The Federal Funds Market, Pre- and Post-2008

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Abstract

This chapter provides an overview of the federal funds market and how the equilibrium federal fund rate is determined. I devote particular attention to comparing and contrasting the federal funds market before and after 2008, since there were several dramatic changes around that time that completely changed the market and the way in which the equilibrium federal funds rate is determined. The size of this structural break is arguably as large and important as the period of reserves targeting under Fed Chairman Paul Volcker from 1979–82. Finally, I discuss the relationship between the federal funds rate and other short-term interest rates in the U.S. and the outlook for the federal funds market going forward.

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1. Introduction

The 2007–09 global financial crisis and 2020-21 Covid pandemic have seen the Federal Reserve and other central banks pursue "unconventional" monetary policies, such as forward guidance and large-scale asset purchases, to an unprecedented extent. Nevertheless, the conventional tool of monetary policy in all major economies remains the short-term interest rate. In the United States, the Federal Reserve's conventional monetary policy tool is the federal funds rate. This chapter provides an overview of the federal funds market and how the equilibrium federal funds rate is determined. I devote particular attention to comparing and contrasting the federal funds market before and after 2008, since there were several dramatic changes around that time that completely changed the market and the way in which the equilibrium federal funds rate is determined. I also discuss the relationship between the federal funds rate and other short-term interest rates in the U.S. and the outlook for the federal funds market going forward. Although the details in this chapter all pertain to the U.S., many of the points are general and provide insights into similar issues in other major economies.

In Section 2, I provide a brief history of the federal funds market and federal funds rate. In Section 3, I describe the main features of the market, including market participants, reserve requirements, the discount window, interest on reserves, and the Fed's reverse repurchase facility. In Section 4, I discuss the equilibrium in the federal funds market, with a particular focus on how that equilibrium has changed pre- and post-2008. In Section 5, I discuss the future of the federal funds market, including the possibility of a negative federal funds rate at some point. Section 6 summarizes and concludes.

2. A Brief History of the Federal Funds Market

The Federal Reserve System was established by law on December 23, 1913, and began operating on November 16, 1914 (Wheelock, 2013). All federally-chartered banks were required by law to become members of their local Federal Reserve Bank, and state-chartered banks and other depository institutions (thrifts and credit unions) had the option of becoming members as well if they met certain technical criteria (Wheelock, 2013). Being a member of the Federal Reserve network provided banks with a number of benefits, including being able to transfer funds electronically to other banks around the country via the Federal Reserve's telegraphic network, and obtaining liquidity as needed via collateralized short-term loans at the Fed's discount window (Anbil et al., 2021; Wheelock, 2013).

The term *federal funds* refers to a bank's deposit account balance held at its local Federal Reserve Bank. Importantly, a bank that is a member of the Federal Reserve network faces regulatory reserve requirements that the bank must maintain in order to operate, and those requirements must be satisfied with federal funds or currency held in the bank's vault (Friedman and Schwartz, 1963).[1] The term *reserves* refers to the sum of a bank's vault cash and federal funds.

Short-term money market loans existed before the Federal Reserve, in the form of commercial paper and "call money" loans to securities brokers and dealers (Anbil et al., 2021). Beginning in 1921, banks in New York City began transacting short-term loans of federal funds to satisfy their reserve requirements, and by the late 1920s, these loans were common across the U.S. (Anbil et al., 2021). Since July 1954, the Federal Reserve Bank of New York has published the daily average interest rate on one-day federal funds loans as the *federal funds rate*.[2] Anbil et al. (2021) have extended this series back to 1928 using daily published federal funds rate quotes in the *New York Herald Tribune* and *Wall Street Journal* from those years. Of course, any individual institution may pay more or less than the average federal funds rate that day, depending on its perceived riskiness and because of fluctuations over the course of the day.

3. Features of the Federal Funds Market

In this section, I summarize the main features of the federal funds market, including the market participants; open market operations by the Federal Reserve; reserve requirements and excess reserves; the discount window and discount rate; interest on reserves; federal funds loan counterparties, maturities, and collateral; and the Federal Reserve's reverse repurchase facility.

3.1 Market Participants

Participants in the federal funds market generally include all institutions that hold deposits at one of the regional Federal Reserve Banks. This includes commercial banks and other depository institutions that are members of the Federal Reserve network, U.S. branches of foreign banks,

[1] At times, only federal funds could be used to satisfy banks' reserve requirements; however, since 1960, banks' vault cash has been allowed to satisfy those reserve requirements as well (Friedman and Schwartz, 1963, chap. 5, footnotes 2 and 10).

[2] Since 1970, the series is referred to as the daily *effective federal funds rate* and is a daily volume-weighted median of interest rates on federal funds loans with a maturity of one business day. From 1954–70, the published rate is not a statistical average but is a "consensus of major market participants in New York City" as to the typical interest rate on federal funds loans that day (Anbil et al., 2021).

and U.S. government-sponsored enterprises (GSEs): the Federal National Mortgage Association (FNMA, or Fannie Mae), Federal Home Loan Mortgage Corporation (FHLMC, or Freddie Mac), the Federal Home Loan Banks, and a few smaller institutions.

The other major participant in the federal funds market is the Federal Reserve itself, which often increases or decreases the total quantity of federal funds in the market via *open market operations.*

3.2 Open Market Operations

When the Federal Reserve wants to increase the total quantity of federal funds in the market, it announces an intention to buy a particular dollar amount of Treasury securities from member banks.[3] Member banks then submit offers to sell securities to the Fed, specifying the exact security and offer price. At 10:30am New York Time, the Federal Reserve Bank of New York's trading desk announces which of those offers it will accept and purchases the securities, crediting each bank's Federal Reserve deposit account with federal funds equal to the purchase.[4]

When the Fed wishes to decrease the total quantity of federal funds in the market, it performs the reverse operation, announcing an intention to sell Treasury securities from its own portfolio, soliciting bids, and at 10:30am executing the best of those bids and removing the federal funds from each counterparty bank's deposit account at the Fed.

3.3 Reserve Requirements and Excess Reserves

The Federal Reserve imposes minimum reserve requirements on its member banks and depository institutions. These requirements have varied over time and vary with the type of deposit—checking, savings, or time deposit—with more liquid deposit types requiring a higher reserve-to-deposit ratio (Federal Reserve Board, 2021).[5] This regulatory requirement creates a very strong demand for federal funds loans when the aggregate quantity of federal funds is reduced to a sufficiently low level, as member banks struggle to meet their reserve requirements.

