

Garratt, Rod; Martin, Antoine; McAndrews, James Joseph; Nosal, Ed

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Federal Reserve Bank of New York
Staff Reports

Segregated Balance Accounts

Rodney Garratt
Antoine Martin
James McAndrews
Ed Nosal

Staff Report No. 730
May 2015



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Abstract

This paper describes segregated balance accounts (SBAs), a concept for a new type of account that could provide increased competition for deposits, reduce system-wide balance sheet costs, and improve the transmission of monetary policy by facilitating greater pass-through of interest on excess reserves (IOER). SBAs are designed to remove credit risk by creating narrow accounts that could allow any bank to compete for money market funds. Because of increased competition, the rates paid on borrowings secured by SBAs, along with other money market rates, would likely be pushed up closer to the IOER rate and would be more tightly linked to that rate. SBAs could promote a more efficient allocation of reserves within the banking sector by shifting reserves from banks with high balance sheet costs to banks with low balance sheet costs. SBAs would not require setting an additional administered rate; IOER would be paid on the balances held in an SBA and the rate paid on the loan secured by the balances in the SBA would be competitively determined. We discuss a number of potential risks that SBAs could pose as well as further steps that would be required before SBAs could be implemented.

Key words: central bank, interest rate

Garratt, Martin, McAndrews: Federal Reserve Bank of New York (e-mail: rodney.garratt@ny.frb.org, antoine.martin@ny.frb.org, jamie.mcandrews@ny.frb.org). Nosal: Federal Reserve Bank of Chicago (e-mail: ed.nosal@chi.frb.org). The authors thank colleagues at the Federal Reserve Bank of New York and the Federal Reserve Bank of Chicago, and the staff of the Board of Governors of the Federal Reserve System. The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Federal Reserve Banks of New York or Chicago or the Federal Reserve System.

1 Introduction

This paper introduces the concept for a new monetary policy tool, segregated balance accounts (SBAs), that could improve competition in money markets and strengthen the floor on overnight interest rates that is created by the payment of interest on excess reserves (IOER). In what follows, we explain how SBAs work, their advantages and potential risks.

SBAs are accounts that a bank or depository institution (DI) could establish at its Federal Reserve Bank using funds borrowed from a lender.¹ What distinguishes an SBA from the bank's Master Account at its Federal Reserve Bank is that the funds deposited in an SBA would be fully segregated from the other assets of the bank and, in particular, from the bank's Master Account. In addition, only the lender of the funds could initiate a transfer out of an SBA; consequently, the borrowing bank could not use the reserves that fund an SBA for any purpose other than paying back the lender. Because of these (and other) conditions, the loan made by the lender to the bank would be collateralized by the reserve balances in the SBA account. The bank receives the IOER rate for all balances held in an SBA. The interest rate that the bank pays the lender of the funds deposited in an SBA would be negotiated between the bank and the lender.

Since funds deposited in SBAs are set aside as collateral and cannot be used by the account holder for its own purposes, the funds would be available to the lender in the event that the account holder goes bankrupt, subject to a stay that would be imposed by the Federal Deposit Insurance Act (FDI Act).² Thus, SBAs could provide banks with a vehicle to borrow funds that is almost free of credit risk.³ The near elimination of credit risk, which is the hallmark of SBAs, would level the playing field so that all banks could borrow in the overnight money market on equal footing. This would increase competition in the market for unsecured funds, and bank

¹While SBA accounts could in principle be used in any jurisdiction, we focus on their potential application in the U.S. context. Appendix A provides a detailed description of the mechanics of SBAs as applied in this context. For purposes of this paper, a DI that establishes SBAs is assumed to be insured by the Federal Deposit Insurance Corporation (FDIC).

²Under the FDI Act, and subject to certain exceptions that are not applicable here, creditors of a DI that is in FDIC receivership are prohibited from exercising their right or power to terminate, accelerate, or declare a default under any contract with the DI, or to obtain possession or control of any property of the DI, without the consent of the receiver during the 90-day period beginning on the date of the appointment of the receiver. For purposes of this paper, it is assumed that the FDIC would act quickly to permit lenders to gain access to SBAs that collateralize their loans. However, this treatment has not been approved by the FDIC, and the decision by the FDIC on treatment of an SBA account in resolution could affect the willingness of firms to participate in these accounts. There are a number of other legal and regulatory issues that would have to be resolved to make SBAs a viable tool.

³Since the IOER paid on SBAs by the Federal Reserve would likely be deposited in the bank's Master Account, the bank's interest payment obligation on funds borrowed through SBAs would be subject to credit risk, but not the principal of the loan. For that reason, we consider SBAs as being almost free of credit risk.

deposits in general, and would lessen the discount at which large banks can currently attract deposits. Our analysis suggests that SBAs could result in a more favorable distribution of reserves across the banking system, which would reduce aggregate balance sheet costs. As we discuss below, competitive frictions in overnight money markets and banks' balance sheet costs are the two key impediments to arbitrage that prevent the IOER rate from being fully passed on to the non-bank sector and, thus, from forming a floor for overnight rates. SBAs could facilitate a more complete pass through of the IOER rate to the non-bank sector and, as a result, overnight unsecured money market rates would be closer to or even above the IOER rate.

