Monetary policy implementation with an ample supply of reserves

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PRELIMINARY: PLEASE DO NOT CITE OR CIRCULATE

Abstract

Methods of monetary policy implementation continue to change. The level of reserve supply --- scarce, abundant, or somewhere in between --- has implications for the efficiency and effectiveness of an implementation regime. We highlight these implications, using a very parsimonious framework and drawing from the experience in the United States since the 2008 financial crisis. We find that the optimal level of reserve supply likely lies somewhere between scarce and abundant reserves, thus highlighting the benefits of implementation with "ample" reserves.

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Introduction

Monetary policy implementation is the process by which a central bank conducts operations to transmit the desired stance of monetary policy to financial markets and the real economy. Much of monetary economics abstracts from policy implementation and simply assumes that the central bank can effortlessly establish any policy stance it desires. Yet, in practice, the challenges of implementing policy constrain the set of feasible policy stances – and, in turn, the choice of a policy stance can influence how policy must be implemented.

The financial crisis a decade ago highlighted these interactions. In many advanced economies, conventional rules called for a negative nominal policy rate in response to the extreme shock of the crisis. Yet in an economy with physical currency, it is essentially impossible to implement a significantly negative nominal interest rate. This implementation problem drove many major central banks after the financial crisis to pursue unconventional policy tools, such as forward guidance and large-scale asset purchases. In turn, asset purchases forced central banks to change their overall frameworks for controlling short-term interest rates: Pre-crisis, these frameworks had typically been based on adjusting the scarcity value of a limited supply of central bank money, but the increase in liquidity as a result of asset purchases made other techniques necessary.

Today, as global central banks unwind their responses to the financial crisis and normalize their policy stances, methods of monetary policy implementation continue to change. Central banks are reviewing what they have learned from the crisis and its aftermath and considering whether they want to continue using the implementation frameworks that they adopted post-crisis, return to their pre-crisis methods, or transition to other methods entirely.

The Federal Reserve, one of the central banks that is farthest along in this process, announced in January 2019 that it plans to remain in a regime of 'ample reserves,' where administered interest rates such as the rate paid on reserves are the primary implementation tool and where active adjustments in reserve supply are not needed to implement policy. However, consistent with its longstanding plan to operate with a balance sheet that is no larger than necessary for efficient and effective policy implementation, the Federal Reserve is also seeking to move to notably lower levels of reserve supply than the peak reached after its asset purchases.

In this paper, we review key features of a central bank operating regime and discuss the costs and benefits of different implementation framework. We begin by reviewing theoretically how the ample reserves regime controls money market interest rates, both directly by arbitrage between market rates and administered rates, and indirectly by influencing the bargaining positions of market participants. An important contrast between these mechanisms and the pre-crisis mechanism of adjusting reserve supply to change the scarcity value of reserves is that the ample reserves regime can exert equal influence on money market rates even after large liquidity injections such as those used in response to the crisis. Throughout the paper, we consider the experience of the Federal Reserve to create a link between theory and practice.

Next, we consider the efficiency of the operating regime. Considering only the regime's influence on money markets, we show that – because an ample reserves regime can be implemented at a wide range of levels of reserves – there is a tradeoff between the size of the central bank's balance sheet and the frequency of the operations needed to implement policy. We present a parsimonious yet instructive theoretical framework for finding an optimal level of reserve supply given this tradeoff.

We also examine the effectiveness of the operating regime: how much control does it provide over short-term money market rates, as measured both by dispersion across these rates and by the pass-through of administered rates to market rates? Evidence so far suggests a high degree of effectiveness.

Finally, considering the broader context of the entire financial system, we argue that financial stability concerns may make it socially efficient for the central bank to supply ample reserves rather than make reserves scarce.

A Simple Model of Monetary Policy Implementation

A key factor in discussing monetary policy implementation is the relationship between reserve supply and the policy rate: the demand curve for reserves. The shape of the demand curve varies across different potential theoretical models, and our framework allows a wide range of possibilities in its shape. To motivate the existence of the demand curve and reasonable assumptions on its shape, a good starting point is Poole (1968).

Poole (1968) Reserve Demand Model

A large literature on monetary policy implementation uses some variant of Poole (1968).[2] This section provides a sketch of the Poole (1968) or *standard* model. The standard model assumes that banks (or depository institutions) demand reserves to meet their regulatory reserve requirements. The central bank provides at least enough reserves to meet these requirements. In other words, aggregate excess reserves – the difference between total reserves and required reserves – are strictly positive. Banks are able to adjust their reserve holdings in an interbank market. The standard model assumes there are no direct or indirect costs associated with trading reserves.

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[2] Some recent work has used other types of model such as search and bargaining or preferred habitat, in contrast to perfect competition in Poole (1968). See for example Afonso and Lagos (2015), Afonso, Armenter, and Lester (2019), Schulhofer-Wohl and Clouse (2018), and Chen, Clouse, Ihrig, and Klee (2016). Still, in many of these works, demand for reserves originates from required reserves and timing of shocks that are broadly consistent with Poole (1968).

After the interbank market closes, banks receive a payment shock that reallocates reserves among them. If a bank's payment shock is sufficiently negative, its reserve holdings will fall below what is required – it will have negative excess reserves. In this situation, the bank must borrow reserves from the central bank at a penalty rate, r_p, so that its excess reserves are at least zero. If the payment shock implies that a bank ends up with positive excess reserves, the central bank pays interest on them, IOR (interest on reserves).

If payment shocks are uniformly distributed around zero, then a bank's demand curve for reserve is described by figure [1] (see Ennis and Keister 2008 for a formal derivation). The demand curve should be interpreted as the locus of indifference points for the bank. If a bank's excess reserves are on the negatively sloped part of the demand curve before the payment shock, the marginal dollar of reserves can be used to reduce borrowing from the central bank or to just earn IOR depending on the realized payment shock: thus the marginal value of reserves in expectation lies between IOR and the penalty rate. Along this negatively sloped part of the demand curve, as excess reserve holdings increase, the probability that excess reserves become negative following the payment shock decreases and, as a result, the amount that the bank is willing to pay for an additional dollar of reserves falls. Hence, the demand curve has a negative slope. The horizontal part of the demand curve equal to IOR corresponds to excess reserve holdings that are so high that the bank will always hold positive excess reserves following any payment shock. In this situation, absent frictions, the bank is indifferent to borrowing or lending at IOR.

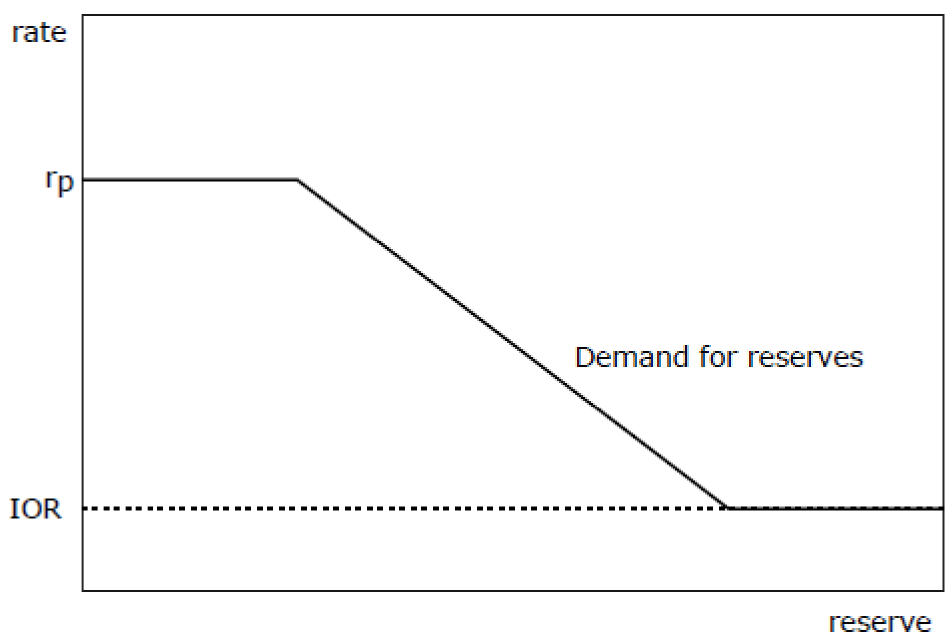

Figure 1: Reserve Demand in the Poole Model.

The equilibrium interbank rate is determined by equalizing aggregate demand and aggregate supply. The aggregate demand curve for reserves is simply the horizontal summation of the individual banks' demand curves. The shape of the aggregate demand curve is identical to the individual demand curve, as in figure [2]. The central bank is assumed to supply an exogenous amount of (excess) reserves to the banking sector. Aggregate supply of (excess) reserves can diagrammatically be represented by a vertical line in the interest rate-excess reserve space. Figure [2] illustrates two different aggregate supply curves, S_1 and S_2. If the aggregate supply of reserves is given by S_1, then the interbank rate, rb_1, exceeds IOR; if the aggregate supply is S_2, then the interbank rate, rb_2, equals IOR.

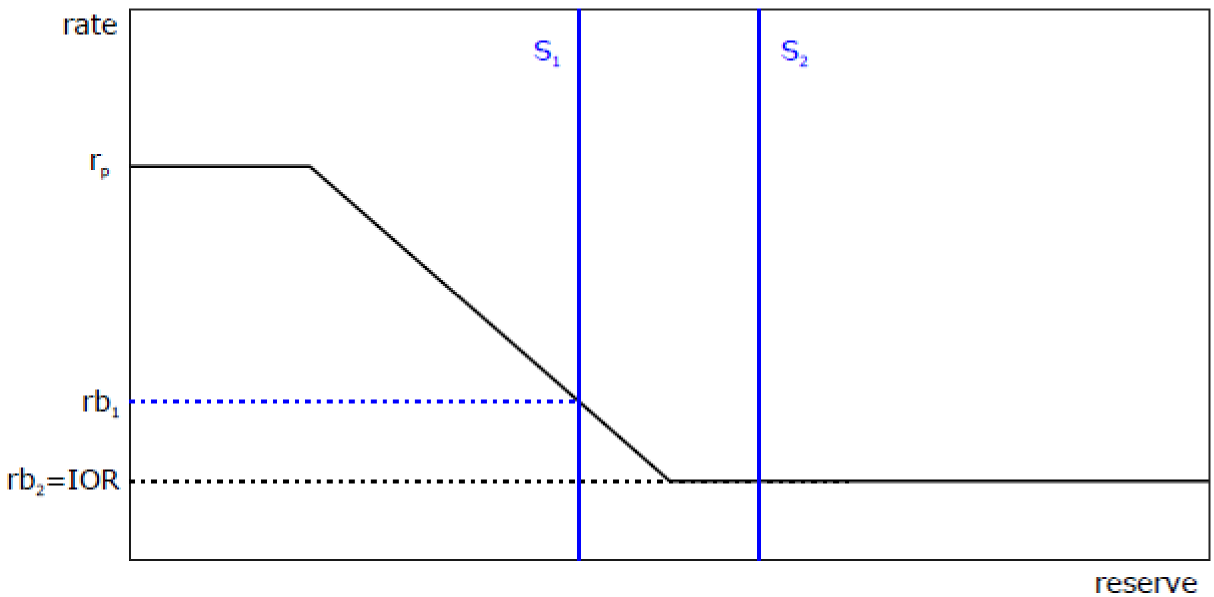

Figure 2: Equilibrium in the Poole Model

In the standard model, equilibrium in the interbank market is characterized by all banks holding the same amount of excess reserves when the interbank market closes, independent of the initial distribution of reserves across banks. This implies that banks holding more than the average amount of excess reserves before the interbank market opens lend in the interbank market and those holding less than the average amount borrow in the interbank market.

Finally, the interbank market can be easily replaced with a more general funding market with non-bank lenders. Therefore, the demand curve for reserves in the standard model remains the same whether trading occurs in an interbank market or in another funding market.

Pre-crisis implementation framework by the Federal Reserve

The standard model can easily describe the implementation framework used by many central banks pre-crisis, including the Federal Reserve. Before September 2008, the Federal Reserve would set a target for the effective federal funds rate above the IOR, which was zero at the time.[3] Therefore, the target was on the negatively sloped part of the aggregate demand curve. The Federal Reserve would supply the appropriate amount of excess reserves to intersect the demand curve at the policy target.[4] The amount of excess reserves supplied by the Federal Reserve to the banking sector was very small, approximately $1.7 billion in 2006, and is represented by S_1 in figure [2]. Since banks held reserves primarily to meet reserve requirements, the aggregate demand curve was highly forecastable. As well, the Federal Reserve could anticipate changes in the aggregate supply of reserves that resulted from changes in the central bank's other liabilities, such as currency in circulation. As a result, by conducting daily open market (repo) operations to offset changes in aggregate supply and demand for reserves, the Federal Reserve could hit its policy target with a high degree of accuracy.

Post-crisis regulation

Post-crisis regulations in the U. S. and many other countries affected reserve demand and the functioning of the interbank market in at least two important ways. First, liquidity regulations mandate holdings of high quality liquid assets (HQLA), effectively increasing the demand for reserves. Furthermore, banks can choose how to allocate their HQLA between reserves and government securities, which increases the uncertainty in the demand for reserves, at least from the central bank's perspective. Second, the leverage ratio resulted in increased marginal trading costs in the interbank market.