Banks with Federal Reserve deposit balances in excess of their reserve requirements have *excess reserves* and will typically seek to lend those reserves to banks that are running short of

[3] The banks with which the Fed will buy and sell Treasury securities are known as *primary dealers.*

[4] Prior to 1997, the Fed conducted open market operations at 11:30am (Federal Reserve Bank of New York, 1998).

[5] Reserve requirements must be met on average over a two-week holding period—the *reserve maintenance period*—beginning on a Thursday and ending on the Wednesday two weeks later (Meulendyke, 1998, Chap. 3; Hamilton, 1996).

their reserve requirements. Note that the GSEs are not depository institutions and do not have any required reserve balances; thus the GSEs essentially always have excess reserves.

In addition to reserve requirements, federal funds market participants are not permitted to let their federal funds balances dip below zero at any point in time. Thus, even without reserve requirements, there is still a liquidity-based demand for federal funds to facilitate electronic transactions with other market participants.

3.4 The Discount Window and Discount Rate

Banks that are in need of reserves can obtain them either by borrowing in the federal funds market or by borrowing directly from the Federal Reserve via the *discount window.* Discount window loans are collateralized; the Fed credits the borrowing institution with an amount of federal funds equal to a discount to the face value of the collateral. In order to discourage discount window borrowing, the Fed sets the interest rate on these loans, the *discount rate,* somewhat above the prevailing interest rate in the federal funds market.[6] Historically, the Fed also used moral suasion to discourage institutions from borrowing at the discount window, but beginning in 2003 reversed this policy and now actively encourages institutions to use the discount window as needed, in the interest of ensuring sufficient overall liquidity and smooth functioning in financial markets (Carlson and Rose, 2017). Nevertheless, borrowing from the Fed's discount window carries a stigma in the financial markets, since it suggests that the borrowing insitution is unable to find counterparties who are willing to lend to it on the open market (Carlson and Rose, 2017).

The total amount of discount window loans in the market is referred to as the quantity of *borrowed reserves,* while the total quantity of reserves in the market excluding discount window lending is *nonborrowed reserves.* These measures are important historically: between 1979 and 1982, the Federal Reserve under Paul Volcker communicated monetary policy in terms of these two measures of reserves rather than the federal funds rate (Bernanke and Mihov, 1998).

3.5 Interest on Reserves

Historically, federal funds earned no interest.[7] However, in 2008, Congress granted the Federal Reserve statutory authority to pay interest on reserves and the Fed began paying depository

[6] From the 1960s to 2003, the Fed actually set the discount rate below the equilibrium federal funds rate, creating an arbitrage opportunity for banks to borrow from the discount window and lend the funds in the federal funds market. To prevent this arbitrage, the Fed required would-be discount window borrowers to show that they were unable to borrow the funds in the private market. In 2003, the Fed redesigned its discount window policies to try to reduce the stigma of borrowing from the discount window. See Carlson and Rose (2017) for details.

[7] However, from the early 1980s to 2012, banks could earn credits on excess reserves by declaring those excess

institutions interest on their reserves in October 2008 (Federal Reserve Bank of New York, 2013). The Fed pays interest on both required and excess reserves, but the interest rates on these two types of reserves has sometimes differed (Federal Reserve Bank of New York, 2013). The interest rate on excess reserves is referred to as the *IOER rate,* and it is the relevant interest rate that affects the federal funds market at the margin.

Importantly, the Fed's policy of paying interest on reserves includes U.S. branches of foreign banks but explicitly excludes the GSEs (Federal Reserve Bank of New York, 2013). These two features of the Fed's policy have very important implications for the equilibrium in the federal funds market after 2008, discussed below.

3.6 Federal Funds Loan Counterparties, Maturities, and Collateral

Like other short-term funding markets (but in contrast to interest rate futures and options markets), the federal funds market is decentralized. Borrowers and lenders of federal funds search for each other and negotiate the terms of the loan bilaterally. However, some large financial institutions act as brokers in the market, facilitating the meeting of smaller borrowers and lenders (Furfine, 1999).

A large majority of federal funds loans have a maturity of one business day, typically called "overnight" loans, although repayment is often made the following afternoon rather than morning (Furfine, 1999). However, federal funds loans can also be contracted for longer terms, up to several months in duration. Naturally, these *term federal funds* loans carry an interest rate that is closely related to the average expected overnight federal funds rate over the lifetime of the loan, plus a premium for risk and liquidity—see Gürkaynak, Sack, and Swanson (2007) for additional discussion and details. The quoting convention in the market is $r/360$—that is, the actual overnight interest rate on the loan is the quoted rate divided by 360 (Gürkaynak et al., 2007).[8] The median size of a federal funds loan was about $75 million in the mid-2000s, but larger banks typically transact much larger amounts, so the mean loan size was much higher, around $1 billion (Afonso, Kovner, and Schoar, 2011; Furfine, 1999).

reserves to be clearing balances and maintaining those balances over the reserve maintenance period. The credits earned on clearing balances could then be used to cover fees for check clearing and other services provided by the Fed to its member banks. De facto, the credits earned on clearing balances were close to the federal funds rate and effectively provided interest on excess reserves up to a point. See Naber, Sambasivam, and Styczynski (2017) for details.

[8] Note that this quoting convention is different from that on commercial paper or Treasury bills, which are quoted on a discount basis for a 365-day year. Thus, when comparing interest rates across these different securities, one must be careful to put them all on an equivalent footing; see Gürkaynak et al. (2007) for details.

In contrast to repurchase agreements, federal funds loans are uncollateralized. The risk of a financial institution defaulting or suspending payments on any particular day is very small, but it is nonzero and thus the federal funds rate is not a risk-free rate. The federal funds rate typically trades slightly above the corresponding general collateral repo rate, and term federal funds typically trade above the corresponding repo and Treasury bill rates.[9] This was particularly true in 2008, when market participants' concerns about counterparty creditworthiness increased dramatically (Afonso et al., 2011).

3.7 The Federal Reserve's Reverse Repurchase Facility

A final feature of the federal funds market that has become important since 2014 is the Federal Reserve's *reverse repurchase facility.* Every business day, the Fed stands ready to borrow federal funds from market participants via repo transactions for a term of one business day; the Fed transfers collateral to the lender in the form of Treasury securities with a haircut, just as in a standard repurchase agreement. The interest rate on these repurchase agreements is the *overnight reverse repurchase* (ON RRP) *offer* rate, which is set by the Fed (Federal Reserve Board, 2018). Of course, the Fed conducts these operations not because it actually needs to borrow federal funds for its own account, but as a way of soaking up excess liquidity in the federal funds market; in particular, it gives the Fed a way to pay the GSEs interest on their reserves, helping to establish a floor on the equilibrium federal funds rate, as discussed in detail below.