The problem of the imperfect pass through of the IOER rate to other overnight rates can be addressed by other policy tools. The Federal Reserve has used a daily overnight reverse repo (ON RRP) operation and, most recently, a term reverse repo (term RRP) operation to address this problem.⁴ Experience to date suggests that RRP operations have been effective in helping to eliminate low-rate transactions in many overnight money markets. SBAs and ON RRP operations could be complementary tools to help firm the floor on money market rates. Nevertheless, there are important differences between the two approaches. SBAs would almost completely eliminate the credit risk that prevents lenders from interacting with some borrowers and, hence, directly address the issue of competitive frictions. ON RRP operations, on the other hand, affect the competitive frictions in the deposit market only indirectly, by improving the bargaining power of some lenders, as the central bank enters the market as a potential borrower.

As is the case with any policy tool, there are a number of uncertainties and concerns surrounding usage of SBAs. One concern is that SBA take-up could be too large. During normal (non-stress) times, market rates will adjust to determine an equilibrium level for SBA balances. However, in times of intense stress, which may be characterized by a flight to quality, flows into SBAs could produce a scarcity of reserves that banks use to meet reserve requirements and could also cause (temporary) dislocations in funding markets for nonbank entities. The scarcity of reserves, however, would trigger an increase in the federal funds rate. As a result, the spread between the federal funds rate and the competitively determined SBA rate—which is tightly linked to the fixed IOER rate through competitive forces—would increase and would help arrest the surge.⁵ In addition, the negotiated terms of SBAs could specify upper limits on balances and, hence, the size of the surge in SBAs would be limited by the amount of capacity banks had in existing SBAs.

SBAs may not have the same moral hazard problems that are associated with deposit insurance because banks could not use or access the funds in SBAs. The

⁴The term RRP has used at quarter-end dates since December 31 2014 to address distortions in the overnight market caused by banks' desire to reduce balance sheet space allocated to short-term borrowing on those dates.

⁵The mechanism is similar to what we observed during a flight into Treasury securities during the crisis. Their yields were depressed, thus reducing the incentives to buy them.

protection afforded funds in SBAs could not be transferred to other bank operations and, as a result, would not induce excessive risk taking by banks. SBAs can be interpreted as narrow bank accounts that deliver the main advantages associated with narrow banks with few, if any, of the disadvantages.

Our discussion of how SBAs could be used to help control money market rates fits broadly into the existing literature on monetary policy implementation, IOER, and reserves. The literature on monetary policy implementation began with Poole (1970). More recently, the Poole model has been used to think about monetary policy implementation with IOER and a large supply of reserves. Ennis and Keister (2008) provide a general framework for understanding monetary policy implementation with IOER. They show that IOER can help implement a floor on market rates and allows the Federal Reserve to manage interest rates when markets are competitive. Bech and Klee (2011) analyze the federal funds market in the presence of excess reserves in a noncompetitive environment. They argue that since government-sponsored enterprises (GSEs) do not have access to IOER, they have lower bargaining power and trade at rates lower than IOER, thus resulting in the observed IOER-federal funds effective rate spread. Martin, McAndrews, Palida, and Skeie (2014) develop a general equilibrium model to study how the Federal Reserve can use its tools to manage short-term interest rates and the large level of reserves on its balance sheet. That model extends Martin, McAndrews, and Skeie (2013) and considers how different monetary policy tools, such as a term deposit facility (TDF) and RRP, can help control interest rates in the face of balance sheet costs. Clouse, Ihrig, Klee and Chen (2014) study a similar question in a “preferred habitat” model. Kashyap and Stein (2012) show that, with both IOER and reserve quantity control, the central bank can simultaneously maintain price stability and address externalities resulting from excessive bank short-term debt issuance. Our model has a similar market structure to Bech and Klee (2011). We have bank to bank and GSE to bank market interactions, but the assumptions on how actors interact within these markets are different. In our model, the former market is competitive while the latter is noncompetitive.

2 IOER and Alternative Policy Tools

The Federal Reserve responded to the 2007-09 financial crisis and its aftermath with a variety of monetary policy measures that dramatically increased the supply of reserves. This contributed to the federal funds rate, and other overnight money market interest rates, being substantially lower than in the past. In October 2008, the Federal Reserve began paying IOER to banks. It was expected that the IOER rate would create a floor for overnight (unsecured) rates since banks would not be willing to lend at a rate below IOER. This did not happen and overnight rates remained significantly below the IOER rate. One reason is that many money market lenders do not have direct access to IOER. Nevertheless, absent frictions, banks would be expected to compete for funds and bid up rates until those rates become very close

to the IOER rate.

Balance sheet costs and imperfect competition are potential frictions that have been suggested to explain the large spread between money market rates and the IOER rate. The friction we emphasize in this paper is that the set of bank counterparties which key lenders are comfortable lending to is too small to absorb their funds. In particular, money market lenders are concerned about the default of their counterparties.⁶ Since lenders restrict the number of borrowing counterparties they are willing to deal with, and because balance sheet considerations prevent the institutions they do trust from engaging in unlimited IOER arbitrage, borrowers end-up having some bargaining power. Consequently, borrowers are able to impose low borrowing rates on the lenders while earning the IOER rate on the reserves associated with the amount they borrow.