Liquidity regulation

The liquidity coverage ratio (LCR) essentially mandates that banks hold a minimum fraction of their assets in a form that can be quickly converted or liquidated into 'cash' without significant losses. These *safe* and *liquid* assets include government securities and central bank reserves. The LCR regulation implies that, compared to the pre-crisis period, banks' demands for both government bonds and reserves increase. In addition, as discussed below, internal liquidity stress tests also play an important role.

In the standard model, a bank's sole reason for demanding reserves is to satisfy reserve requirements. The post-crisis liquidity regulation results in a new and independent source for demand for reserves by banks. Figure [3] illustrates the effect that liquidity regulation has on the demand for reserves. In particular, starting from the standard model's demand curve, the liquidity regulation has the effect of shifting out the demand curve from the standard model's

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[3] The Financial Services Regulatory Relief Act of 2006 authorized the Federal Reserve Banks to pay interest on balances held by or on behalf of depository institutions at Reserve Banks, subject to regulations of the Board of Governors, effective October 1, 2011. The effective date of this authority was advanced to October 1, 2008, by the Emergency Economic Stabilization Act of 2008.

[4] At the time, the federal funds market was primarily interbank.

demand curve by the additional amount of reserves that banks choose to hold. In figure 3, the outer demand curve represents demand for reserves associated with satisfying *all* of the LCR requirements by using reserves. This outer demand curve is effectively the 'maximum' reserve demand curve for reserves. The actual amount of reserves that banks demand for LCR purposes will depend on factors such as money market interest rates, government security rates, bank preferences regarding asset portfolio allocation and so on. Therefore, banks' actual aggregate reserve demand curve can reside anywhere between the standard demand curve – where there is zero LCR reserve demand – and the maximum demand curve in figure 3.

If the aggregate supply of reserves is given by S_1 in figure [3], then the pre-LCR interbank rate equals IOR while the post-LCR interbank rate associated with the maximum demand curve exceeds IOR. If, however, the aggregate supply of reserves is instead very large and given by S_2, then the interbank rate is equal to IOR for both the pre- and post-crisis demand curves.

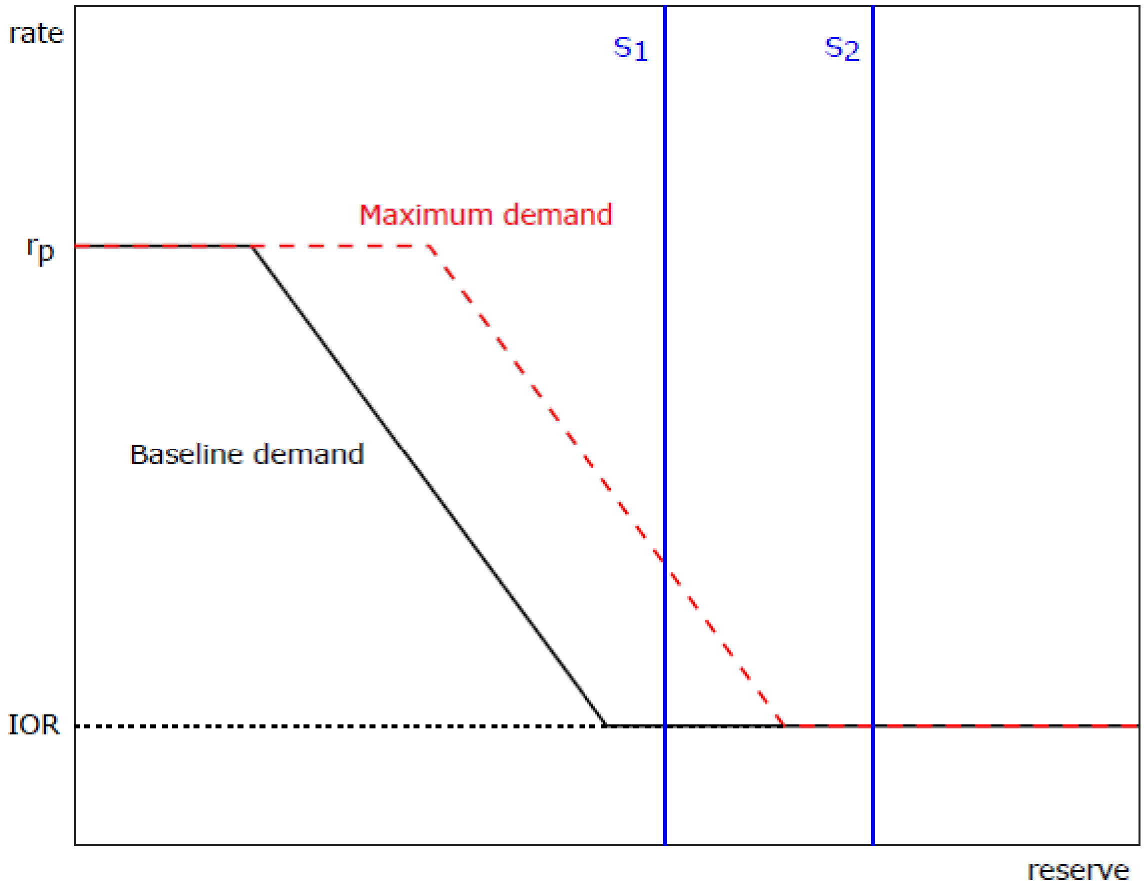

Figure 3: Effect of Demand Uncertainty.

Balance sheet costs

Other post-crisis regulations, such as the leverage ratio, can be interpreted as a tax on the size of a bank's balance sheet. Another example is the FDIC fee that a bank pays as a function of the size of its balance sheet (pre-crisis the fee was a function of the size of a bank's deposit liabilities.) If a bank *borrows* on the interbank market but ends up with positive excess reserves after the payment shock, then the interbank borrowing increases the size of its balance sheet. As a result, the bank pays a higher FDIC fee. If a bank *lends* in the interbank market but ends up with negative excess reserves following the payments shock – meaning it must borrow from the central bank – the size of its balance sheet also increases (compared with the situation where it did not lend in the interbank market in the first place). The cost imposed by the FDIC regulation affects the amount of reserves traded in the interbank market. The amount of trading in the interbank market unambiguously falls compared with the standard model.

Suppose for simplicity there is a constant marginal cost equal to c associated with the imposition of a regulation such as the FDIC fee. This means if a bank's balance sheet increases by a dollar, then the bank's regulation fee increases by c. This sort of regulation drives a wedge between a (potential) borrowing bank's demand curve and a (potential) lending bank's demand curve for reserves, where the size of the wedge equals c (for details see Kim, Martin and Nosal 2018). Figure 4 illustrates demand curves for borrowing and lending banks. When $c = 0$, the two curves coincide.

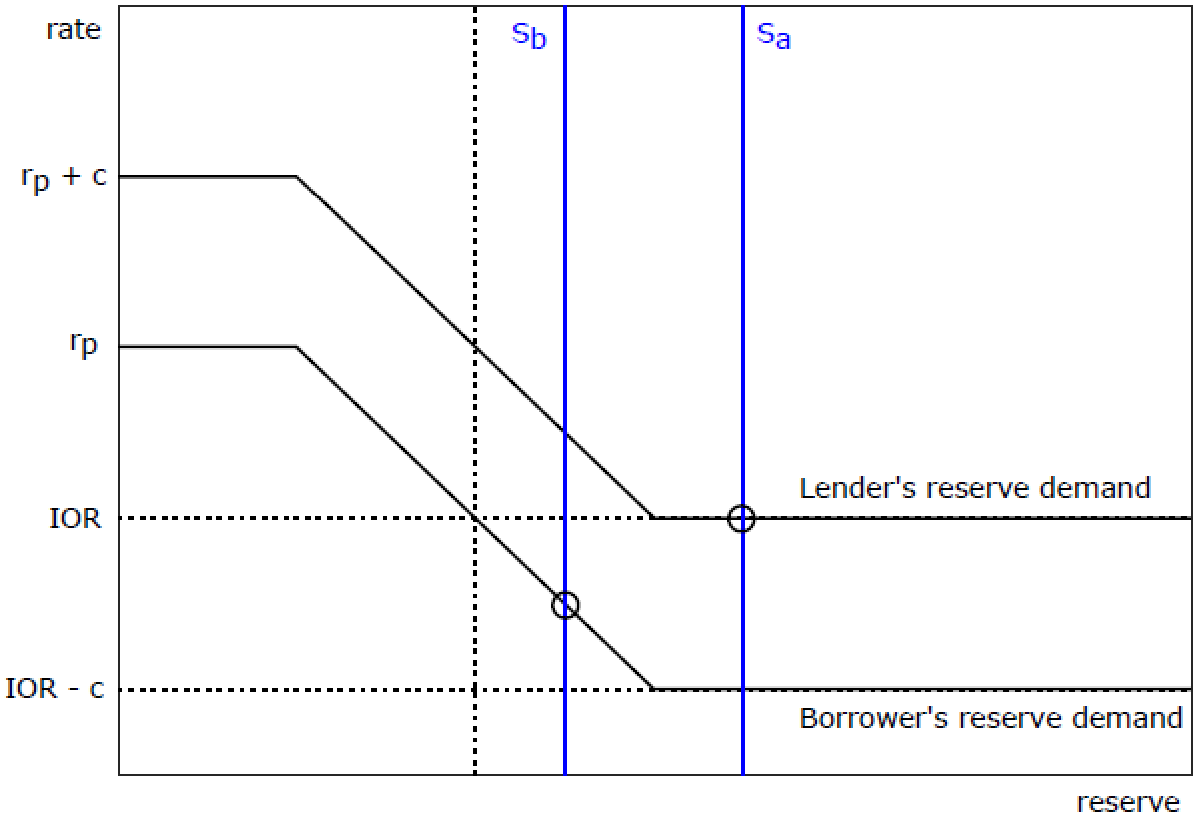

Figure 4: Balance Sheet Cost Wedge.

Suppose that the demand curves in Figure 4 are for two banks, where S_a represents the excess reserves held by bank a and S_b represents the excess reserves held by bank b. Since $S_a > S_b$, bank a is a potential lender and bank b is a potential borrower in the interbank market. Therefore, the upper demand curve is associated with bank b and the lower demand curve is associated with bank a. A necessary condition for any interbank volume is that the interest rate associated with bank a's demand curve evaluated at S_a must exceed the interest rate associated with bank b's demand curve evaluated at S_b; otherwise there will be zero interbank trade. Figure 4 illustrates a situation where there is zero volume in the interbank market. If instead S_b was to the left of the vertical line marking where bank b's demand curve meets IOR, then banks a and b trade in the interbank market. In this diagram, bank b will borrow so that its final excess reserves position is zero. (Note: there is nothing special about zero excess reserves; it is just the way the diagram is drawn.) Notice two things about the existence of interbank trades: (1) banks must have substantially different holdings of excess reserves before the market opens if there is to be any interbank trade volume; and (2) in contrast to the standard model, interbank trades do *not* completely equalize banks' excess reserve holdings.

In the standard model, all banks exit the interbank market holding the same level of reserves. This implies that the aggregate demand curve is simply a scaled up version of individual banks' demand curve and the initial distribution of individual banks' excess reserve holdings is irrelevant. When marginal trading costs exist, however, the initial distribution of excess reserves before the interbank market opens is relevant for determining the volume of interbank trade and the interbank rate. A simple way to introduce heterogeneity of excess reserve holdings before the interbank market opens is to modify the timing of the standard model in the following way: (1) All banks start off with the same level of excess reserves by borrowing from non-bank lenders; (2) banks are hit by a 'reallocation of reserves' shock after which excess reserve holdings among banks are different; (3) the interbank market opens and trade occurs; and (4) the interbank market closes and banks are hit by the payment shock.