4. Equilibrium in the Federal Funds Market

In this section, I discuss details of the equilibrium in the federal funds market, including the factors that determine the level of the federal funds rate, the amount of federal funds lending, the institutions borrowing and lending in the market, and how the Federal Reserve implements its target for the equilibrium federal funds rate. Note that in 2008, there were several dramatic changes in the market, so that the market equilbrium before 2008 is very different from the market equilibrium after that date. I discuss each of these periods in turn.

[9] In addition to being essentially default-free, Treasury bills also have some tax advantages that lower their yields; see Gürkaynak et al. (2007).

FIGURE 1: EQUILIBRIUM IN THE FEDERAL FUNDS MARKET, PRE-2008

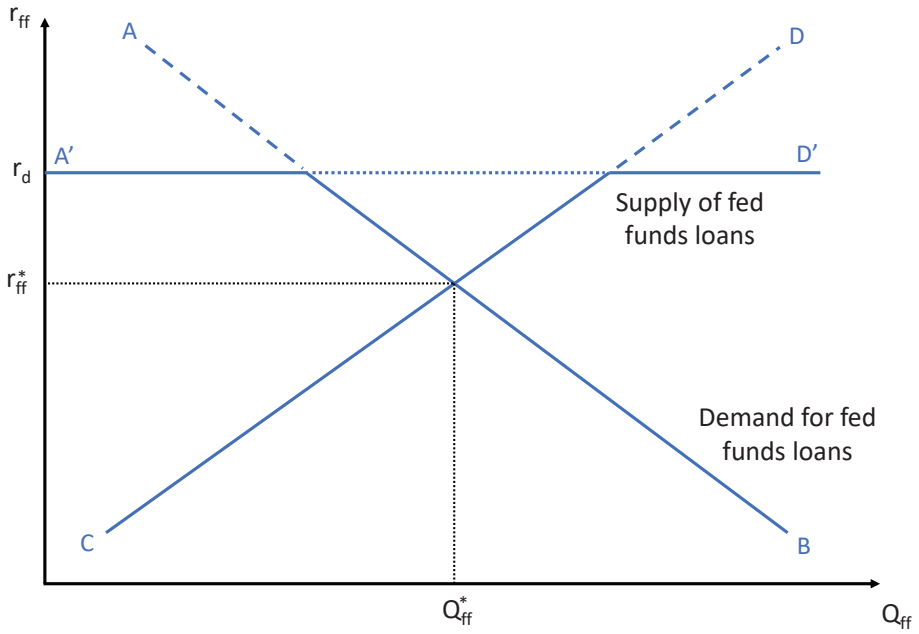


Diagram of factors determining equilibrium in the federal funds market on a typical day prior to 2008. r_{ff} denotes the federal funds rate, r_d the discount rate, and Q_{ff} the total dollar value of federal funds loans in the market. See text for details.

4.1 Equilibrium before 2008

The factors determining equilibrium in the federal funds market on a typical day before 2008 are depicted in Figure 1. The vertical axis considers different levels of the federal funds rate, r_{ff}, while the horizontal axis depicts different levels of the total dollar value of federal funds loans in the market, Q_{ff}.[10]

The fundamental demand for federal funds loans in the market is depicted by the downward-sloping line AB: all else equal, as the federal funds rate is reduced, more banks are willing to borrow in the federal funds market (and each such bank is willing to borrow a larger amount at the margin) for precautionary or liquidity reasons, so the demand for federal funds loans increases. The fundamental supply of federal funds loans in the market is given by the upward-sloping line CD: all else equal, a higher federal funds rate induces more banks to economize on their

[10] Note that I have chosen to draw Figure 1 with the total quantity of federal funds *loans* on the horizontal axis; an alternative approach would be to depict the total quantity (stock) of federal funds on the horizontal axis, as in Ihrig et al. (2020). In that case, the total supply of federal funds would be a vertical line whose horizontal position is set by the Federal Reserve. The disadvantage of that approach is that it is not very closely related to the federal funds *market*—e.g., the total quantity of federal funds in existence could be large even though the amount of trading in the federal funds market is zero. In Figure 1, Q_{ff} is exactly equal to the amount of lending and borrowing in the market.

reserves and lend federal funds on the market (and each such bank is willing to lend a larger amount), increasing the total supply of loans.

The demand and supply for federal funds are complicated somewhat by the presence of the Federal Reserve's discount window. The horizontal line $A'D'$ is drawn at the level of the discount rate, r_d. In theory, if r_{ff} lies above r_d, banks would no longer borrow federal funds in the open market and would instead go to the Fed's discount window and borrow federal funds directly from the Fed, causing the demand for loans in the federal funds market to drop to zero. Thus, the effective demand for federal funds in the market is given by the kinked line $A'B$ rather than AB. Similarly, if r_{ff} lies above r_d, banks who are potential suppliers of federal funds to the market could borrow arbitrarily large amounts directly from the Fed at the discount window and lend those funds out in the federal funds market, earning profits on the difference in rates. Thus, the effective supply of federal funds loans is given by the kinked line CD' rather than CD. It is important to note, however, that banks in practice are typically averse to borrowing at the discount window—because the Fed discouraged it historically and because banks who borrow from the discount window are viewed by their peers as being in distress—so the effective demand for federal funds loans when the funds rate is above the discount rate will lie somewhere in between A' and A, and the effective supply somewhere between D' and D, but the general point is the same.[11]

The equilibrium in the federal funds market is given by the rate r^*_{ff} and total quantity of lending Q^*_{ff}, with r^*_{ff} typically bounded between 0 and r_d. Every day, the equilibrium in the market can change as the demand and supply for federal funds loans fluctuates. Market participants' demand and supply for federal funds loans can shift from one day to the next for several reasons: for example, financial market volatility or high volumes of customer transactions may increase banks' uncertainty and liquidity needs, reducing the number of banks willing to lend funds (and the amount of funds each bank is willing to lend), while simultaneously increasing the number of banks looking to borrow funds (and the amount of funds each bank is looking to borrow); this shifts the supply curve in Figure 1 to the left and the demand curve to the right, raising r^*_{ff} (and having an ambiguous effect on Q^*_{ff}). Alternatively, the Federal Reserve might increase the total quantity of federal funds through open market operations, shifting the supply

[11] There have also been important brief periods when borrowing from the discount window carried essentially no stigma, such as after the September 11, 2001, terrorist attacks and the August 14, 2003, Northeast blackout, because the need for banks to borrow directly from the Fed was clear and obviously not a result of individual bank weakness (Carlson and Rose, 2017). During these periods, the discount rate r_d did serve as an effective upper bound on the equilibrium federal funds rate.

of federal funds loans to the right and the demand for federal funds loans to the left, lowering r^*_{ff} (and again having an ambiguous effect on Q^*_{ff}).[12]

By varying the total quantity of federal funds up or down by a carefully calculated dollar amount of open market operations each day, the Federal Reserve was able to maintain r^*_{ff} very close to a target level for that rate. Thus, the Federal Reserve had very tight control over a key market interest rate in a market that all large banks participated in to satisfy reserve requirements. Arbitrage by these large banking institutions then ensured that other short-term interest rates closely tracked the federal funds rate. In this way, the Fed exerted tight control over essentially all short-term interest rates in the U.S. economy.