In June of 2011, the FOMC announced the creation of two new tools—term RRP and a TDF—aimed at managing short-term market interest rates and keeping them close to the IOER rate. These tools could provide support for overnight rates by draining reserves from the balance sheets of banks. However, to be effective the amount of reserves drained from the banking system would need to be rather significant.

In August 2013, the FOMC announced that an overnight ON RRP facility could be used as another potential tool. The ON RRP facility addresses the competitive frictions that limit the pass through of the IOER rate to other overnight market rates by allowing a set of non-banks to lend directly to the Federal Reserve at a fixed rate on an overnight basis.⁷ The ON RRP facility has been effective in creating a soft floor for money market interest rates. That said, if the spread between the IOER rate and the ON RRP rate is kept wide, then the spread between many overnight market rates and the IOER rate will remain wide.

SBAs could complement the set of tools already available and help make these tools more effective.

3 Federal Funds Market

To understand the channels through which SBAs could improve the pass through of the IOER rate to other overnight rates, we focus our discussion and analysis on a particular overnight rate, the federal funds rate. Nevertheless, many of our results can be interpreted broadly and apply to money markets more generally. The federal funds market is a market for (typically) overnight loans between banks and other institutions, such as GSEs, that maintain reserves at the Federal Reserve.

⁶Money market lenders may also be concerned about the willingness or ability of their counterparties to borrow on a consistent basis. Since monitoring borrowers is costly, lenders are likely to only undertake such costs if they expect to be able to lend on a regular basis.

⁷Strictly speaking, the ON RRP is an auction and the resulting interest rate from the auction could be lower than the offering rate if the quantity of bids exceeded the ON RRP cap. In practice, the cap did bind only once, on a quarter-end date, and is generally not expected to bind.

One can think of the federal funds market as consisting of two sub-markets: an interbank market, in which DIs trade with one another, and an IOER arbitrage market, in which GSEs lend to DIs. Following the naming convention of Bech and Klee (2011), we refer to the first market as b2b and the second market as g2b. Because the g2b market consists of non-banks—that are ineligible for IOER—lending to banks overnight, it can be thought of more generally as a market for large overnight deposits.

Participants in the b2b market are DIs that have reserve requirements and earn IOER. Participants in the g2b market are the DIs (or a subset of them) and GSEs. Since the biggest current lenders in the federal funds market are Federal Home Loan Banks (FHLBs), we model lending behavior in the g2b market after FHLBs.⁸ FHLBs are not subject to reserve requirements and do not earn IOER on their deposits at the Federal Reserve. The demand for reserves by DIs stems from their need to meet reserve requirements and their ability to earn IOER on any excess reserves they acquire. Although FHLBs do not have reserve requirements, they do need to maintain a non-negative balance at the Federal Reserve for business purposes. FHLBs can also lend to the ON RRP facility (up to their counterparty cap) and this implies that they should have an infinite demand for reserves at rates below the ON RRP rate.

The supply of total reserves—reserves held by DIs and GSEs—is determined by the size of the Federal Reserve’s balance sheet. However, not all reserves are necessarily available in the b2b market. Reserves that lenders in the g2b market hold on to (i.e., do not lend to DIs) are not part of the supply of reserves in the b2b market.

In the model, the g2b market meets first. Each lender in the g2b market lends to a select group of banks that it is able to monitor and this market is noncompetitive, (details are provided below). The outcome of trade in the g2b market determines the aggregate supply of bank reserves in the b2b market. That is, the amount of reserves that lenders lend to DIs in the g2b market becomes part of the DIs’ aggregate reserve holdings, and this determines the relevant aggregate supply of reserves for the b2b market.

The federal funds rate is a weighted average of rates negotiated in the g2b market and the b2b market. Currently, most federal funds trades occur in the former market.⁹

3.1 The b2b Market

We adapt the simple model of the market for reserves found in Ennis and Keister (2008) to understand interest rate determination in the b2b market. In the model, the Federal Reserve determines the supply of reserves by undertaking open market operations. If the Federal Reserve purchases assets on the open market, then the supply of reserves will increase; if they sell assets from their portfolio, then reserves

⁸More broadly, they could represent any set of large money market lenders, noting that these other money market lenders do not have Federal Reserve accounts and, therefore, do not have access to IOER.

⁹See Afonso, Entz and LeSueur (2013).

will decrease. Banks are required to hold reserves and this generates the demand for reserves. Banks with too many reserves supply them in the federal funds market and banks with too few demand them in the federal funds market.

We start by considering $i = 1, \dots, n$ “creditworthy” banks. The real world counterparts of these creditworthy banks are those (large) banks that have the ability to raise large deposits in the unsecured fed funds (or eurodollar) markets.¹⁰ The reserve requirement for bank i is denoted by RR_i . Banks can borrow and lend reserves in the b2b market at the rate, r_{b2b} . After the b2b market winds down, each bank i receives a payments shock, ε_i , that can either increase or decrease its reserve holdings. Suppose, for simplicity, that bank i ’s payment shock is distributed uniformly over the interval $[-P_i, P_i]$ and that $RR_i > P_i$.¹¹ If a bank’s reserve holdings are below the required amount after the payment shock, then it must borrow reserves from the Federal Reserve’s discount window at the “penalty” rate, r_{PCR} , to make up the difference.