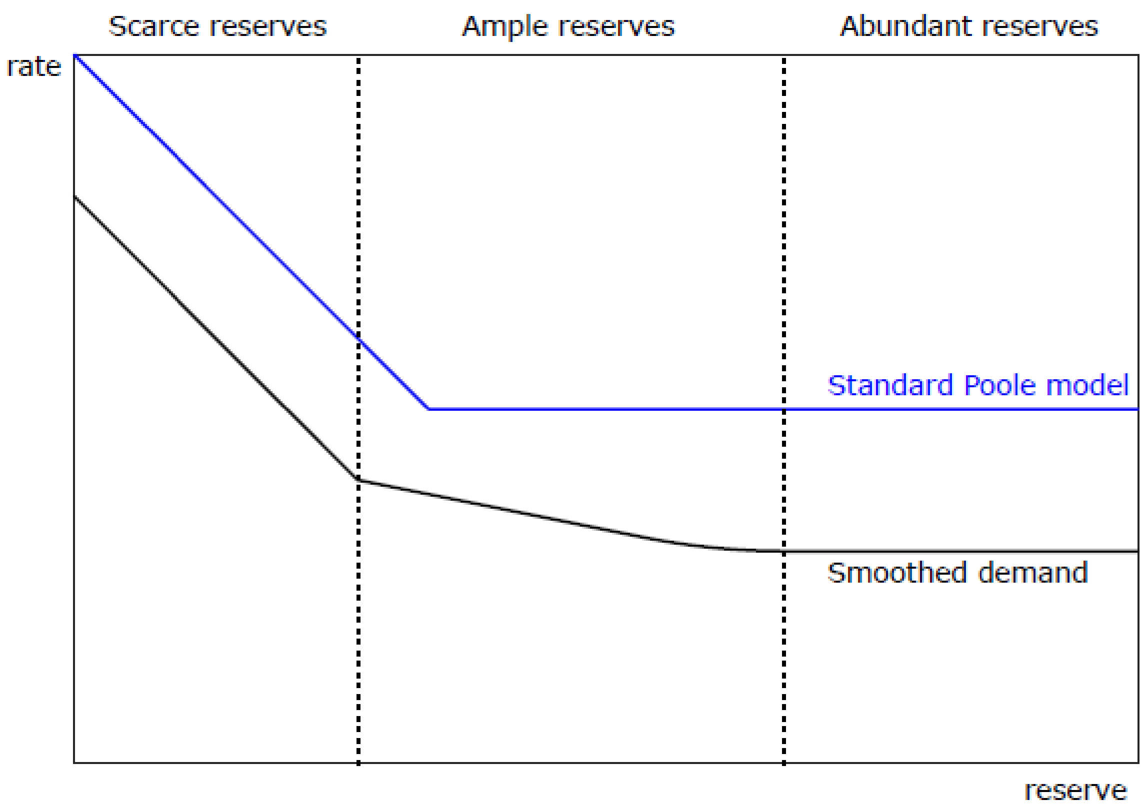

Figure 5: Smoothed Out Reserve Demand.

Since interbank trades do not equalize banks' excess reserves holdings, the reserve demand curve, which is the banks' funding rate from non-bank lenders from step 1, will be different from figure 2: The demand curve for reserves is 'smoothed out' compared to the kinked demand curve from the standard model, as illustrated in figure [5]. Even when excess reserves are above the kink in the standard model's aggregate demand curve, they may not be 'abundant': There is still a chance that a bank may experience a negative reallocation shock that reduces its excess reserves below the kink if excess reserves are close to the kink. As marginal balance sheet costs will prevent interbank trades from completely offsetting the shock, banks would be willing to pay more to borrow reserves beforehand. This willingness gradually decreases as excess reserves increase, all the way down to zero, smoothing out the kink.

The following definitions will be useful. When marginal balance sheet costs exist, we say that reserves are *abundant* when the aggregate demand curve is horizontal (see figure [5]). We say that reserves are *scarce* when the demand curve reaches its maximum negative slope. Otherwise, reserves are *ample*: between scarcity and abundance.

A Simple Framework for Aggregate Reserve Demand and Supply

We now synthesize the above models into a simple but general framework. We assume that the central bank's policy rate (for example the effective federal funds rate in the U.S.) is a function of aggregate reserve supply, a reserve demand shock ($\delta DEMAND$) and IOR:

$$rate(reserve\ supply, \delta DEMAND, IOR).$$

This function specifies the equilibrium rate. Since reserve supply is an exogenous quantity this is equivalently the aggregate demand curve for reserves --- the supply curve is a vertical line. We assume that an increase or decrease in IOR shifts the *rate* function up or down one-for-one, since a basis point increase in both IOR and banks' funding rate does not change the net cost of obtaining reserves.[5] The demand shock shifts the demand curve to the left or right as the shock is negative or positive, respectively. Therefore, the *rate* function can be written as

$$rate = spread(reserve\ supply - \delta DEMAND) + IOR.$$

We note that *spread* can be negative, especially with significant balance sheet costs. Furthermore, we assume that the function *spread* is continuous, monotonically decreasing and convex. In the absence of changes in market structure linked to changes in reserve supply, the assumption of monotonic decrease is generally accepted. Convexity is also reasonable and consistent with the rate being insensitive to changes in reserves supply with an abundant supply of reserves and being very sensitive with a scarce supply.[6]

Reserve supply is also subject to shocks due to changes in autonomous factors, such as withdrawal and deposit of physical bills and coins and movements of reserves between the

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[5] This assumption is consistent with various models if we assume that the penalty rate and rates on other facilities (such as the overnight reverse repo program by the Federal Reserve) increase or decrease, one-for-one, with changes in the IOR.

[6] If market structure or trade patterns change as reserve supply changes then convexity is no longer a reasonable assumption. For examples of such cases see Afonso, Armenter, and Lester (2019) and Kim, Nosal and Martin (2018).

banking system and special accounts outside the banking system. In the absence of open market operations to offset such shocks, we can write

$$reserve\ supply = TARGET + \delta SUPPLY,$$

where *TARGET* is the target level of reserve supply that the central bank chooses and $\delta SUPPLY$ is the shocks to reserve supply.

We interpret this framework as describing what happens on a single day and ,abstract from the accumulation of shocks over multiple days, trends in reserve demand, and so on.

Benefits and costs of large and small reserve supply

A direct cost associated with scarce excess reserves is the cost of conducting frequent, often daily, open market operations to fine-tune the supply of reserves to keep the policy rate at a given target. With increased balance sheet costs, it may be difficult for a central bank to find a willing counterparty for repo and reverse repo operations. Put another way, since repo operations increase the size of the counterparty's balance sheet, the counterparty may be reluctant to participate at rates at which the central bank would like to transact. Later we will characterize the relationship between reserve supply and the frequency of operations using our simple framework.

A simple way to eliminate the need for operations is to have a very large supply of reserves, but there are benefits to having scarce reserves. One of the main benefits is the small "footprint" that the central bank leaves on financial markets. Another benefit associated with a small footprint may be the avoidance of political costs associated with paying significant interest income to banks.

There are a number of benefits associated with abundant reserves in addition to eliminating the cost of open market operations. As discussed below, a large supply of reserves may provide financial markets with stability. In addition, the so-called Friedman rule, which calls for supplying sufficient money (reserves) that holding money (reserves) is costless, has been shown to have desirable macroeconomic properties in a variety of very different economic models. In the context of our monetary policy implementation model, the Friedman rule is achieved when banks' funding rate equals IOR minus marginal balance sheet costs, and this can only occur when the aggregate reserves in the banking sector are abundant. Finally, a major function of the banking sector is to process economy-wide payments. Payments are processed or cleared by the transfer of reserves from one bank to another. If reserves are abundant, then banks have little incentive *not* to clear payments as they arise, because banks have sufficient reserves remaining for other purposes even after they transfer reserves for payments purposes. By contrast, if reserves are scarce, banks may have an incentive to delay sending outgoing payments until they have received incoming payments, to reduce the risk of facing a shortfall of reserves. Hence, abundant reserves promote the efficient clearing of payments.[7]

Post-Crisis Changes in the U. S.

Our framework is a useful tool in discussing how monetary policy implementation may respond to changes in the financial system. In this section, we describe how day-to-day changes in both reserve supply and demand have become much bigger in the U. S. in recent years. As we will see in the next section, this can make implementation with ample reserves more desirable.

In the absence of open market operations by the Federal Reserve, the supply of reserves available to banks changes every day, as reserves are withdrawn as physical currency (bills and coins) and moved to and from accounts held by non-bank entities, such as the Treasury General Account (TGA) and the foreign repo pool. Generally, exogenous (excluding Federal Reserve operations) day-to-day changes in the supply of reserves are predictable, but the volatility of these changes has increased significantly over recent years.

Figure 6 shows that the volatility in exogenous changes to reserve supply has increased substantially since the financial crisis. Specifically, the figure shows that the week-to-week volatility in selected autonomous factors increased substantially. The factors are physical currency and reserve accounts held by non-bank entities; thus, a dollar increase in a factor causes a dollar decrease in reserve supply available to banks. In principle, the Federal Reserve can affect the volatility of some of the factors. For example, it can change explicit rules or implicit agreements governing the use of accounts held by non-banks, but only to a limited extent.[8]

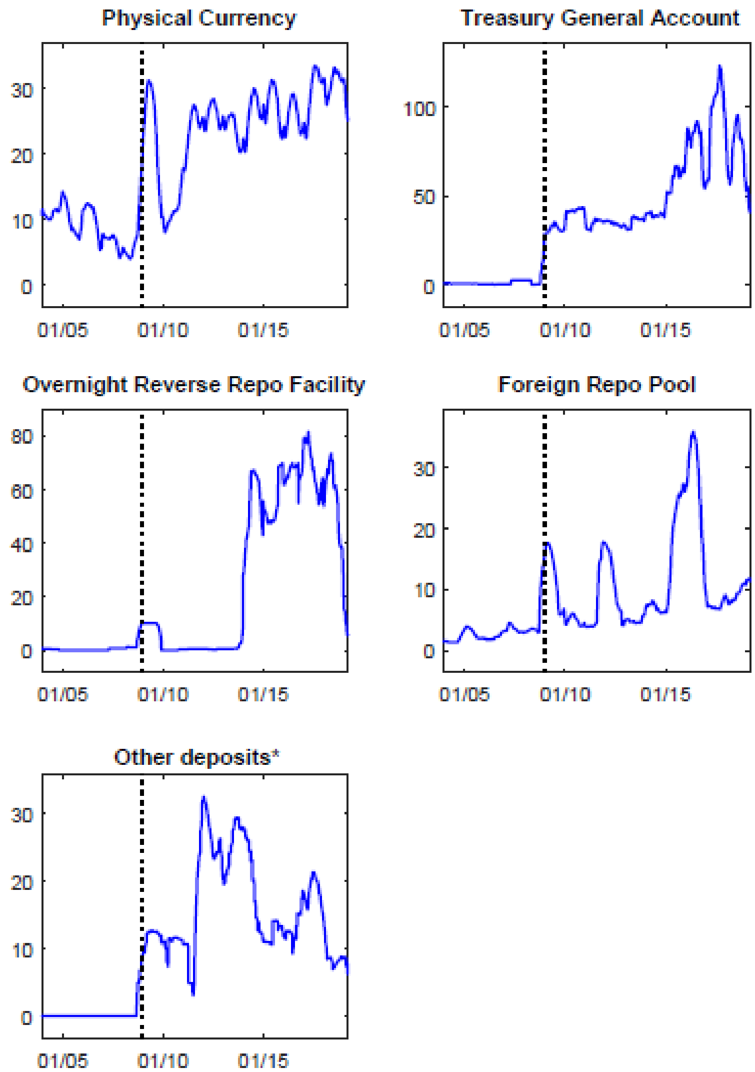
Restricting this volatility may not always be desirable. For example, since 2015 Treasury attempts to manage a 5 day liquidity buffer, to limit the risk that it might not be able to access the market, for example due to an operational outage, such as a cyber-attack.[9] While this contributes to large autonomous factors, there are several reasons why it might not be possible or desirable to return to the pre-crisis situation. In addition to the resiliency benefit to Treasury, one reason is that banks are less interested in taking large and volatile cash balances from Treasury given the constraints imposed by the leverage ratio. The overall week-to-week

[7] See Bech, Martin, and McAndrews (2012) and Garratt, Martin, and McAndrews (2014), for example.

[8] For example, it would be difficult to regulate withdrawal and deposit of physical currency. Similarly, it will be hard to force entities holding these accounts to reduce volatility in their account balance substantially without regard to their operational needs; indeed free withdrawal and deposit is a primary advantage of holding cash or reserves.