4.2 Equilibrium after 2008

Several features of the federal funds market changed dramatically beginning in 2008. First, in October 2008 the Federal Reserve began paying interest on reserves. Second, in late 2008 the Fed began conducting a series of *large-scale asset purchases* (LSAPs) of long-term Treasury securities, mortgage-backed securities, and GSE-issued securities that ultimately increased the total quantity of federal funds by a factor of about sixty (from $46 billion to $2.7 trillion), flooding the market with reserves. Third, to comply with the Dodd-Frank Act, the Federal Deposit Insurance Corporation (FDIC) in 2011 began assessing U.S. depository institutions fees based on total assets held rather than just deposits (Craig and Millington, 2017).

4.2.1 Theoretical Equilibrium with Interest on Reserves: Corridor System

Theoretically, the effect of interest on reserves is relatively straightforward and should act as a floor in the federal funds market, as depicted in Figure 2. Note that Figure 2 is theoretical only, and applies to the counterfactual case where all federal funds market participants are able to earn the IOER rate on their excess reserves. In Figure 2, the IOER rate is depicted by the horizontal line $C'B'$ at r_{ioer}. For values of r_{ff} below r_{ioer}, potential lenders of federal funds would just hold

[12] Other technical factors affect the supply and demand for federal funds as well. When the U.S. Treasury makes large payments, such as for Social Security, there is a large transfer of federal funds from the Treasury's account to private-sector banks, resulting in a large increase in the amount of federal funds in the hands of the private sector and a corresponding decrease in federal funds loan demand and an increase in federal funds loan supply, all else equal. Also, in the days of physical check clearing, there is a period of a few days after deposit when the amount of the check is essentially double-counted in the banking system, being credited to its depositor but not yet debited from the check-writer's account. The total dollar value of checks in transit was called the *float,* and the float could increase substantially if bad weather in a major city delayed the physical transportation of checks. A higher value of the float increases banks' required reserves since they must hold reserves against the deposits, thereby increasing the demand and reducing the supply of federal funds loans in the market. See Meulendyke (1998), Chap. 6, for additional details and discussion.

FIGURE 2: THEORETICAL EQUILIBRIUM IN THE FEDERAL FUNDS MARKET WITH INTEREST ON RESERVES

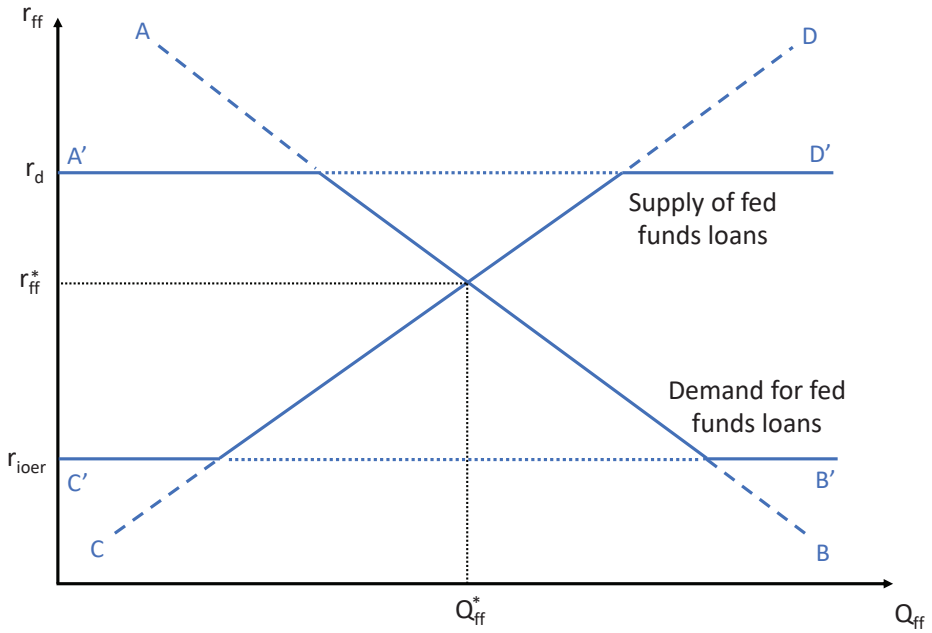


Diagram of factors determining theoretical equilibrium in the federal funds market when all market participants earn interest on excess reserves. r_{ff} denotes the federal funds rate, r_d the discount rate, r_{ioer} the interest rate on excess reserves, and Q_{ff} the total dollar value of federal funds loans in the market. See notes to Figure 1 and text for details.

those funds in their account at the Fed and earn the rate of return r_{ioer}, causing the supply of federal funds loans to fall to zero. Similarly, for potential borrowers of federal funds, for values of r_{ff} less than r_{ioer}, those borrowers could borrow arbitrarily large quantities of federal funds in the private market and hold those funds in their account at the Fed, earning r_{ioer} on the deposit but paying only r_{ff} on the loan, earning large profits—a trading strategy known as *IOER arbitrage* (Banegas and Tase, 2020)—and driving the demand for federal funds loans to infinity. As a result, the theoretical demand for fed funds loans is given by the piecewise linear $A'B'$ rather than AB, while the theoretical supply of fed funds loans is given by $C'D'$ rather than CD.

The theoretical equilibrium r^*_{ff} can fluctuate from day to day depending on shifts in the supply and demand for federal funds loans, as before, but r^*_{ff} is now bounded between r_{ioer} and r_d rather than 0 and r_d. This feature of equilibrium in the short-term money market is known as a *corridor system,* because the equilibrium rate over time lies in the corridor bounded below by r_{ioer} and above by r_d but otherwise is free to fluctuate within the corridor.

4.2.2 Actual Equilibrium after 2008

Figure 2 doesn't capture the actual equilibrium in the federal funds market for several reasons.