Reserves deposited at the Federal Reserve receive an interest payment of r_{IOER} per dollar. However, holding reserves can be costly. Banks face costs when an increase in the supply of reserves leads them to expand or modify the composition of their balance sheets. The costs associated with expanding a bank’s balance sheet may include an FDIC assessment fee, as well as the cost of raising additional capital. Indeed, a bank may need additional capital if the size of its balance sheet increases, but it does not want to increase its leverage ratio.¹² While the cost of the FDIC assessment fee appears to be approximately linear, the cost of capital is likely to be increasing in the amount of capital being raised. As an alternative to adding capital when the size of its balance sheet increases, a bank that wants to keep its leverage ratio constant could modify the composition of its balance sheet by replacing other assets with reserves. The cost of this adjustment is likely to be increasing with the amount of reserves since the composition of the bank’s balance sheet will move further away from its desired composition.¹³ It is reasonable to assume, however, that this cost does not kick in until reserve levels are high. We will assume for convenience that they kick in precisely at $R_i = RR_i + P_i$. If we assume that the linear cost coefficient is $a > 0$ and the convex cost coefficient is $b/2 > 0$, then the balance sheet costs for

¹⁰Later, when we introduce SBAs, there will be a role for m less credit worthy bank. Less credit worthy banks are those that are unable or unwilling to borrow in the unsecured money market.

¹¹Relaxing the uniformity assumption changes the shape of the demand curve we will discuss below in ways outlined in the working paper version Ennis and Keister, but does not change the qualitative implications of the analysis.

¹²While actions that increase bank reserves do not necessarily increase bank assets, evidence suggests that for LSAPs conducted through 2012:Q3, assets were ultimately sourced primarily from non-banks—households (including hedge funds), broker-dealers, and insurance companies. All else equal, this would imply that the purchases increased bank assets. See Carpenter et al (2013).

¹³This type of effect is discussed in the preferred habitat model outlined in Clouse et al (2014).

an individual bank i with reserve holdings R_i are given by

$$\begin{aligned} aR_i & \text{ if } R_i < RR_i + P_i \\ aR_i + \frac{b(R_i - RR_i - P_i)^2}{2} & \text{ if } R_i \geq RR_i + P_i \end{aligned}$$

A deposit at the Federal Reserve represents, from the bank's point of view, a perfectly safe loan to the Federal Reserve. A federal funds loan, however, is an unsecured loan to a DI. Let $c > 0$ represent the credit risk premium that makes a bank indifferent between lending to the Federal Reserve, at the IOER rate, and lending in the b2b market.¹⁴ If the risk adjusted interest rate, $r_{b2b} - c$, exceeds the penalty rate, r_{PCR} , then a bank has no incentive to hold reserves since the expected cost of having an additional dollar in reserves, which equals $r_{b2b} - c - r_{IOER}$, exceeds the expected benefit, which is less than or equal to $r_{PCR} - r_{IOER}$. Hence, when $r_{b2b} - c > r_{PCR}$, the bank's demand for reserves in the b2b market is zero.¹⁵ It is worth noting that in these cases the bank's balance sheet cost is always equal to aRR_i , which is the minimum cost that a bank will incur given that it is required to hold reserves RR_i .

Suppose now that the risk adjusted interest rate in the b2b market is less than or equal to the penalty rate, but greater than the IOER rate, i.e., $r_{IOER} \leq r_{b2b} - c \leq r_{PCR}$. A bank may now find it advantageous to borrow in the b2b market to avoid having to borrow from the Federal Reserve at the penalty rate. A bank will have to borrow from the Federal Reserve if $R_i + \varepsilon_i < RR_i$. Since the payment shock is uniformly distributed on $[-P_i, P_i]$, we have that

$$\Pr[R_i + \varepsilon_i < RR_i] = \Pr[\varepsilon_i < RR_i - R_i] = \frac{RR_i - R_i + P_i}{2P_i}.$$

When the risk adjusted federal funds rates is less than or equal to the penalty rate but greater than or equal to the IOER rate, a bank's demand for reserves is determined by an indifference condition which equates the expected benefit of allocating an additional dollar to the federal funds market with the expected cost of investing in reserves. The expected cost is the return forgone in the b2b market, $r_{b2b} - c - r_{IOER}$, plus the expected addition to balance sheet costs that result from holding the additional dollar, $[1 - (P_i - RR_i + R_i)/2P_i]a$. Notice that $1 - (P_i - RR_i + R_i)/2P_i$ is the probability that the bank does not have to borrow from the Federal Reserve; if the bank does not have to borrow, then the bank could have avoided the cost a associated with holding the dollar at the Federal Reserve rather than investing it in the b2b market. The expected net benefit is given by the probability of borrowing reserves from the Federal Reserve times the (net) cost of borrowing, $r_{PCR} - r_{IOER}$. Therefore, demand for reserves is determined by the indifference condition

¹⁴Note that c is the solution to the equation $r_{IOER} = (1 - q)(r_{IOER} + c) - q$, where q is the probability of default in the b2b market, and hence c will vary with the IOER rate.