[9] The May 6 2015 Treasury Quarterly refunding statement notes "Based on our review, the TBAC's recommendations, and an assessment of emerging threats, such as potential cyber-attacks, Treasury believes it is prudent to change its cash management policy starting this month. To help protect against a potential interruption in market access, Treasury will hold a level of cash generally sufficient to cover one week of outflows in the Treasury General Account, subject to a minimum balance of roughly $150 billion."

volatility in reserve supply currently stands at around $150 billion as figure 7 illustrates; note that it accurately reflects exogenous supply changes only for the post-crisis period.[10]

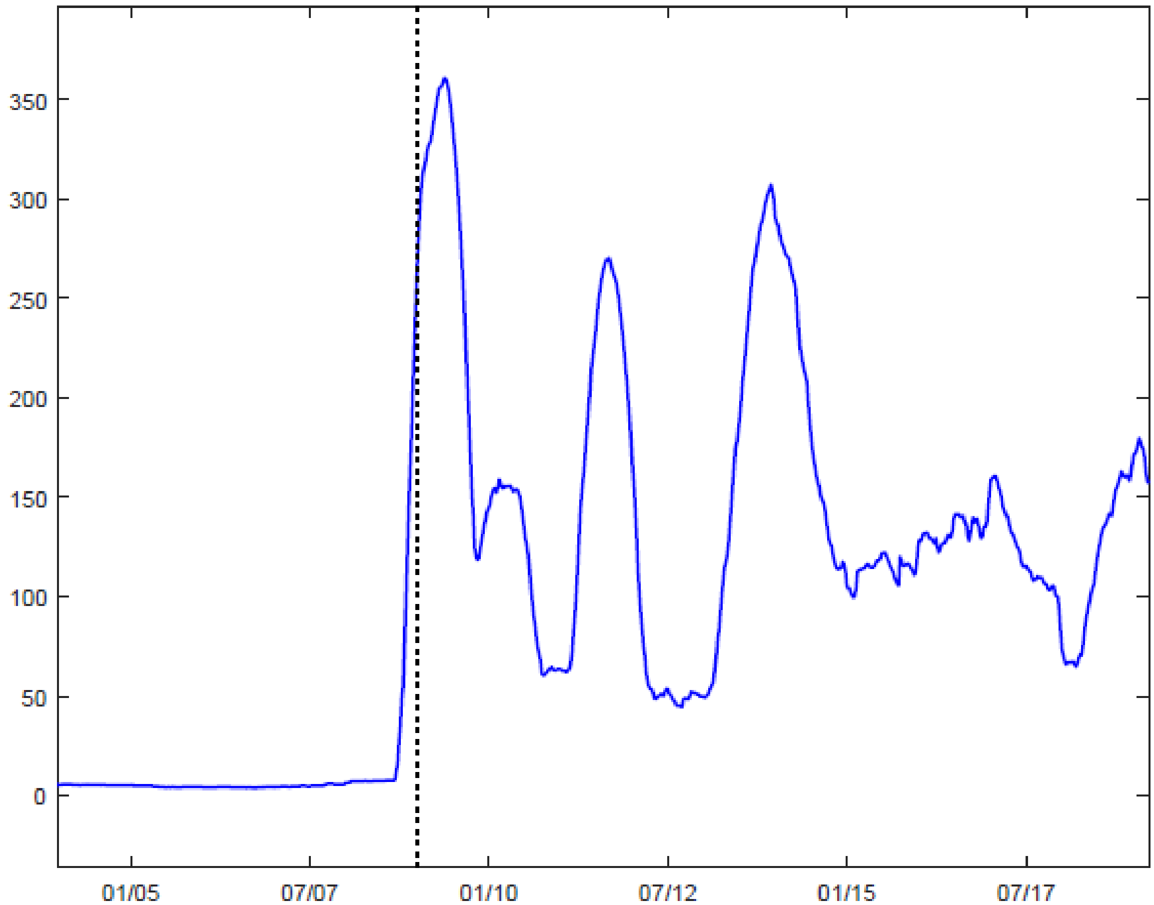


* Other deposits are held by various official and private institutions.
** The vertical line marks the beginning of 2009, a few months after the first series of large-scale reserve injections.
*** All numbers are in billions of USD.

Figure 6: Volatility in Selected Autonomous Factors.[11]

[10] After large-scale reserve injections following the crisis the Federal Reserve no longer conducted daily open market operations to fine-tune reserve supply. However, it did so pre-crisis. Therefore pre-crisis figures do not reflect volatility in exogenous reserve supply.

[11] Time period covered is from 2003 to present. Volatility is calculated using publicly released weekly snapshots for 52-week trailing windows.



* The vertical line marks the beginning of 2009, a few months after the first series of large-scale reserve injections.
** All numbers are in billions of USD.

Figure 7: Volatility in Reserve Supply.[12]

Similarly, the uncertainty in banks' demand for reserves increased substantially after the crisis. Pre-crisis, banks' aggregate demand for reserves was always close to required reserves, plus a very small buffer for unexpected payment outflows. However, post-crisis regulatory changes introduced significant uncertainty in banks' aggregate demand for reserves.

One notable source is the requirement to hold a large portfolio of High-Quality Liquid Assets (HQLA) to meet the Liquidity Coverage Ratio (LCR). Banks meet this requirement mostly by holding reserves and Treasury securities. However depending on the shape of Treasury yield curve and market environment, the preferred composition of HQLA could change, affecting banks' demand for reserves. By nature the resulting demand for reserves is difficult to forecast

[12] Time period covered is from 2003 to present. Volatility is calculated using publicly released weekly snapshots for 52-week trailing windows.

precisely, as individual banks' demands will depend on their liquidity management and compliance strategies.

Regulatory changes also made it more expensive for financial institutions to expand their balance sheets. These apply to counterparties for the Federal Reserve's open market operations as well, making them less willing to engage in repo transactions with the Federal Reserve.[13]

Overall both the easy-to-forecast supply shocks and hard-to-forecast demand shocks increased in magnitude since the financial crisis. Combined with the increase in balance sheet cost, these changes would create challenges for the pre-crisis implementation regime based on scarce reserves, as we discuss in the next section.

Implementation in the Post-Crisis Environment

In this section, we show that the changes described above could make it more challenging for a central bank to use a scarce reserves regime. For a moment, we ignore uncertainty in reserve demand and focus only on supply shocks. Under a scarce-reserves regime, open market operations would likely need to be conducted every day to offset exogenous reserve supply shocks. This is necessary because the policy rate is very sensitive to changes in the supply of reserves when reserves are scarce.

If the magnitude of reserve supply shocks has increased, controlling the policy rate would require correspondingly larger offsetting operations. At the same time, financial institutions are less willing to engage in open market operations, more so if the operations are larger. Therefore, it could be challenging at times for a central bank facing large autonomous factors to conduct open market operations in the desired size.

Adding in demand uncertainty, such as demand shocks that are hard for the central bank to forecast, the scarce-reserves regime could become even more difficult to implement. If demand shocks cannot be forecasted precisely, they cannot be offset perfectly. As a result, the policy rate would fluctuate with the realization of demand shocks.

With abundant reserves, rate control is generally not an issue. If reserves are abundant enough, the policy rate would not be expected to move for any realization of supply and demand shocks. In particular, this remains true even without any open market operations by the central bank. This is currently the case for the U. S., where the federal funds rate almost never changes from one day to the next even without any operation by the Federal Reserve.

[13] If a bank or a dealer borrows cash from the Federal Reserve, its balance sheet expands. However if a bank or a dealer lends cash to the Federal Reserve, its balance sheet size stays constant.

If reserves are already abundant, adding any more reserves does not enhance monetary policy implementation. The primary costs of smaller reserves discussed earlier, policy rate volatility and cost of open market operations, are already zero and cannot decrease further.

Over a range of reserve supply where these costs are zero, the central bank can choose its preferred level of reserves using any other criteria; for example, it can simply choose the lower bound of the range. Indeed a central bank that has a preference for lower reserves for a given level of policy rate volatility and a given cost of open market operations will generally choose a level of supply below the lower bound.

Therefore, for a central bank that finds it difficult to use a scarce-reserves regime, the optimal choice of reserve supply is somewhere between scarcity and abundance: ample.[14] To discuss how ample reserves need to be, we characterize the costs of rate volatility and open market operations as a function of reserve supply.

In the following, we present a very simple characterization of such costs. The central bank chooses a target level of reserves supply, *TARGET*. The central bank can satisfy its rate control objective without any open market operation if

$$\begin{aligned}|spread(TARGET + \min(\delta SUPPLY) - \max(\delta DEMAND)) \\ - spread(TARGET + \max(\delta SUPPLY) - \min(\delta DEMAND))| \leq TOL.\end{aligned}$$

For simplicity, we assume that supply and demand shocks are independent. Figure 8 illustrates the case graphically. min and max are the minimum and maximum of supply and demand shocks and the constant *TOL* is a very small number representing the central bank's tolerance for policy rate volatility. Realistically the min values will be negative and the max values will be positive for both shocks. With a convex *spread* function, this is satisfied only if *TARGET* is larger than a certain level.[15]

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[14] The language of 'between scarcity and abundant' is approximate. For example it is possible that a target level of reserve is in the abundant range but demand and supply shocks are large enough to sometimes move reserve supply outside the abundant range. In that case, if the target reserve supply is close to the lower limit of the abundant range, the costs associated with rate volatility and open market operations may not be zero.

[15] Since *spread* is continuous the relationship is also satisfied at the threshold level. Generally we are not rigorous about such details given the purpose of this note.

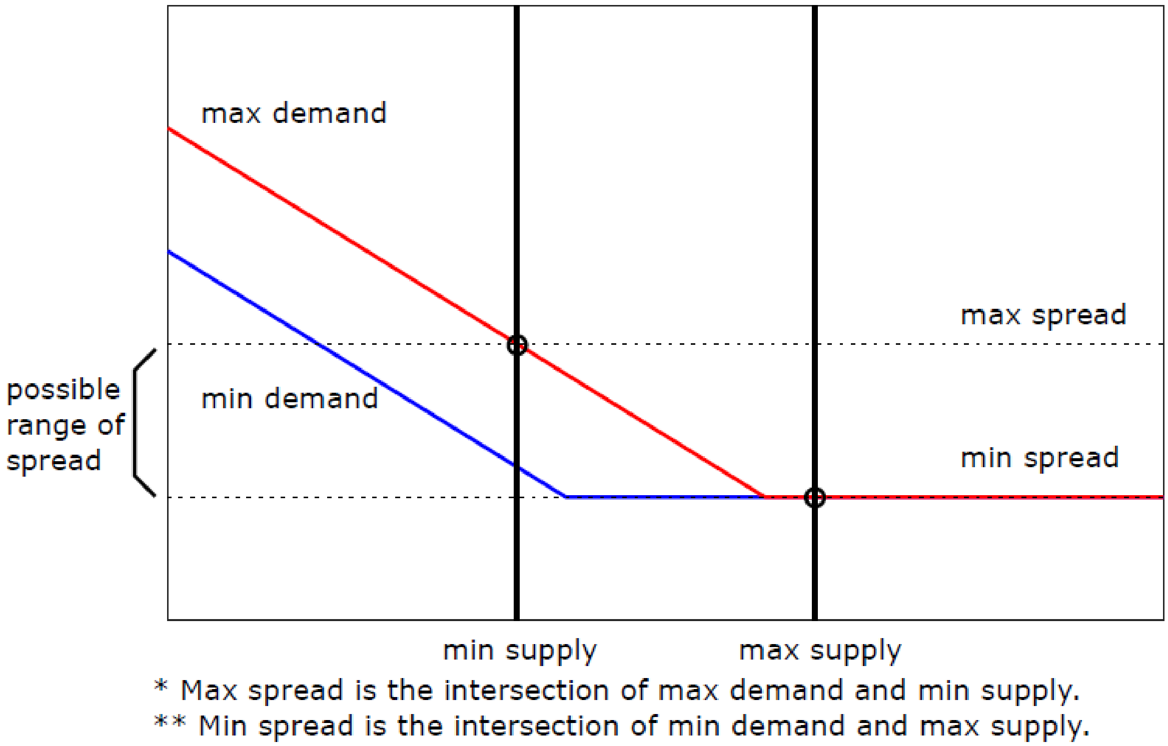


Figure 8: Possible Range of Spreads.

At the other extreme, it may not be possible to achieve tight rate control even if supply shocks are completely offset by operations because demand shocks are, by nature, unknown and cannot be offset preemptively. This will happen if

$$|spread(TARGET - \max(\delta DEMAND)) - spread(TARGET - \min(\delta DEMAND))| > TOL.$$

Given convexity, this will happen only if *TARGET* is smaller than a certain level.

Figure 9 illustrates the two limit levels of reserves. The region between the limits is our region of interest. If a central bank wanted to adopt a scarce-reserves framework with no remedy for increased volatility in supply and uncertainty in demand, it might fall into the region of 'too much rate volatility'. In contrast, if the supply of reserves is sufficiently large, a central bank would fall into the region of 'no need for operations'.

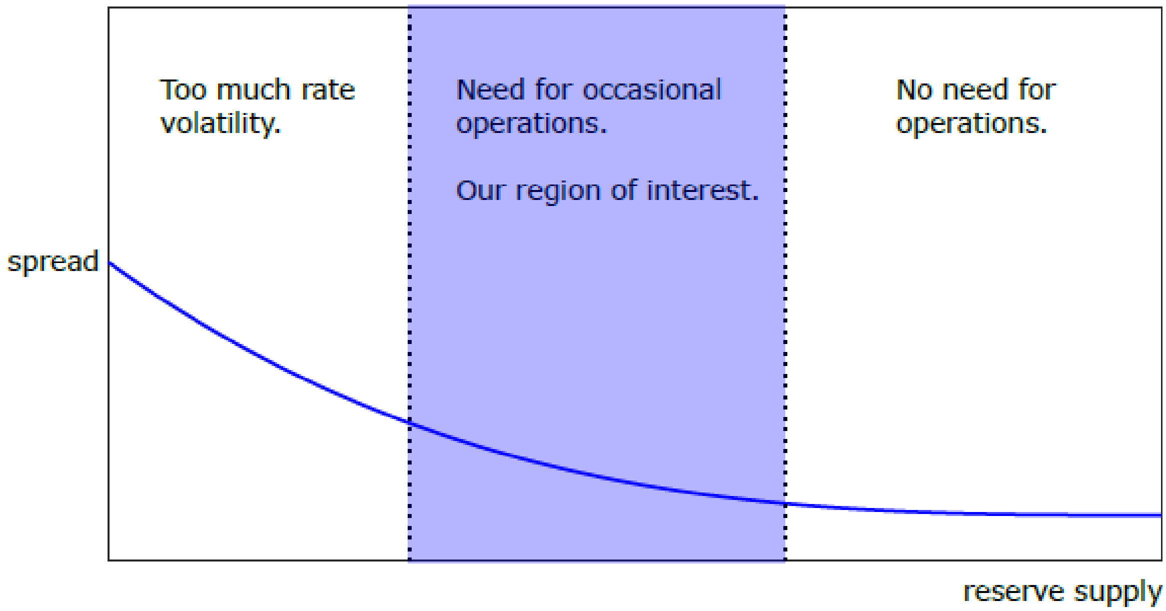


Figure 9: Illustration of the Three Regions.