FIGURE 3: EQUILIBRIUM IN THE FEDERAL FUNDS MARKET, POST-2008

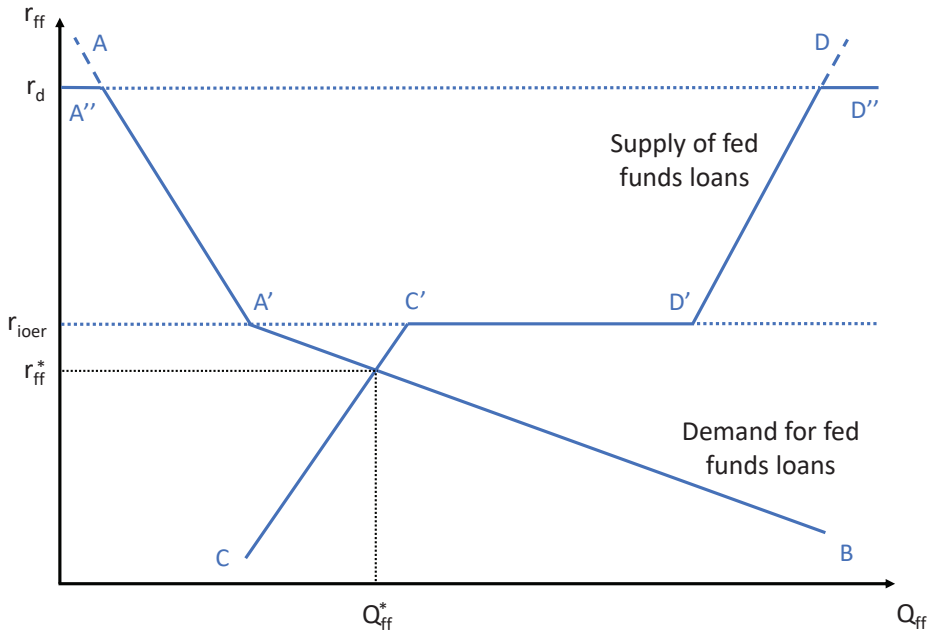


Diagram of factors determining equilibrium in the federal funds market on a typical day after 2008. r_{ff} denotes the federal funds rate, r_d the discount rate, r_{ioer} the interest rate on excess reserves, and Q_{ff} the total dollar value of federal funds loans in the market. See notes to Figures 1–2 and text for details.

First, some large suppliers in the market—the GSEs—do not earn interest on their reserves. As a result, the supply curve in Figure 2 below r_{ioer} lies somewhere in between C and C'. Second, the FDIC's fees on total assets of U.S. depository institutions imply that the IOER arbitrage strategy mentioned above is costly—so the demand for federal funds loans below r_{ioer} lies in between B and B'.[13] Third, the Federal Reserve's large-scale asset purchases tremendously increased the total quantity of federal funds, driving the supply of fed funds loans in Figure 2 far to the right and the demand for those loans far to the left. U.S. depository institutions have become so saturated with reserves that there is essentially no need for them to ever borrow in the market to meet their reserve requirements or liquidity needs.

As a result, the equilibrium in the federal funds market after 2008 looks more like Figure 3. In Figure 3, the supply of federal funds loans is shifted far to the right and the demand far to the left, so that the intersection of the two curves lies below r_{ioer} rather than above it. The supply of federal funds loans decreases gradually from D'' down to D' as r_{ff} decreases, and then

[13] Craig and Millington (2017) report that the cost of holding fed funds imposed by the FDIC is effectively as much as 35 basis points for large financial institutions.

jumps downward from D' to C' when r_{ff} hits r_{ioer}: when the federal funds rate falls below the IOER rate, all depository institutions cease providing federal funds loans in the private market and instead hold those reserves at the Fed to earn the return r_{ioer}. The supply of federal funds loans does not fall all the way to zero, however, because the GSEs do not earn interest on reserves and continue to supply fed funds loans to the market as long as r_{ff} is greater than zero; thus, the supply of loans continues to decrease gradually from C' to C. Along this bottom portion of the curve, all supply of federal funds loans is coming from the GSEs. Overall, the supply of fed funds loans is given by the piecewise linear $CC'D'D''$, where the last kink up at r_d is for the same reasons as in Figure 1.

The demand for federal funds loans increases gradually from A'' to A' as r_{ff} declines, and then increases more rapidly once r_{ff} drops below r_{ioer}. When the federal funds rate lies below r_{ioer}, banks can earn profits from IOER arbitrage, borrowing at the rate r_{ff} in the private market and earning r_{ioer} from the Fed. IOER arbitrage does not lead to infinite demand for fed funds loans for two reasons: first, FDIC-imposed regulatory fees on U.S. depository institutions make this trading strategy unprofitable for most U.S. institutions, as discussed above. Second, even though U.S. branches of foreign banks are not subject to FDIC fees, they are still subject to regulatory constraints from their home country regulators, and these constraints limit their demand for IOER arbitrage (Bech and Klee, 2011; Banegas and Tase, 2020). Thus, the bottom part of the demand curve from A' to B is not infinitely elastic and is made up almost entirely of U.S. branches of foreign banks conducting IOER arbitrage.

The post-2008 equilibrium in the federal funds market is thus completely different than the pre-2008 equilibrium. First, U.S. depository institutions are now essentially absent from trading in the market. The supply side of the market consists entirely of GSEs, while the demand side consists almost entirely of U.S. branches of foreign banks conducting IOER arbitrage (Bech and Klee, 2011; Craig and Millington, 2017; Banegas and Tase, 2020). Second, the demand for federal funds loans is no longer related to banks' need to meet reserve requirements or to hold reserves for liquidity or precautionary motives; instead, almost all trading in the federal funds market is now conducted solely for the purpose of IOER arbitrage. Without that arbitrage between the GSEs and the Fed, conducted by U.S. branches of foreign banks, trading in the federal funds market would almost completely disappear.