¹⁵We could also include a small "wedge" above r_{PCR} to reflect stigma.

$$r_{b2b} - c - r_{IOER} + \left(1 - \frac{RR_i - R_i + P_i}{2P_i}\right)a = \frac{RR_i - R_i + P_i}{2P_i}(r_{PCR} - r_{IOER}). \quad (1)$$

When the risk adjusted b2b rate equals the penalty rate, $r_{b2b} - c = r_{PCR}$, (1) implies that

$$\frac{RR_i - R_i + P_i}{2P_i} = 1,$$

which means that bank i borrows from the Federal Reserve with probability one. Bank i will borrow with probability one only if $R_i \in [0, RR_i - P_i]$. Therefore, when $r_{b2b} - c = r_{PCR}$ the demand for reserves, R_i^d , will be perfectly elastic over the region of reserve holdings $[0, RR_i - P_i]$.

The indifference condition (1) can be rearranged into the demand for reserves curve

$$R_i^d = \frac{(RR_i + P_i)(r_{PCR} - r_{IOER}) + (RR_i - P_i)a - (r_{b2b} - c - r_{IOER})2P_i}{r_{PCR} - r_{IOER} + a}.$$

Notice that the demand for reserves is a strictly declining function of the risk adjusted b2b rate for all $r_{PCR} + c < r_{b2b} < r_{IOER} - a$. For a given level of reserve holdings, R_i , as the risk adjusted b2b rate declines from r_{PCR} , the cost of an additional dollar in reserves declines, but the benefit of the additional dollar remains unchanged (being the difference $r_{PCR} - r_{IOER}$ times the probability that the bank will have to borrow an additional dollar). The expected benefit associated with an additional dollar can be reduced—and thereby equated with the cost associated with an additional dollar in reserves—by increasing reserve holdings R_i : Increasing reserve holdings reduces the probability that the bank will have to borrow at the penalty rate and, hence, reduces the expected benefit associated with an additional dollar of reserves.

When the risk adjusted rate in the b2b market is below the IOER rate, the bank equates the balance sheet cost associated with purchasing an additional unit of reserves with the benefit of borrowing the unit of reserves at the b2b rate and reinvesting it at the IOER rate, i.e.,

$$a + b(R_i - RR_i - P_i) = r_{IOER} - (r_{b2b} - c).$$

The resulting demand for reserves curve is

$$R_i^d = RR_i + P_i + \frac{r_{IOER} - a - (r_{b2b} - c)}{b}$$

Notice that for reserves $R_i > RR_i + P_i$ the non-linear part of the balance sheet cost function kicks in and the bank's demand curve lies below the IOER rate by the amount of $a - c + b(R_i - RR_i - P_i)$.

The aggregate demand curve for reserves is obtained by horizontally summing the individual bank demand curves. For this analysis, we assume that all n banks are

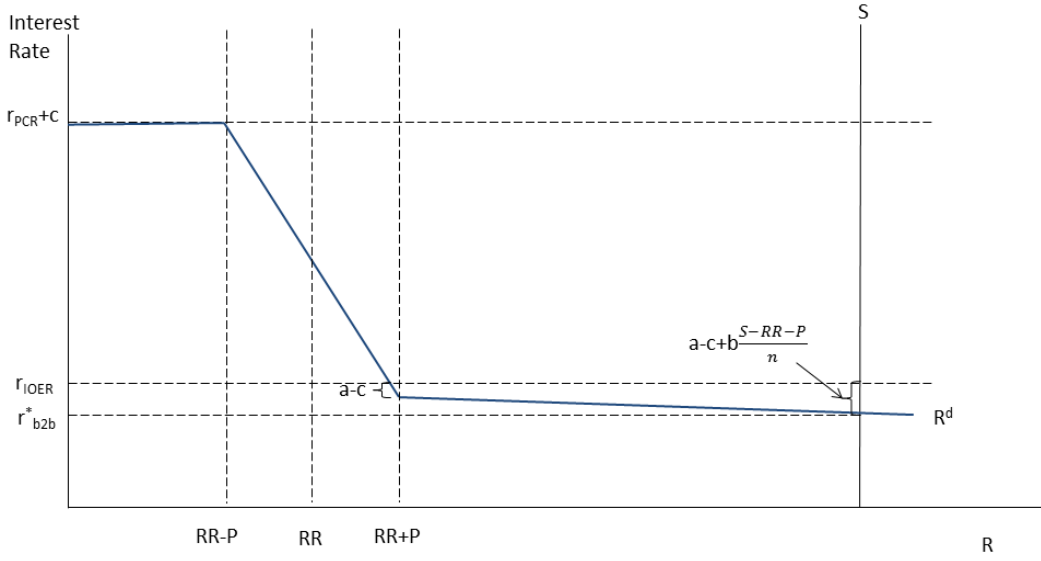


Figure 1: Aggregate Supply and Demand for Reserves with Balance Sheet Costs

identical. Hence, pick any bank $i = 1, \dots, n$, and let $RR = nRR_i$ and $P = nP_i$. The aggregate demand curve, R^d , is given by

$$R^d = \begin{cases} 0 & \text{if } r_{b2b} - c > r_{PCR} \\ \in [0, RR - P] & \text{if } r_{b2b} - c = r_{PCR} \\ \frac{(RR+P)(r_{PCR}-r_{IOER})+(RR-P)a-(r_{b2b}-c-r_{IOER})2P}{r_{PCR}-r_{IOER}+a} & \text{if } r_{IOER} - a < r_{b2b} - c < r_{PCR} \\ RR + P + n \frac{r_{IOER}-a-r_{b2b}+c}{b} & \text{if } r_{b2b} - c \leq r_{IOER} - a \end{cases} \quad (2)$$