Between these two limits, the policy rate can be controlled tightly but only with operations. Generally, an implementation regime can be represented by a target level of reserve supply and intervention thresholds: If the supply shock is predicted to be too small or too large, the central bank conducts operations to offset the shock.

We simplify the problem even further by considering only reserve-injecting operations: There will be an offsetting operation only if the supply shock will be below a (negative) threshold. With this constraint, there is no guarantee that the rate control objective can be achieved for relatively low levels of target reserve supply even if it is between the two limits in figure 9. Still, in practice, we believe that this simplification does not create an excessive constraint on rate implementation. Given the convexity of *spread* the central bank would generally prefer more frequent reserve-injecting operations than reserve-draining ones to reduce the frequency of operations overall. This will especially be the case if there is a relatively sharp kink in the rate curve: The rate will become much more sensitive to changes in reserve supply as it declines to cross over the kink.

We represent the cost of operations using the frequency or the probability of conducting operations. Then given a target level of reserve supply this cost is minimized, while maintaining a tight rate control, by choosing the lowest possible threshold *THRES*:

$$\begin{aligned} &spread(TARGET + THRES - \max(\delta DEMAND)) \\ &\qquad - spread(TARGET + \max(\delta SUPPLY) - \min(\delta DEMAND)) = TOL. \end{aligned}$$

Therefore

$$THRES = spread^{-1}(spread(TARGET + \max(\delta SUPPLY) - \min(\delta DEMAND)) + TOL) - TARGET + \max(\delta DEMAND).$$

Since *spread* is convex, *THRES* increases as *TARGET* decreases. Intuitively, for smaller target supply of reserves more frequent operations are necessary, as the policy rate becomes more sensitive to shocks.

This relationship is key in determining the optimal level of reserve supply. If *THRES* increases only a little as *TARGET* decreases, it will generally make sense to reduce *TARGET* further as long as there is some outside preference for smaller reserve supply. However, if *THRES* increases relatively much as *TARGET* decreases over a certain range of *TARGET*, then it will be sensible to keep *TARGET* above that range.

The rate at which *THRES* increases as *TARGET* decreases is generally determined by the rate of change in the slope of *spread*. If *TARGET* decreases by 1, both minimum and maximum reserve supply after shocks decrease by 1 as well. However if the slope of *spread* is steeper at the minimum reserve supply than at the maximum, the range of policy rate expands. Thus, *THRES* needs to increase in response to offset the expansion and maintain rate control. Quantitatively,

$$\frac{\partial THRES}{\partial TARGET} = \frac{spread'(TARGET + \max(\delta SUPPLY) - \min(\delta DEMAND))}{spread'(TARGET + THRES - \max(\delta DEMAND))} - 1.$$

A Simple Criterion for Optimal Reserve Supply

We have just showed that in determining the optimal level of reserve supply the rate of change in the slope of *spread* matters. In this section, we develop this idea further: It is important to determine whether the rate curve, or *spread*, has a relatively sharp kink, around which its slope transitions between near-zero and very steep over a narrow range of reserve supply. In such a case, the optimal reserve supply is essentially the location of the kink plus some buffer. In contrast, if the rate curve steepens gradually over a broad range of reserve supply, the optimal reserve supply becomes more sensitive to the exact shape of the preference over operation frequency and smaller reserve supply. Also, it would make sense to conduct both reserve-injecting and draining operations depending on the predicted sign of the supply shock.

A simple and effective example to illustrate the effect of a sharp kink in the rate curve is the standard model discussed earlier. As illustrated by figure 10, the rate curve in this model has a sharp distinction between scarce and abundant reserves: It has a completely flat region and a downward-sloping region with nothing in between.

For this example, we first assume that demand shocks are zero. There is a simple rule for operations: If a negative supply shock is large enough to decrease reserve supply below the value illustrated by the left vertical line in figure 10, then the central bank needs to offset the shock. Therefore the threshold for intervention increases one-to-one as the target reserve supply declines; this is the largest possible rate of increase, as can be seen from the expression for $\partial THRES/\partial TARGET$.

If the supply shock is uniformly distributed over its support then the increase in intervention probability associated with a decrease in the target reserve supply will be constant over the region between the two vertical lines in figure 10. This leads to a very simple rule for the optimal target reserve supply: If the marginal cost due to the increase in intervention frequency dominates the marginal benefit of a smaller reserve supply, the optimal point will be the upper limit of the region. This corresponds to the lowest level of reserves such that even with large negative supply shocks the reserve supply does not decrease beyond the kink. This is illustrated by figure [10].

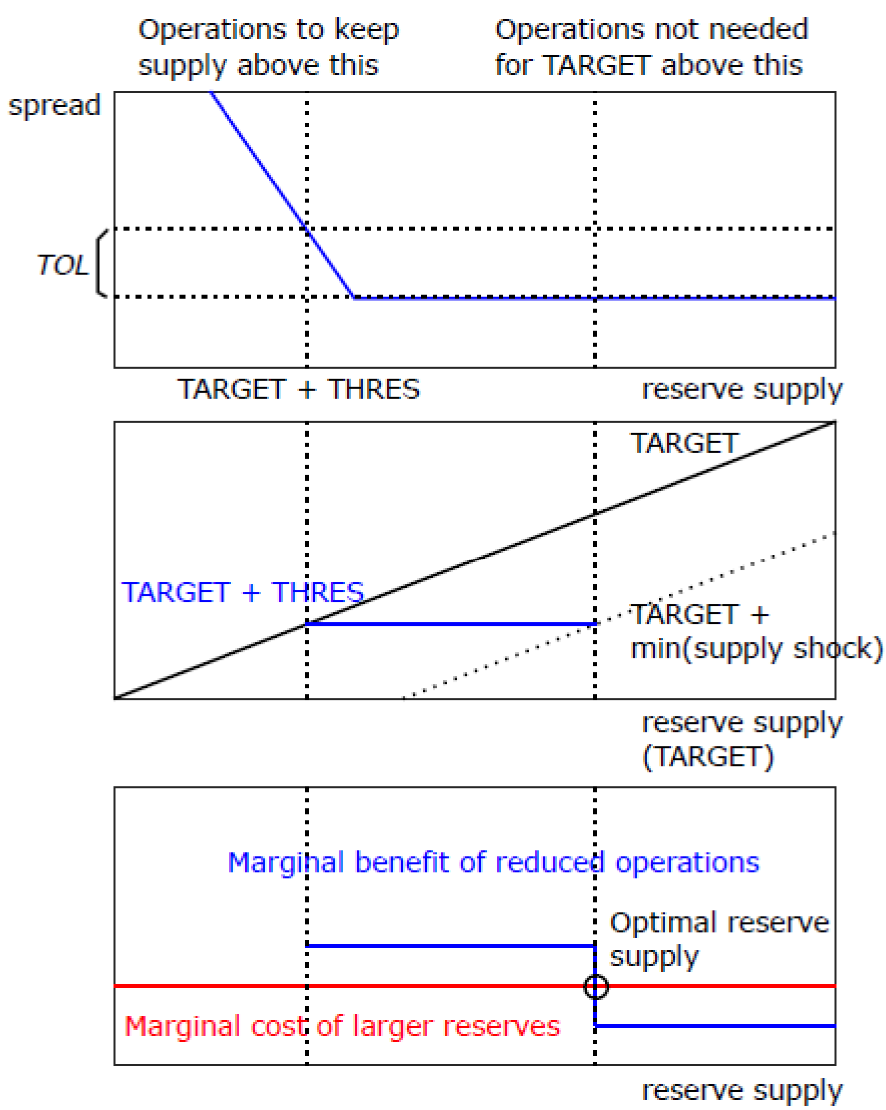


Figure 10: Implementation with a Sharp Kink.

With a less sharp change in the slope of *spread*, we expect a more gradual change in the operation threshold, as illustrated by figure [11]. In addition, the operation frequency increases at a lower and variable rate as reserve supply decreases, thus finding the optimal supply would be more sensitive to the exact form of the rate curve or *spread* and the central bank's preference. In the example given in figure [11], the rate of change in operation frequency is non-monotonic, further complicating the determination of optimal supply: If the marginal benefit of smaller reserves were relatively small the optimal reserve supply would be at the vertical line. Otherwise, the optimal supply would be smaller.

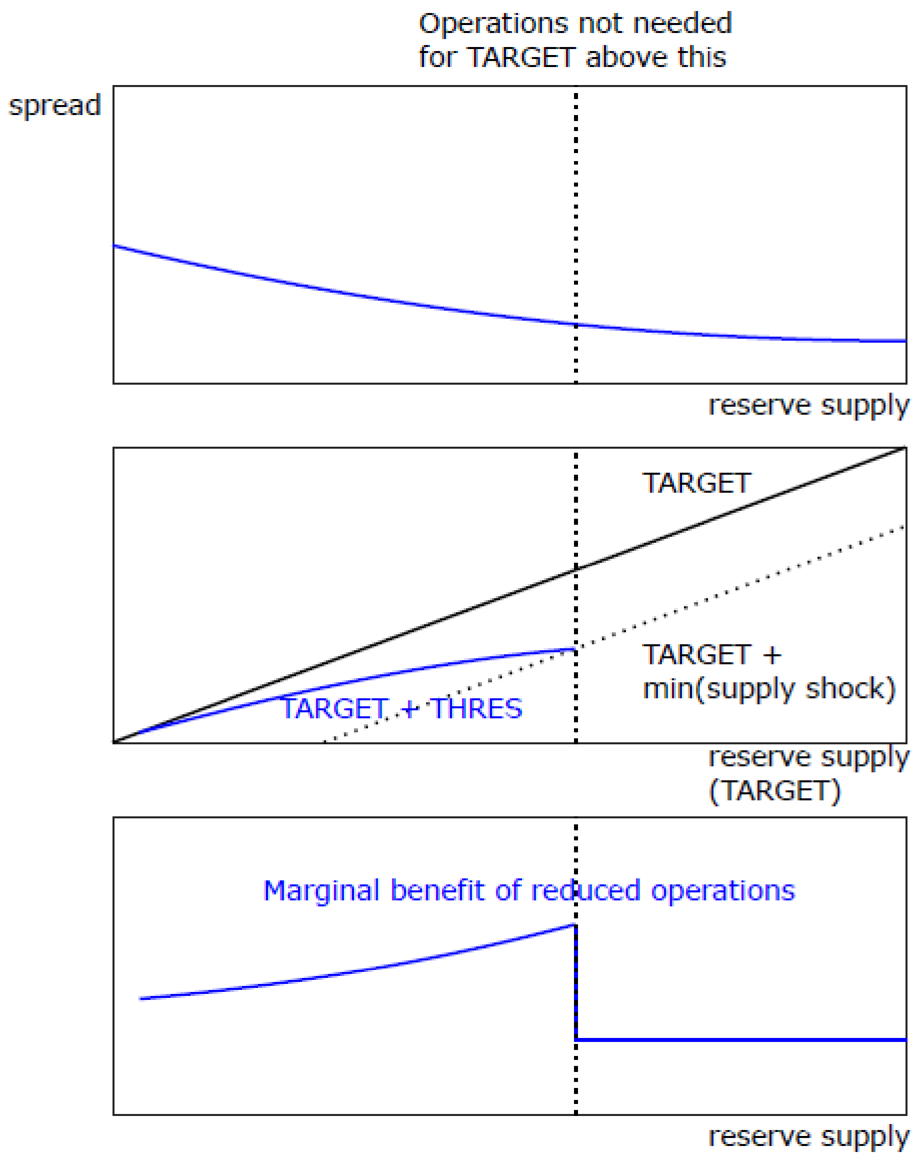


Figure 11: Implementation without a Sharp Kink.

Also with a gradual change in the slope, the rational for one-sided operations is less clear, because the difference in the slope when reserves are hit by a negative supply shock and when hit by a positive shock is small. In contrast, in the previous example with the standard model, the central bank will choose to conduct only reserve-injecting operations because reserve-draining operations are not necessary.

Taking the demand uncertainty into account in the first example, with a sharp kink, is simple. Since the demand shock cannot be offset preemptively, the buffer against the policy rate rising too high, or equivalently reserve supply net of demand shock reaching the left vertical line in figure 10, needs to increase by the size of the maximum demand shock. Similarly, the lowest target level of reserve supply for which operations are necessary increases by the same amount.

Without a sharp kink, the threshold similarly increases but not simply by the magnitude of the maximum demand shock; the minimum demand shock and the target reserve supply also matter, as the slope of *spread* changes gradually. Figure 12 illustrates the shifts in the threshold for operations, with or without a sharp kink. Because of demand uncertainty operations become necessary at larger levels of reserve supply.