FIGURE 4: EQUILIBRIUM IN THE FEDERAL FUNDS MARKET, POST-2008, WITH OVERNIGHT REVERSE REPURCHASE FACILITY

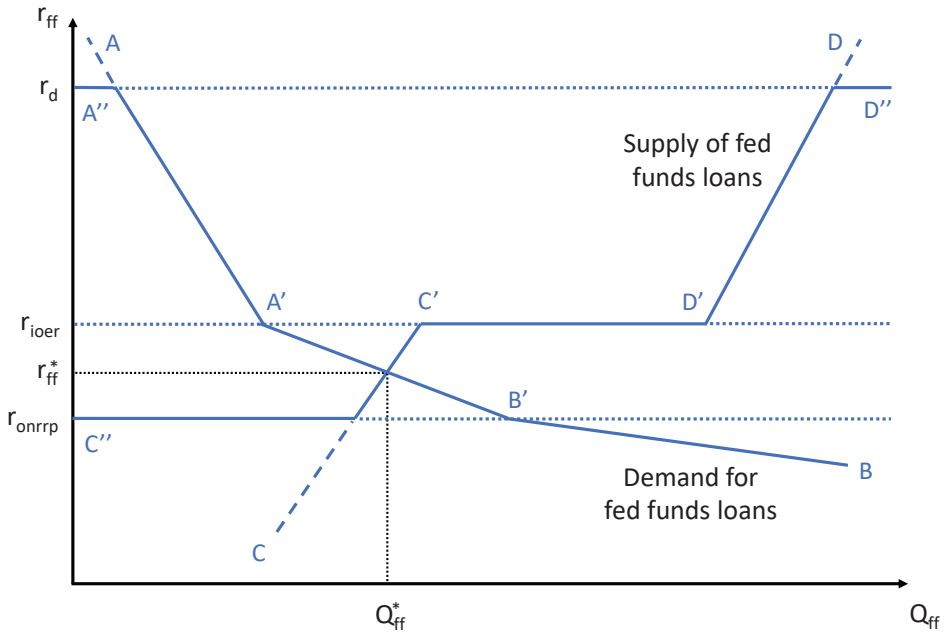


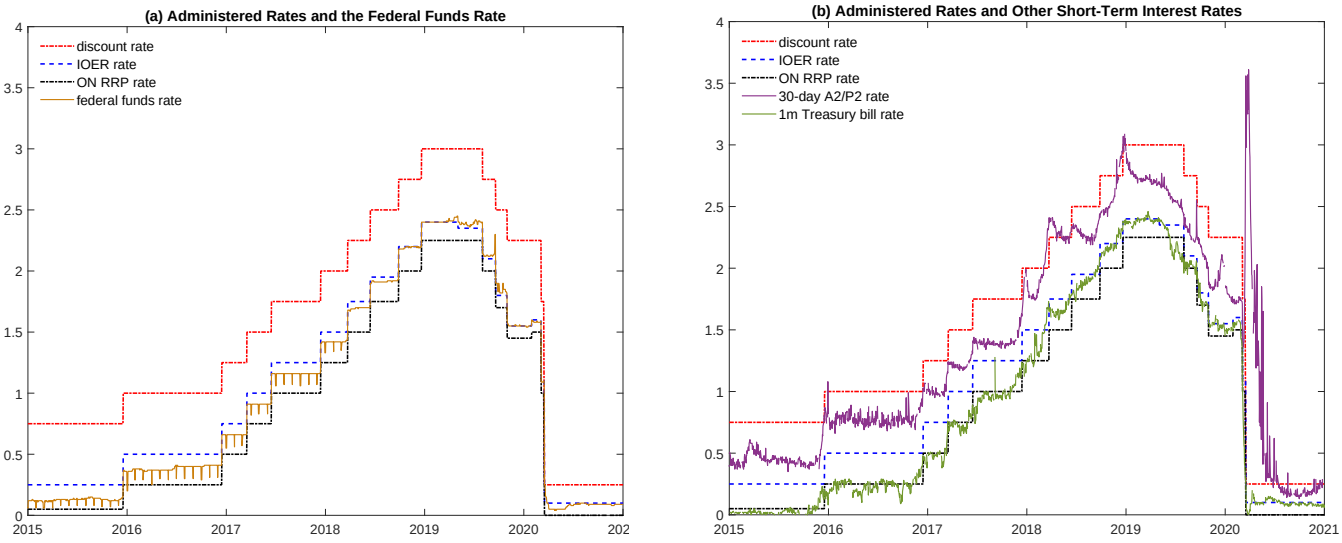
Diagram of factors determining equilibrium in the federal funds market on a typical day after 2008. r_{ff} denotes the federal funds rate, r_d the discount rate, r_{ioer} the interest rate on excess reserves, r_{onrrp} the interest rate on the Fed's overnight reverse repurchase facility, and Q_{ff} the total dollar value of federal funds loans in the market. See notes to Figures 1–3 and text for details.

4.2.3 The Federal Reserve's Reverse Repurchase Facility

One important feature of Figure 3 is that r^*_{ff} is not bounded below and can fall to essentially zero. In order to reduce volatility in the federal funds market and better achieve a target value for the federal funds rate, the Fed introduced a standing overnight reverse repurchase (ON RRP) facility in 2014, as discussed in Section 2. The ON RRP facility stands ready to borrow federal funds from all institutions in the federal funds market (including the GSEs) at a set ON RRP offer rate. Thus, the ON RRP offer rate is essentially like the IOER rate, except that it is available to all institutions in the federal funds market, including the GSEs.

The equilibrium in the federal funds loan market then looks essentially like Figure 4. The ON RRP offer rate is depicted by the horizontal line at r_{onrrp} in the figure. Above that line, the supply and demand for federal funds loans are the same as in Figure 3. Once the federal funds rate falls below r_{onrrp}, however, the supply of federal funds loans in Figure 4 drops to zero, because at that point even the GSEs can earn r_{onrrp} by lending their reserves directly to the Fed instead of the private market. One can thus think of r_{ioer} and r_{onrrp} as providing a "two-floor" system for the federal funds rate, with the first floor applying to depository institutions and the

FIGURE 5: RELATIONSHIP BETWEEN THE FED'S ADMINISTERED RATES AND OTHER SHORT-TERM INTEREST RATES SINCE 2015



Relationship between the Fed's directly administered interest rates (discount rate, IOER rate, and ON RRP rate), the federal funds rate (panel a), and other short-term interest rates (panel b) from 2015 to 2020. See text for details.

second floor to the GSEs. Overall, the supply of federal funds loans is given by the piecewise linear $C''C'D'D''$.

On the demand side, if the federal funds rate drops below r_{onrrp}, even the GSEs can start to conduct arbitrage by borrowing at r_{ff} in the private market and earning r_{onrrp} lending those reserves directly to the Fed, so the demand for federal funds loans increases even more rapidly for rates below r_{onrrp}. Overall, the demand for federal funds loans is given by the piecewise linear $A''A'B'B$.

With the Federal Reserve's ON RRP facility, the equilibrium r^*_{ff} is bounded below by r_{onrrp}, no matter how much the supply and demand for reserves shift on any given day. In practice, the Fed has set the ON RRP rate below the IOER rate, so depository institutions do not use the ON RRP facility and instead earn i_{ioer} by holding their federal funds in their accounts at the Fed.