The b2b interest rate that clears the market is determined by the intersection of the aggregate demand curve, R^d , and the supply of reserves curve, which we denote by S . The supply of reserves in the b2b market includes all reserves initially held by DI's at the start of each trading day plus the quantity of reserves borrowed from lenders in the g2b market. As shown in Figure 1, the supply of reserves in the b2b market is “very large,” which results in an equilibrium risk adjusted interest rate in the b2b market that is equal to the IOER rate minus marginal balance sheet costs; i.e.,

$$r_{b2b}^* = r_{IOER} - a + c - \frac{b(S - RR - P)}{n}.$$

3.2 The g2b Market

The participants in the g2b market are DIs and GSEs, most notably the FHLBs. FHLBs primarily provide funding for home mortgage loans to member institutions by issuing debt in financial markets. As a result, at any particular time FHLBs typically have large amounts of cash on hand. FHLBs have reserve accounts at the Federal Reserve, so they can always deposit cash that is not currently needed for its member institutions overnight at the Federal Reserve. However, unlike banks, GSEs do *not* receive IOER on their deposits at the Federal Reserve. To obtain interest on their cash balances, FHLBs can and do make overnight loans in the federal funds market and at the Federal Reserve's ON RRP facility.

We assume that the lenders in the g2b market are identical and initially hold in aggregate R_g reserves at the Federal Reserve. They are willing to lend these reserves to DIs at sufficiently high rates. A practical consideration is that in reality FHLBs and other large money market lenders, such as money market funds, deal only with a limited set of highly creditworthy counterparties and place concentration limits on the amounts they are willing to lend to any particular counterparty. Taking into account these considerations, we model the g2b market in a manner that is consistent with the following stylized facts: (1) lenders in the g2b market deal only with a small number of borrowers, (2) lenders in the g2b market are only willing to lend to individual banks up to prespecified concentration limits, (3) borrowing banks make take-it-or-leave-it offers to lenders in the g2b market, meaning that g2b lenders are essentially price takers, and (4) rates offered to lenders in the g2b market must exceed their threat point, which is the overnight secured rate (we use the ON RRP rate as a proxy for rates in the secured overnight market).

To incorporate noncompetitive frictions we assume that the n creditworthy banks and the many identical FHLB-type lenders are distributed around a circle. For convenience we can assume there are equal numbers of creditworthy banks and lenders in the g2b market and that they are distributed so that each lender has a creditworthy DI to the left and to the right. We assume it is costless for a lender to monitor creditworthy banks to its immediate left and right and infinitely costly to monitor other creditworthy banks. A lender will not give a loan to a bank that it cannot monitor. As a result, a lender will provide loans to at most two creditworthy banks.¹⁶ We assume lenders set concentration limits for each of their potential borrowers equal to half of the amount they are willing to lend.

The interaction between lenders and borrowers in the g2b market is as follows. First, each borrower announces an amount it wants to borrow and the rate it is willing to pay to its two potential of lenders. These are take-it-or-leave offers on the borrowing rate. Next, lenders either accept or reject posted offers; if they accept,

¹⁶The assumption that there are the same number of borrowers and lenders is not crucial. We could assume, for example that there were half as many lenders so that there were two potential borrowers to the left and right of every lender. None of the following analysis would be substantially changed.

then they submit loan amounts up to their concentration limits. If a lender has funds left over—either because the posted interest rates were unacceptable or because the borrowers do not take all of the lender’s submitted loan amounts—then the lender invests the remaining funds at the ON RRP facility at the ON RRP rate, r_{ONRRP} . We assume that each bank’s demand for borrowed funds is less than the maximum amount of funds it can receive from its two lenders, where the maximum is simply the sum of the two lenders’ concentration limits for that bank.

In equilibrium, the lender will offer the same loan size to each bank and each bank offers the interest rate

$$r_{g2b}^* = r_{ONRRP} + k,$$

where k is the credit risk premium on g2b loans. (See Appendix B for a formal derivation of this equilibrium result.) The equilibrium risk adjusted interest rate in the g2b market equals the lender’s outside option, which is the Federal Reserve’s ON RRP rate, r_{ONRRP} .¹⁷ Since the lender is indifferent between accepting and rejecting the offers, it accepts it.

The above equilibrium condition relies on the fact that each lender’s threat to lend at the ON RRP facility is credible. While each lender faces a cap that limits the amount it can lend to the ON RRP facility, the level the cap is currently set at \$30 billion, which is far in excess of any FHLBs unsecured overnight activity.