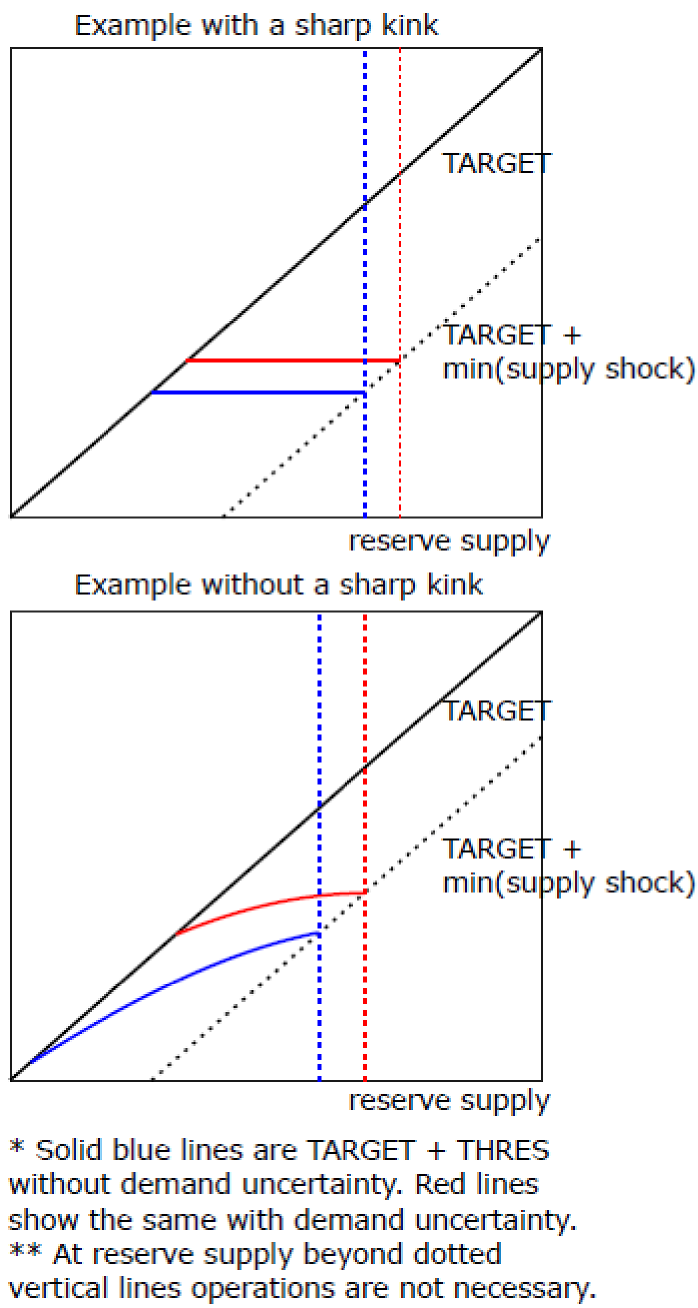


Figure 12: Implementation under Demand Uncertainty.

In practice, the shape of the rate curve is not known perfectly. This presents a problem for a central bank trying to reduce its abundant reserve supply to reach an optimal level. Other than spending more resources to learn the shape of the *spread* function better, a central bank might want to reduce reserve supply in a conservative pace. Also, it might be helpful to pay attention to market pressures on days subject to large supply and demand shocks: days with large net issuance of government securities, special days such as quarter-ends on which 'snapshots' are taken for regulatory or reporting purposes, and so on.

Financial stability is an important element of reserve supply consideration that we have mostly ignored in this section. We generally treated a central bank as having a preference for smaller reserve supply, outside the cost of policy rate volatility and open market operations. However, in practice a central bank might prefer to maintain some buffer of reserve supply above required reserves to boost financial stability. If the optimal reserve supply based on other considerations were already large enough to provide this buffer, then it would still be optimal even under added financial stability considerations. However if the optimal supply were not large enough, then the central bank might decide to provide extra reserve supply to provide a financial stability buffer. Figure [13] illustrates this.

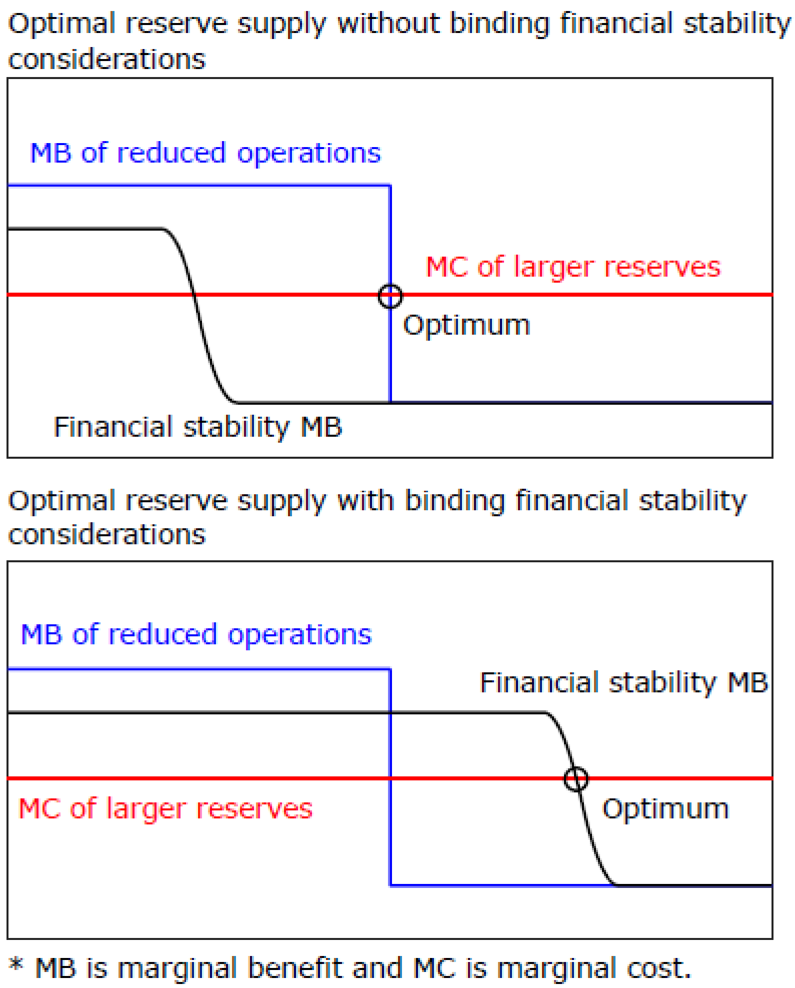


Figure 13: Financial Stability Buffer.

Effectiveness

A key consideration for a monetary policy implementation framework is its “effectiveness.” A framework is effective if it provides good control over short-term money market rates.

Policy rates

The policy rate performs two important roles in a monetary policy framework. The first role is setting and communicating the stance of policy: Typically, a central bank conveys the stance of monetary policy to the public by announcing the setting of its policy rate. The second role is policy transmission: A change in the policy rate is expected to transmit to money market rates and broader financial conditions to affect the real economy.

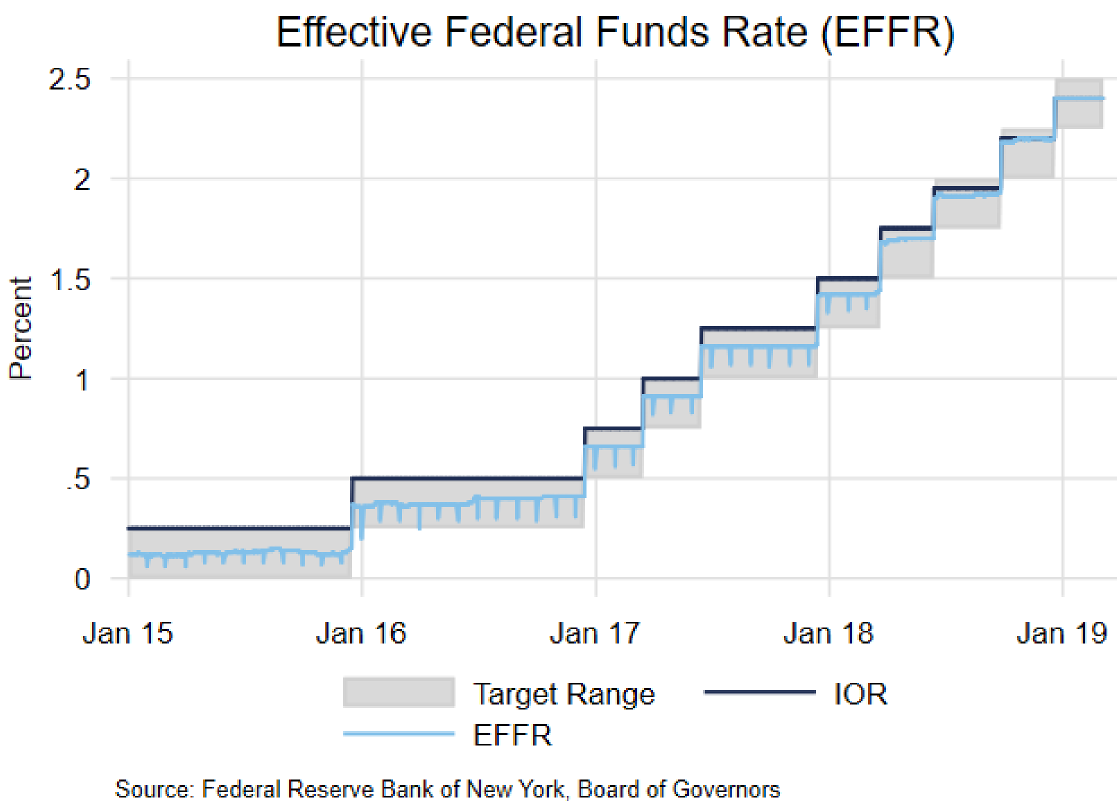
Central banks have used a variety of interest rate as policy rate, including secured and unsecured rates, as well as market determined or "administered" rates. The choice seems to depend on the specific institutional setting in different jurisdiction, as well as the liquidity of available markets. In practice, the distinction between market and administered policy rates is small, as central banks that choose an administered policy rate usually also refer to a market rate, either explicitly or implicitly.

Most central banks, regardless of their choice of policy rate, have reasonable control over short-term rates and changes in the stance of policy are generally transmitted effectively to longer-term interest rates and overall financial conditions, allowing monetary policy to influence activity in the real economy.

Measurement of effectiveness

Duffie and Krishnamurthy (2016) create an index intended to capture rate dispersion across different segments of money markets. They consider the volume-weighted average absolute deviation from the volume-weighted average rate, which captures how much each market rate deviates from the average rate across markets. To implement the index, Duffie and Krishnamurthy adjust rates for term and credit spreads, and weight each instrument's influence by its outstanding amount. This index is designed to equal zero in a world without any frictions, where all rates yield the same adjusted return, and to be constant in a world with perfect pass-through, where all rates move in lockstep. Afonso, Biesenbach, and Eisenbach (2017) show that the implementation framework used by the Federal Reserve post crisis as achieved good pass-through.

Potter (2018) discusses a number of measures of effective control of rates. Specifically, he notes that the effective federal funds rate, the Federal Reserve's current policy rate has remained within the FOMC's target range during the post crisis period, as shown in figure 14.



Source: Federal Reserve Bank of New York, Board of Governors.

Figure 14: Effective Federal Funds Rate

Increases in the target range for the federal funds rate passed through fully and immediately to the other rates, as seen in figure 15. The figure also shows that other money market interest rates have remained close to the effective federal funds rate. Another relevant measure is the low dispersion between various unsecured and secured overnight rates as another metric that could reflect the efficacy of policy pass-through.