To raise the federal funds rate target, the Fed can raise each of its directly administered interest rates r_{onrrp}, r_{ioer}, and r_d in Figure 4, pushing the equilibrium r^*_{ff} up along with them. This can be seen empirically in the left-hand panel of Figure 5: in the figure, the infrequent, discrete changes in the Fed's administered rates are clearly visible, with the equilibrium federal funds rate lying between r_{onrrp} and r_{ioer} throughout, except for a few brief periods in 2019 when $r_{ff} > r_{ioer}$. The federal funds rate also has clear downward spikes at the end of each month

from 2015 to 2018, as U.S. branches of foreign banks pursue "window dressing" for their home regulators and reduce the amount of IOER arbitrage on their balance sheets at the end of the month (Banegas and Tase, 2020). By varying these three administered interest rates, the Fed has thus been able to adjust its target for r^*_{ff} without changing the total quantity of federal funds in the market.

Thus, although the Federal Reserve continues to communicate monetary policy through a target for the federal funds rate, the way in which that target is implemented is very different from before. Prior to 2008, the Fed achieved its target for r^*_{ff} by varying the total quantity of federal funds in the market, shifting the supply and demand for fed funds loans left and right in Figure 1. Now, the Fed implements its target for r^*_{ff} by varying the administered interest rates r_{onrrp}, r_{ioer}, and r_d in Figure 4, without changing the quantity of reserves or shifting those supply and demand curves left or right.

Afonso, Armenter, and Lester (2019) provide a detailed estimation of the supply and demand for federal funds loans in the pre- and post-2008 periods that takes into account each of these key interest rates and the search process between would-be federal funds borrowers and lenders. See also Ihrig, Senyuz, and Weinbach (2020).

4.2.4 Other Short-Term U.S. Interest Rates after 2008

Despite the dramatic changes in the federal funds market since 2008, the relationship between the equilibrium federal funds rate and other short-term interest rates in the U.S. has remained largely unchanged. Essentially all large U.S. financial institutions now hold enormous quantities of federal funds and earn the IOER rate on those reserves. If other short-term interest rates in the U.S. differed very much from the IOER rate, then arbitrage by these U.S. financial institutions would drive that rate back toward r_{ioer}.[14] Thus, by setting the IOER rate, the Fed effectively controls all short-term interest rates in the U.S. economy. This is illustrated in the right-hand panel of Figure 5, which depicts the relationship between the Fed's directly administered interest rates and two representative short-term market rates: the 1-month Treasury bill rate and 30-day A2/P2 commercial paper rate. Note that both of these market rates are 1-month rates rather than overnight, and have different risk, liquidity, and tax characteristics than the federal funds rate, so these market rates are not necessarily bounded between r_{onrrp} and r_d the way the federal

[14] Of course, this arbitrage is now subject to the same FDIC-imposed costs discussed above, which prevents arbitrage of very small differentials. Nevertheless, the point remains valid that other short-term U.S. interest rates cannot deviate very far from the IOER rate.

funds rate is. For example, the 1-month Treasury bill is safer than a federal funds loan and has tax advantages, leading its yield to frequently fall below r_{onrrp}, while 30-day A2/P2 commercial paper is riskier than overnight fed funds loans and sometimes trades above r_d, especially in early 2020 at the onset of the Covid pandemic. Nevertheless, these short-term market interest rates track the Fed's administered interest rates closely.

5. The Future of the Federal Funds Market

Going forward, the Federal Reserve has declared that it will continue to express monetary policy in terms of a target for the federal funds rate, and will implement this policy through the administered ON RRP offer rate, IOER rate, and discount rate, just as it has been doing for the past several years (Federal Reserve Board, 2019). Thus, we should expect the equilibrium in the federal funds market to remain consistent with Figures 4 and 5 for the foreseeable future.

Despite the fact that the Fed will continue to communicate monetary policy in terms of the federal funds rate going forward, that interest rate is very different from what it was in the past. The market participants are very different (trading is now completely dominated by the GSEs and U.S. branches of foreign banks), the reasons for trading federal funds in the market are completely different (trading is now dominated by arbitrage between two of the Fed's administered interest rates, the ON RRP rate and IOER rate), and the way the Fed implements the federal funds rate target is completely different (varying the administered rates r_{onrrp}, r_{ioer}, and r_d rather than the quantity of reserves). These changes are arguably as large and important as those during the period of reserves targeting under Paul Volcker from 1979–82, discussed by Bernanke and Mihov (1998). It is thus somewhat surprising that the FOMC has decided to continue to put so much emphasis on an interest rate that is now little more than an arbitrage indicator, as opposed to communicating policy in terms of the IOER rate directly.

Another interesting question going forward is whether the Fed will at some point set the federal funds rate target below zero. Several other central banks, including the Swiss National Bank, Swedish Riksbank, European Central Bank, Danish Nationalbank, and Bank of Japan have all set negative policy rate targets and maintained those targets for several years (Swanson, 2018). The Danish Nationalbank and Swiss National Bank, in particular, have set their policy rates as low as -0.75 percent. In Figure 4, the Federal Reserve could attain such an equilibrium by setting r_{ioer} and r_{onrrp} less than zero—in other words, by charging institutions a fee to hold

federal funds deposits at the Fed. Although this gives the institutions an incentive to convert reserves into physical currency, the costs of holding physical currency (storage, transportation, security, risk of loss due to theft or accident, etc.) make this alternative unattractive for all but the smallest quantities of currency unless the IOER rate becomes substantially negative, appreciably less than the -0.75 percent seen in Europe so far (Swanson, 2018). Moreover, the convenience and efficiency of conducting interbank transactions via federal funds rather than physical currency are so large that there will always be a market for federal funds at the margin even at very negative interest rates.

Once the Fed has set a negative IOER rate, the same arbitrage arguments as in the previous section apply to other short-term market rates, driving them negative as well, analogous to Figure 5(b). This has certainly been the case in Europe, where yields on government bonds have fallen below zero for maturities out to several years in some cases.

To date, the Fed has equivocated regarding its views about the costs and benefits of a negative federal funds rate. In testimony before Congress in 2016, Fed Chair Yellen stated that "I'm not aware of anything that would prevent us from doing it," but also that there were legal questions and technical issues with the Fed's internal computer systems that would need to be resolved (Derby and Zumbrun, 2016). But with medium- and long-term interest rates near historic lows, there is a limit to the effectiveness of the Fed's other unconventional monetary policy tools—forward guidance and large-scale asset purchases—that makes consideration of a negative federal funds rate a distinct possibility in the next crisis.