3.3 Equilibrium Federal Funds Rate

The observed federal funds rate is given by the weighted sum of equilibrium rates that prevail in each market;

$$r_{FF}^* = \lambda r_{b2b}^* + (1 - \lambda)r_{g2b}^*$$

where λ is the share of transactions in the b2b market. The Federal Reserve started paying interest on excess reserves in October 2008 and, since 2009, the rate has been 25 basis points. Beginning in January 2009, excess reserves in the US banking system have been at least ten times greater than the level of required reserves, and as of 2014 it is about thirty times greater. In these circumstances, activity in the b2b market is predicted to be very small (i.e., λ is close to 0). As such the model predicts that the federal funds will be close to the rate in the g2b market, a result that is not too far from reality, as shown in Figure 2.

4 Segregated Balance Accounts

Competitive frictions in the g2b market arise because the credit risk concerns that lenders have regarding banks lead them to restrict their interactions to a small set of

¹⁷We assume that the spread banks earn, $r_{IOER} - r_{ONRRP} - k$, is greater than their marginal balance sheet costs.

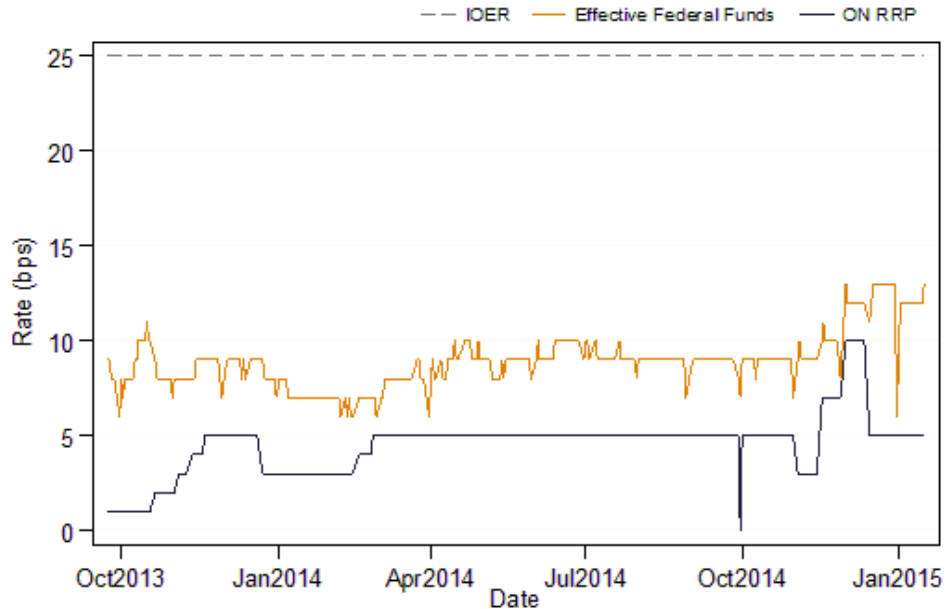


Figure 2: The sample is 9/23/2013-1/16/15.

counterparties that have fixed loan limits. Since, by design, SBAs would eliminate counterparty credit risk—they would be nearly safe assets—there are two possible channels by which SBAs can eliminate noncompetitive frictions in our model. First, since any bank can offer an SBA, the number of eligible bank counterparties increases. This means that cash investors can shop around for the best rates that are available, where all offered rates effectively carry zero counterparty credit risk. Second, there is no need to impose a concentration limit or caps on funds placed in an SBA with a particular bank.

We now introduce m “less-creditworthy” banks, where m is large relative to n . One can think of these banks as being smaller regional banks. Our designation of the banks as less-creditworthy may mean that they are deemed by the market to be risky or simply that they are too small and infrequent participants in overnight markets to warrant monitoring efforts by lenders. Consistent with this interpretation, we also assume that these banks do not face meaningful payment shocks and, hence, hold reserves exactly equal to their reserve requirements. We denote the aggregate reserve holdings of these banks by \hat{S} . These banks are too small to have leverage ratio problems. Therefore, we model them as having constant marginal balance sheet costs equal to a , the FDIC assessment fee.

Since SBAs eliminate credit risk and remove the need for monitoring, any of the m less-creditworthy banks can borrow from any lender using SBAs. We anticipate that banks seeking to attract funds will be able to post their SBA borrowing rates

for all to see. The posting of rates implies that Bertrand competition will lead to an equilibrium SBA rate, r_{SBA}^* , that is the same across all providers of SBAs and equal the IOER rate minus the marginal balance sheet cost, i.e.,

$$r_{SBA}^* = r_{IOER} - a.$$

Since the less-creditworthy banks have lower balance sheet costs than current federal funds participants and because there are a large number of these banks, they will likely be able to attract all of the funds that go into SBAs.

The willingness of the lenders to supply funds secured by SBAs will, of course, depend on alternative investment opportunities, including unsecured lending. Banks that undertake unsecured (federal funds) borrowing, either for the purposes of IOER arbitrage or for their own use—e.g., to meet reserve requirements—will have to pay a rate above the SBA market rate by an amount that just is sufficient to compensate lenders for credit risk. We now demonstrate that the resulting market equilibrium will have the vast majority of excess reserves in the system residing in SBAs, while levels of reserves needed to meet reserve requirements would remain in banks' own master accounts.