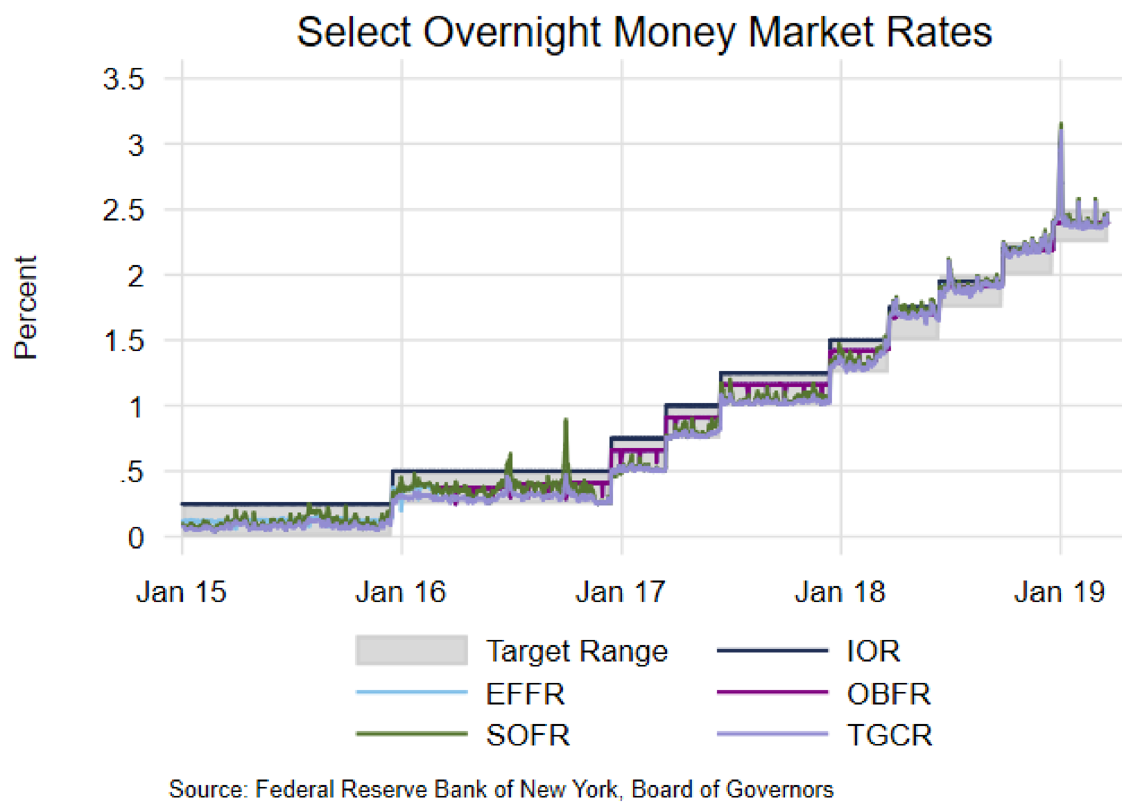


Figure 15: Overnight Money Market Rates

Technical adjustments

A particularly interesting way to look at the effectiveness of the Federal Reserve's current implementation framework is to consider the effect of the "technical adjustments" on various money market rates. During the second half of 2018, a number of money market rates increased relative to IOER. At least two factors are believed to have contributed to this increase, one is the decrease in the supply of reserves and the other is a large increase in Treasury issuance (see Lee 2019 and Schulhofer-Wohl and Clouse 2018). This led to a decision by the FOMC to increase the IOER by less than the increase in the policy range on two occasions, following the June and the December 2018 meetings. In each case, the target range for the federal funds rate was increased by 25 basis points and the level of the IOER was increased by only 20 basis points. The purpose of the technical adjustment was to keep the effective federal funds rate well within the target range. Figure 16 zooms in around the June and December technical adjustments and shows that short-term money markets rose by about 20 basis points following the technical adjustments, consistent with an effective framework.

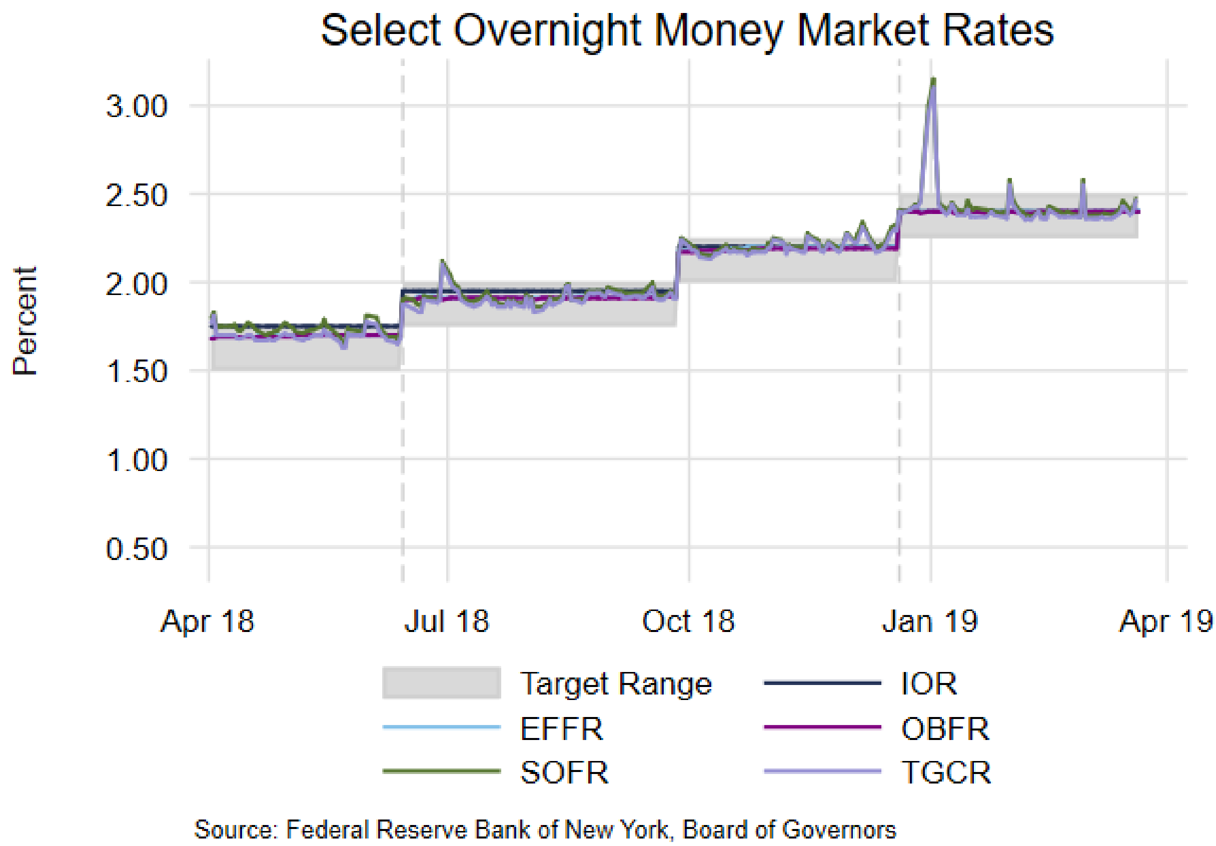


Figure 16: Technical Adjustments and Overnight Money Market Rates

Financial stability benefit of a framework with an ample supply of reserves

Facilitating liquidity provision to markets

In a framework that relies on reserve scarcity, such as the one used by the Fed pre-crisis, there can be a tension between maintaining interest rate control and providing liquidity to markets. In this section, we illustrate that potential tension using data about the Fed's liquidity injections during the crisis.

Figure 17 shows the level of the federal funds rate target from January 1, 2007, to December 15, 2008. The target rate was at 5.25% until September 2007. On December 12, 2007, when the term auction facility (TAF) was announced, the target was still at 4.25%.[16] On the eve of the bankruptcy of Lehman Brothers, the target rate was 2%. This meant that throughout this period, maintaining control of the policy rate required sterilizing reserve injections.

[16] See Armantier, Krieger and McAndrews (2008) for an overview of the TAF.

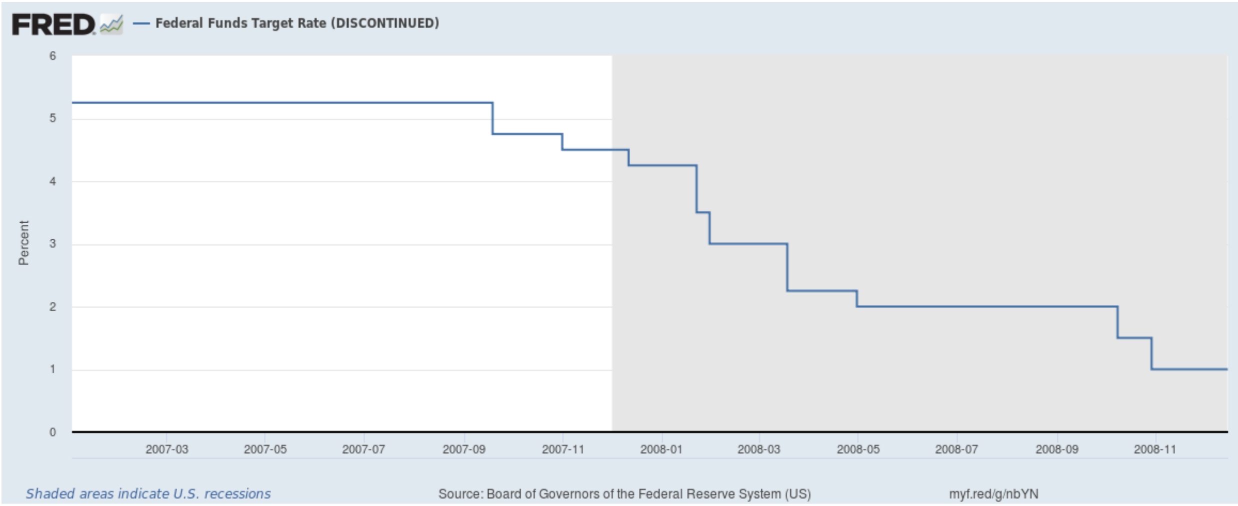


Figure 17: Federal Funds Rate Target

Figure 18 shows several Fed lending operations between January 1, 2007, and September 12, 2008, the Friday before the bankruptcy of Lehman Brothers. The two largest sources of liquidity to the market were the term securities-lending facility (TSLF) and the TAF.[17]

The Term Securities Lending Facility (TSLF) was a weekly loan facility that promoted liquidity in Treasury and other collateral markets and thus fostered the functioning of financial markets more generally. The program offered Treasury securities held by the System Open Market Account (SOMA) for loan over a one-month term against other program-eligible general collateral.[18] One benefit of the TSLF is that it does not affect the supply of reserve and, thus, does not need to be sterilized.

The TAF auctioned 28-day loans, and, beginning in August 2008, 84-day loans, to depository institutions in generally sound financial condition. The TAF was introduced because bank funding markets, especially term funding markets, came under severe pressure at the start of the financial crisis in 2007. The TAF was useful, in part, because many banks were reluctant to borrow at the discount window out of fear that their borrowing would become known and would be erroneously taken as a sign of financial weakness. A number of design features of the TAF were specifically aimed at reducing banks' reluctance to borrow.

[17] For more detail about the primary dealer credit facility (PDCF), see Adrian, Burke, and McAndrews (2009). More details about the discount window can be found at this link: https://www.federalreserve.gov/regreform/discount-window.htm.

[18] See Fleming, Hrung, and Keane (2009) for an overview of the TSLF.

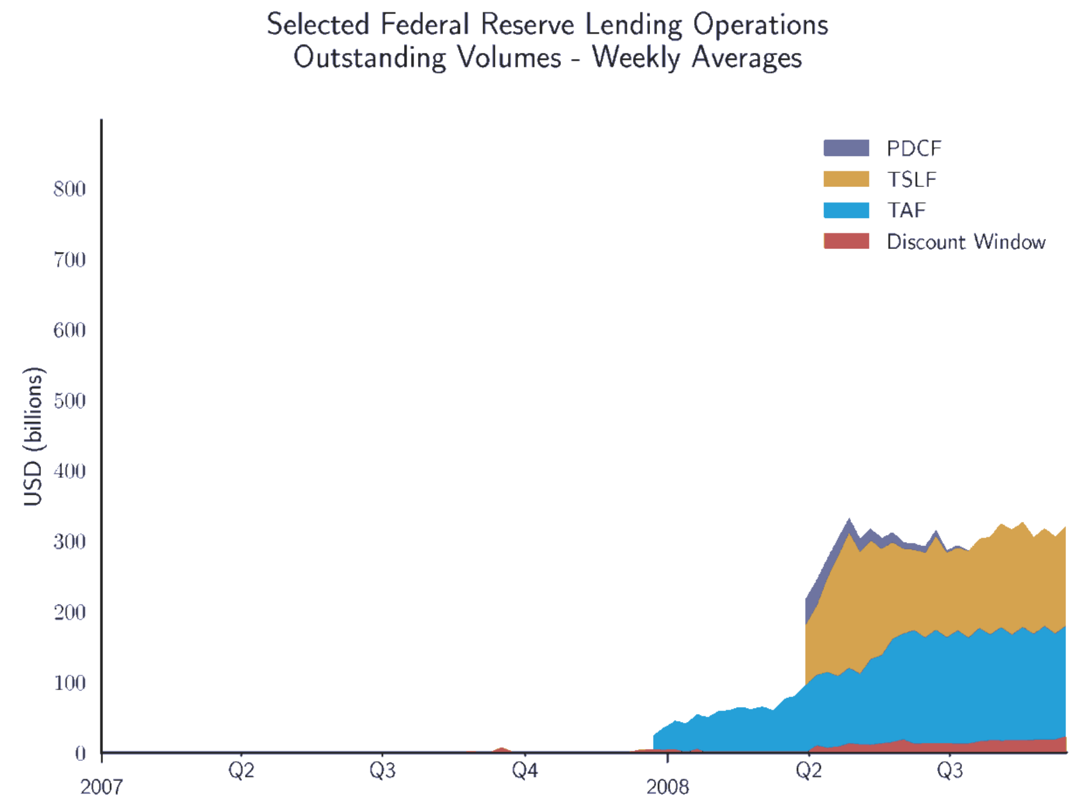


Figure 18: Federal Reserve Lending Operations

TAF loans increase the amount of reserves held by banks. Everything else equal, every dollar of TAF loans increases the supply of reserves by a dollar. To sterilize these reserve injections, and maintain interest rate control, the Fed would let Treasury securities from its portfolio mature, instead of rolling them over.[19] This can be seen in Figure 19, which represents the asset side of the Fed's balance sheet between January 1, 2007, and September 12, 2008, the Friday before the bankruptcy of Lehman Brothers.