6. Summary

The federal funds market has changed dramatically since its inception in the 1920s. Traditionally, U.S. depository institutions used the federal funds market to meet their reserve requirements or to earn interest on excess reserves. Beginning in 2008, several major policy changes completely transformed the market: the Fed began paying interest on reserves, the Fed increased the total quantity of federal funds in the market by a factor of sixty, and the FDIC began charging U.S. depository institutions a fee on total assets held rather than just deposits. As a result of these changes, U.S. depository institutions have now largely left the federal funds market, since they are almost never short of their reserve requirements, they can earn the IOER rate on reserve balances held at the Fed, and the FDIC fees make IOER arbitrage unprofitable for them except

in rare cases. Essentially all federal funds lending is now done by the GSEs, who are ineligible to receive interest on reserves, and almost all federal funds borrowing is now done by U.S. branches of foreign banks, who are exempt from FDIC fees and can profitably conduct IOER arbitrage between the GSEs and the Fed.

The Federal Reserve also implements its target for the federal funds rate very differently than it did before. Traditionally, the Fed would vary the total quantity of reserves to shift the supply and demand for federal funds loans in the market. Now, the Fed uses its directly administered interest rates—the ON RRP rate, the IOER rate, and the discount rate—to implement its target for the federal funds rate without changing the quantity of reserves.

The federal funds market is thus not at all what it used to be, and the structural break is arguably as large and significant as that documented by Bernanke and Mihov (1998) for 1979–82. Researchers thus need to be mindful of the break in structure and behavior of the federal funds market around 2008 that continues to this day.

Going forward, the Federal Reserve has declared its intention to continue communicating monetary policy in terms of a target for the federal funds rate, and to continue operating in an environment of abundant reserves, as it has been doing since late 2008. An interesting open question is whether, in some future crisis, the Fed will set a negative value for the federal funds rate target as many other central banks around the world have done recently with their own short-term interest rate targets.

References

Afonso, Gara, Roc Armenter, and Benjamin Lester (2019). "A Model of the Federal Funds Market: Yesterday, Today, and Tomorrow," *Review of Economic Dynamnics* 33, 177–204.

Afonso, Gara, Anna Kovner, and Antoinette Schoar (2011). "Stressed, Not Frozen: The Federal Funds Market in the Financial Crisis," *Journal of Finance* 66, 1109–39.

Anbil, Sriya, Mark Carlson, Christopher Hanes, and David Wheelock (2021). "A New Daily Federal Funds Rate Series and History of the Federal Funds Market, 1928–54," *Federal Reserve Bank of St. Louis Review* First Quarter, 45–70.

Banegas, Ayelen, and Manjola Tase (2020). "Reserve Balances, the Federal Funds Market, and Arbitrage in the New Regulatory Framework," *Journal of Banking and Finance* 118, 105893.

Bech, Morten, and Elizabeth Klee (2011). "The Mechanics of a Graceful Exit: Interest on Reserves and Segmentation in the Federal Funds Market," *Journal of Monetary Economics* 58, 415–31.

Bernanke, Ben, and Ilian Mihov (1998). "Measuring Monetary Policy," *Quarterly Journal of Economics* 113, 869–902.

Carlson, Mark, and Jonathan Rose (2017). "Stigma and the Discount Window," *Federal Reserve Board* website, https://www.federalreserve.gov/econres/notes/feds-notes/stigma-and-the-discount-window-20171219.htm, Dec. 19, 2017, accessed Oct. 22, 2021.

Craig, Ben, and Sara Millington (2017). "The Federal Funds Market since the Financial Crisis," *Federal Reserve Bank of Cleveland Economic Commentary* 2017–07.

Derby, Michael and Josh Zumbrun (2016). "Fed Nods to Negative Rates, Hurdles and All," *The Wall Street Journal,* Feb. 11, 2016, available at https://www.wsj.com/articles/fed-nods-to-negative-rates-hurdles-and-all-1455126278.

Federal Reserve Bank of New York (1998). "Open Market Operations During 1997," *Federal Reserve Bank of New York* website, https://www.newyorkfed.org/medialibrary/media/markets/omo/omo97.pdf, accessed Jan. 24, 2022.

Federal Reserve Bank of New York (2013). "Federal Funds and Interest on Reserves," *Federal Reserve Bank of New York* website, https://www.newyorkfed.org/aboutthefed/fedpoint/fed15.html, updated Mar. 2013, accessed Oct. 11, 2021.

Federal Reserve Board (2018). "Overnight Reverse Repurchase Agreement Facility," *Federal Reserve Board* website, https://www.federalreserve.gov/monetarypolicy/overnight-reverse-repurchase-agreements.htm, updated Jan. 3, 2018, accessed Oct. 16, 2021.

Federal Reserve Board (2019). "Timelines of Policy Actions and Communications: Policy Normalization Principles and Plans," *Federal Reserve Board* website, https://www.federalreserve.gov/monetarypolicy/timeline-policy-normalization-principles-and-plans.htm, updated Feb. 22, 2019, accessed Oct. 16, 2021.

Federal Reserve Board (2021). "Reserve Requirements," *Federal Reserve Board* website, https://www.federalreserve.gov/monetarypolicy/reservereq.htm, updated Feb. 3, 2021, accessed Oct. 6, 2021.

Friedman, Milton, and Anna Jacobson Schwartz (1963). *A Monetary History of the United States, 1867–1960* (Princeton University Press, Princeton).

Furfine, Craig (1999). "The Microstructure of the Federal Funds Market," *Financial Markets, Institutions & Instruments* 8, 24–44.

Gürkaynak, Refet, Brian Sack, and Eric Swanson (2007). "Market-Based Measures of Monetary Policy Expectations," *Journal of Business and Economic Statistics* 25, 201–12.

Hamilton, James (1996). "The Daily Market for Federal Funds," *Journal of Political Economy* 104, 26–56.

Ihrig, Jane, Zeynep Senyuz, and Gretchen Weinbach (2020). "The Fed's 'Ample Reserves' Approach to Implementing Monetary Policy," *Federal Reserve Board Finance and Economics Discussion Series* 2020-022.

Meulendyke, Ann-Marie (1998). *U.S. Monetary Policy and Financial Markets* (Federal Reserve Bank of New York, New York).

Naber, Jeffrey, Richard Sambasivam, and Mary-Frances Styczynski (2017). "Demand for Voluntary Balance Requirements: the U.S. Experience with Contractual Clearing Balances from 2000 to 2007," *Federal Reserve Board* website, https://www.federalreserve.gov/econresdata/notes/feds-notes/2017/demand-for-voluntary-balance-requirements-the-us-experience-with-contractual-clearing-balances-from-2000-to-2007-20170104.html, Jan. 4, 2017, accessed Oct. 6, 2021.

Swanson, Eric (2018). "The Federal Reserve Is Not Very Constrained by the Lower Bound on Nominal Interest Rates," *Brookings Papers on Economic Activity* Fall 2018, 555-71.

Wheelock, David (2013). "The Fed's Formative Years," *Federal Reserve History* website, https://www.federalreservehistory.org, accessed Oct. 6, 2021.