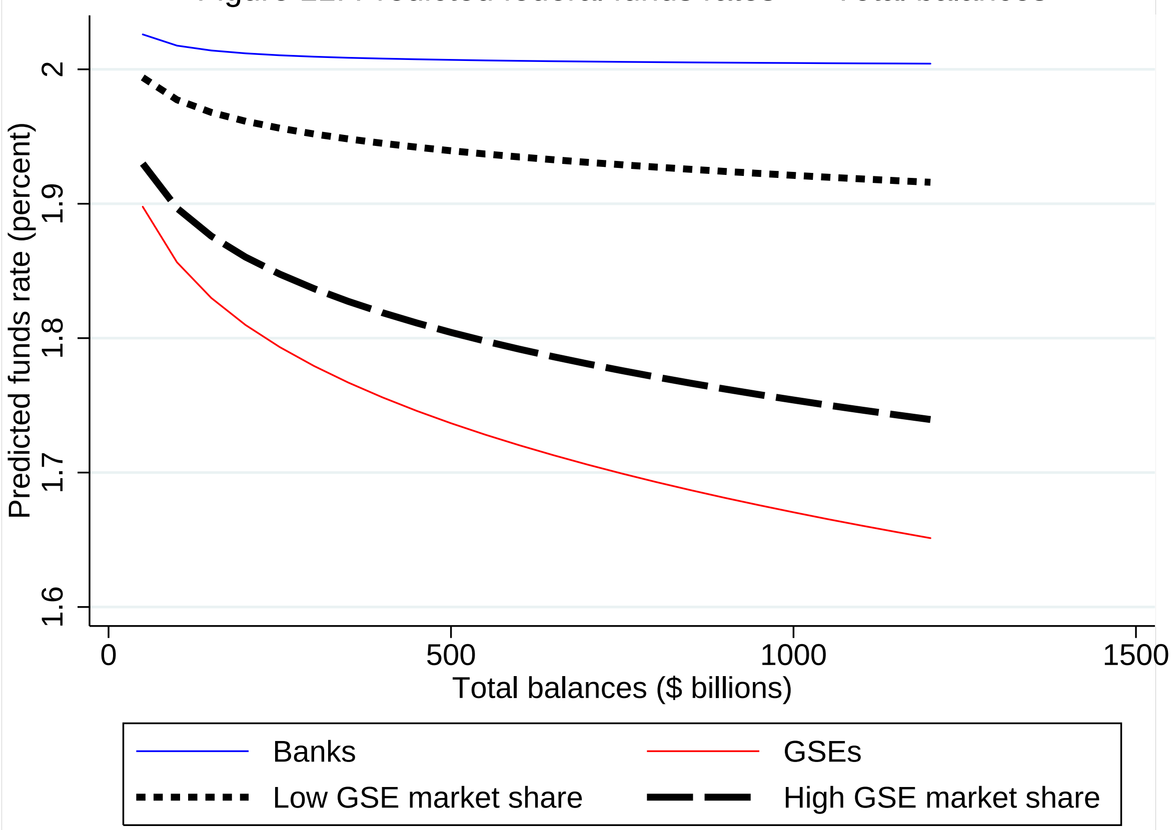


Figure 12: Spread between Excess rate and Predicted federal funds rate
(keeping GSE market share of federal funds market constant)