Before the crisis, the System Open Market Account (SOMA) was composed primarily of Treasury securities. The SOMA held a significant share of Treasury securities with a short time to maturity that could be allowed to roll-off if it became necessary to sterilize reserve injection. The decrease in the stock of Treasuries in the SOMA in Figure 19 corresponds to increase in TAF loans. By the end of Q2 2018, the SOMA had run out of maturing Treasury securities, making further sterilization of TAF loans impossible. This put an effective cap on the size if the TAF, as

[19] Leonard, Martin, and Potter (2017) explain how rolling over securities, or not doing so, affects the Fed's balance sheet.

can be seen in Figure 18.[20] This provides evidence that the need to maintain interest rate control could have put a limit on the Fed's ability to provide markets with more liquidity.

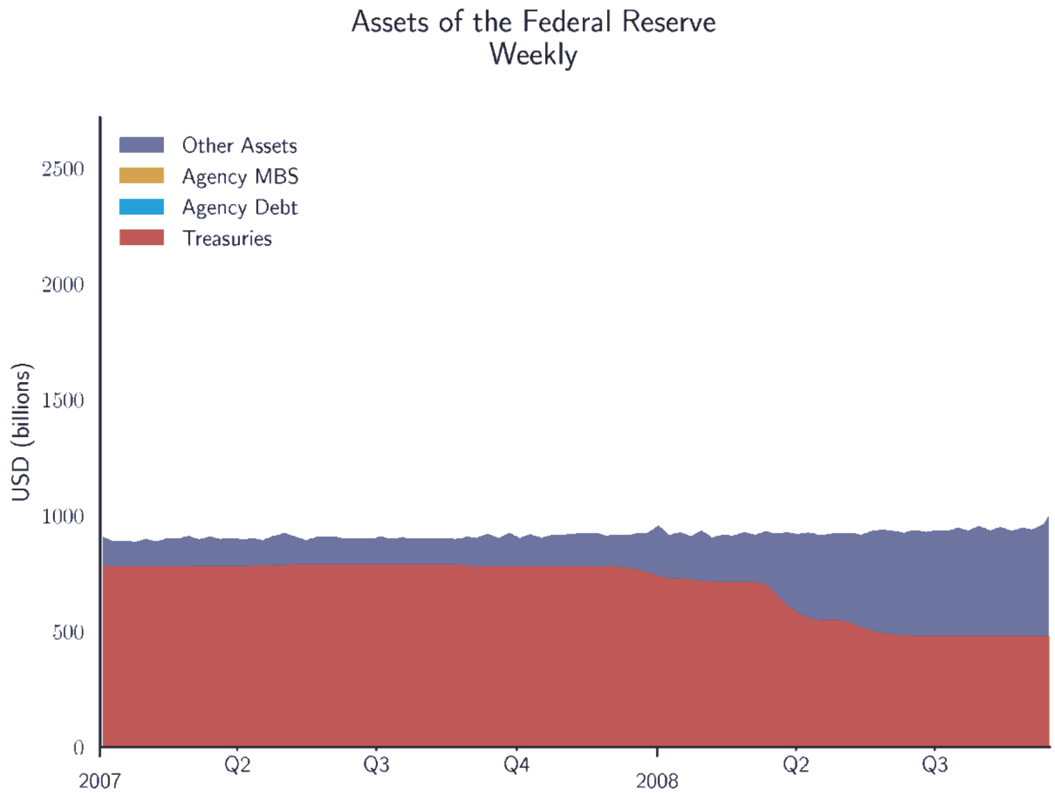


Figure 19: Federal Reserve Assets

Further evidence is provided by considering the Fed's liquidity provision after the Lehman bankruptcy. On October 1, 2008, a couple of weeks after the bankruptcy of Lehman Brothers, the Fed received from Congress the authority to pay interest on reserves. With this new authority, reserve scarcity was no longer necessary to maintain interest rate control and the Fed was able increase its supply of liquidity to markets considerably. Figure 20 extends Figure 18 and shows the Fed's lending operations between January 1, 2007, and December 31, 2010. The figure illustrates the striking increase in the amount of liquidity the Fed is injecting in financial markets, in particular in the amount of TAF lending.

By operating a monetary policy implementation regime in which control over the level of the federal funds rate and other short-term interest rates is exercised primarily through the setting of the Federal Reserve's administered rates, the Fed doesn't have to face a trade-off between

[20] In principle, the Fed could have sterilized reserve injections by selling Treasury securities. However, this option may not have been perceived as particularly attractive since financial markets were under stress.

interest rate control and liquidity provision to market during times of stress. This means that the Fed can respond more effectively to financial market stress and limit the impact of such stress on the broader economy.

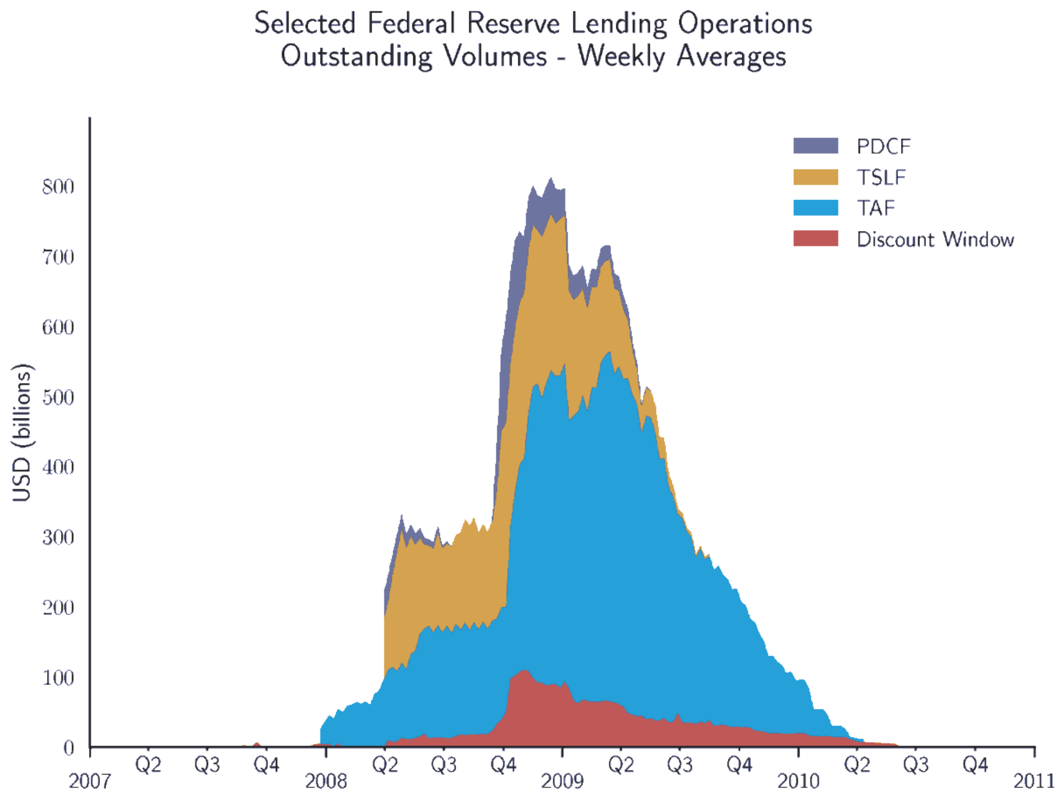


Figure 20: Federal Reserve Lending Operations

Supporting the banking system's need during times of stress

While the previous section emphasized a central bank's ability to provide liquidity to markets without sacrificing interest rate control, another benefit of a system with ample reserves is that banks are better prepared to respond to financial stress, should it occur, reducing the need for central bank intervention in the first place.[21]

One of the responses to the 2007-2009 financial crisis was the introduction of liquidity regulation as part of the Basel III reforms, including the liquidity coverage ratio (LCR). The LCR requires banks to hold sufficient high-quality liquid assets (HQLA) to meet net cash outflows over a thirty-day stress period. In the United States, HQLA include reserve balances held in a Federal Reserve account and Treasury securities, as well as some other assets. In addition to

[21] This section draws heavily from Bush et al. (2019).

liquidity regulation, banks conduct internal liquidity stress test to evaluate their liquidity needs in times of stress.

In thinking about their HQLA buffers, banks need to consider how much reserve they hold and how quickly they would be able to “monetize” securities; that is, turn them into cash. While assets are considered HQLA in part because they should be reasonably easy to monetize at any time of the day, rapidly turning very large quantities of assets—even Treasury securities—into cash could be challenging. One problem is operational, as it might be difficult to find counterparties willing to purchase or repo unusually large quantities of assets on the same day an outflow occurs. Another issue is that potential counterparties may perceive an attempt to monetize a large quantity of assets as a signal of stress and, in response, hold on to their cash in case they need it later. Or they might bargain aggressively if they believe that the bank is desperate to sell, causing banks to accept extremely low prices. In turn, these fire-sale prices could spill over to the broader financial system by causing the price of related securities to crash as well. In contrast, reserves, because they are already cash, don’t need to be monetized. So reserves are particularly useful to meet sudden outflows.

To get a sense of the potential size of bank outflows in a stress event, Bush et al. (2019) examined publicly disclosed LCR data for the very largest domestic banks—the eight that are currently in the Large Institution Supervision Coordinating Committee’s (LISCC) portfolio. Based on some assumptions, they are able to compute an estimate of the net outflows of these banks for a period of one business day. A one-day horizon is particularly interesting because this is the timeframe over which it might be most difficult to liquidate large amounts of Treasury securities under a stress scenario. Table 1 summarizes the results of their analysis for three scenarios.

Day 1 Stressed Outflows (Millions of U.S. Dollars)			
	Baseline Scenario	Reduced Outflows Scenario	Enhanced Outflows Scenario
Bank of America	136,548	101,447	163,244
Bank of New York Mellon	61,913	44,624	72,037
Citigroup	158,417	117,570	187,884
Goldman Sachs	61,457	45,245	77,195
JPMorgan Chase	175,925	134,660	207,645
Morgan Stanley	53,842	39,510	67,697
State Street	37,218	28,158	43,665
Wells Fargo	98,735	76,055	114,585
Total	**784,054**	**587,269**	**933,951**

Source: Banks' public 2018:Q2 LCR disclosures.

Table 1: Day 1 Stressed Outflows of LISCC firms

Under all three scenarios, the aggregate potential outflow from domestic LISCC banks are very large, representing several hundred billions of dollars. The potential outflows of individual banks are large as well, typically tens of billions of dollars and, in a few instances, in excess of a hundred billion. Liquidating securities to meet such large outflows would likely be very difficult and could have severe negative consequences for the bank attempting to do it.

The amount of reserves available to the banking sector is primarily a choice of the Fed (see Keister and McAndrews 2009). Banks can redistribute reserves among themselves, but they have very limited ability to change the total amount of reserves in the system. Thus, only the Fed can ensure that the supply of reserves is sufficient for banks to meet their day 1 outflows. As of Feb 2019, the supply of reserves is approximately $1.7 trillion, more than enough to meet banks' needs. However, before the crisis of 2007-08, the total amount of reserves in the U.S. banking system was quite small, for example, under $50 billion in 2006.

A monetary policy implementation regime with an ample supply of reserves allows the central bank to make sure that the banking system has enough reserves for banks to meet their day 1 outflow during a time of stress. This makes the financial system safer and can reduce the need for banks to borrow from the central bank.[22]

An ample supply of reserves increases the supply of money-like assets to the financial system

A literature, which has developed since the 2007-2009 financial crisis, argues that short-term safe assets, or “money-like” assets, are particularly attractive to some investors and, for that reason, carry a premium that reduces their yield (see Carlson et al. (2016) and the references therein). When the supply of money-like asset is too small, private sector participants have an incentive to issue liabilities that have money-like properties because of their low cost. This can result in excessive maturity transformation, which makes the financial system more fragile.

Official sector liabilities, such as Treasury bills or reserves have money-like properties and Carlson et al. (2016) provide evidence of substitution between money-like assets issued by the public and the private sector. When the supply of publicly issued money-like assets increases, the premium enjoyed by all such assets decreases, dampening the incentive of private sector institutions to engage in excessive maturity transformation. Since the official sector is less likely to be subject to runs or panics than private sector entities, a greater supply of publicly issued money-like assets could contribute to financial stability.

It is important to recognize that, in addition to the aggregate supply of money-like assets, its composition might also matter. Reserves can only be held in a Fed account and most non-bank financial institutions cannot have such an account. Once the supply of reserves has increased enough to satiate banks’ demand for money-like assets, there is little benefit to be gained from increasing the supply of reserves, even if some non-banks would like more money-like assets. In contrast, Treasury bills can be held by anyone, making them particularly useful in meeting the demand for money-like assets of non-banks.

On its own, an ample supply of reserves may not be able to satisfy the demand for aggregate demand for money-like assets. Nevertheless, one benefit of a monetary policy implementation framework with an ample supply of reserves is that it can contribute to satiating that demand.

Conclusion

[TBA]

[22] An alternative would be for the central bank to offer a liquidity facility to “monetize” Treasury securities and, perhaps, other HQLAs. See Andolfatto and Ihrig (2019), for example. Such an alternative would only be effective if the liquidity facility does not suffer from stigma.

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