4.1 Federal Funds Market Equilibrium With SBAs

We will describe the market equilibrium in two steps. Owing to higher balance sheet costs, (large) creditworthy banks are unable to compete with the less-creditworthy banks that borrow using SBAs and can offer a borrowing rate equal to $r_{IOER} - a$. As a result, in the first step, lenders in the g2b market will lend all of their reserves, R_g , to less creditworthy banks, who invest the reserves in SBAs. This would effectively eliminate the noncompetitive g2b market discussed above. If nothing else were to happen, creditworthy banks would, in aggregate, hold reserves equal to $S - R_g$ and the interest rate in the b2b market would increase from r_{b2b}^* to r_{b2b}^{**} , as illustrated in Figure 3. The increase in the b2b interest rate reflects the decline in balance sheet costs incurred by the creditworthy banks because the aggregate reserves they hold decline.

But this is not the end of the story; something else happens. The remaining reserves held by the creditworthy banks have offsetting liabilities, the vast majority of which are in the form of bank deposits. The interest rate on bank deposits can be viewed as being determined by a bargaining outcome between the bank and its depositors. Notice that the maximum deposit rate that a creditworthy bank can pay is equal to the IOER rate minus the marginal balance sheet costs. (In practice, banks likely pay considerably less than this.) However, the competitive interest rate on SBAs exceeds the IOER rate minus the creditworthy bank's marginal balance sheet costs since creditworthy banks incur the additional non-linear balance sheet cost.

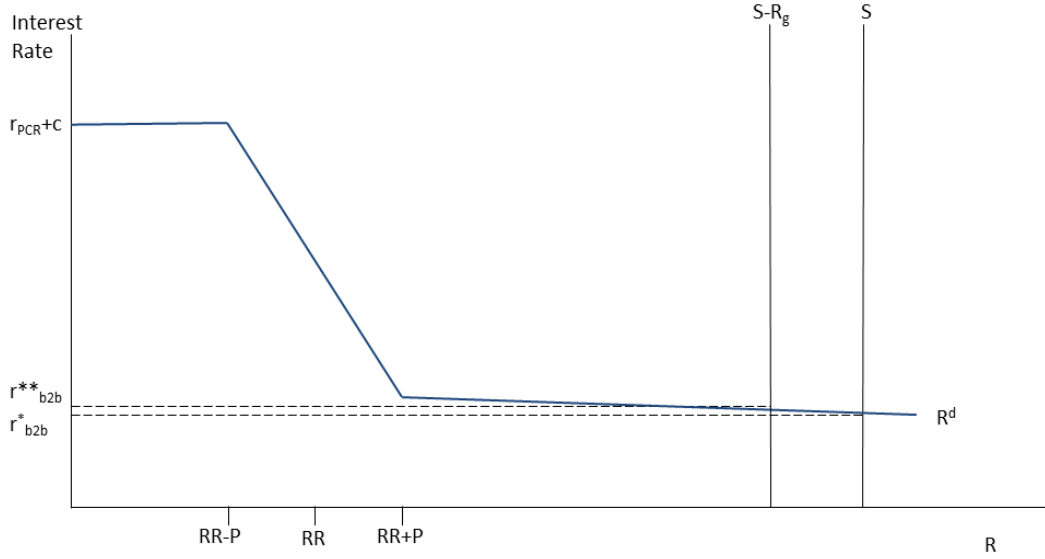


Figure 3: Aggregate Supply and Demand for Reserves with Balance Sheet Costs

Deposit holders will therefore have an incentive to liquidate some of their deposit holdings and convert them into loans secured by SBAs.

We now describe the second step. Reserves in SBAs that collateralize the loan cannot be used by the bank to meet another depositor's payment request and these reserves cannot be counted toward the balances a bank maintains in order to satisfy its reserve requirements. The introduction of SBAs, therefore reduces the supply of (usable) reserves available to the creditworthy banks from S to $S - q_{SBA}$, where q_{SBA} denotes the aggregate quantity of outstanding SBA balances. The first step 1, above, described the situation where $q_{SBA} = R_g$. But there may be additional demand for SBAs associated with depositors of creditworthy banks who convert some of their (low interest rate) deposits into loans secured by SBAs. It should be emphasized that we do not restrict lenders whose loans are secured by SBAs to be GSEs. In principle, a broad set of individuals and institutions could have their loans to a DI secured by an SBA. Therefore, we expect equilibrium levels of SBAs to be greater than the reserve holdings of FHLBs, i.e., $q_{SBA}^* > R_g$.

SBA balances are at their equilibrium level when the intersection of the aggregate demand curve for reserves by creditworthy banks, R^d , and the supply of (usable) reserves curve, $S - q_{SBA}$, generate an interest rate that makes investors indifferent between investing in SBAs and investing in the unsecured b2b market. The equilibrium federal funds rate r_{FF}^* is now determined solely in the b2b market (loans secured by SBAs are not included in this rate). Hence,

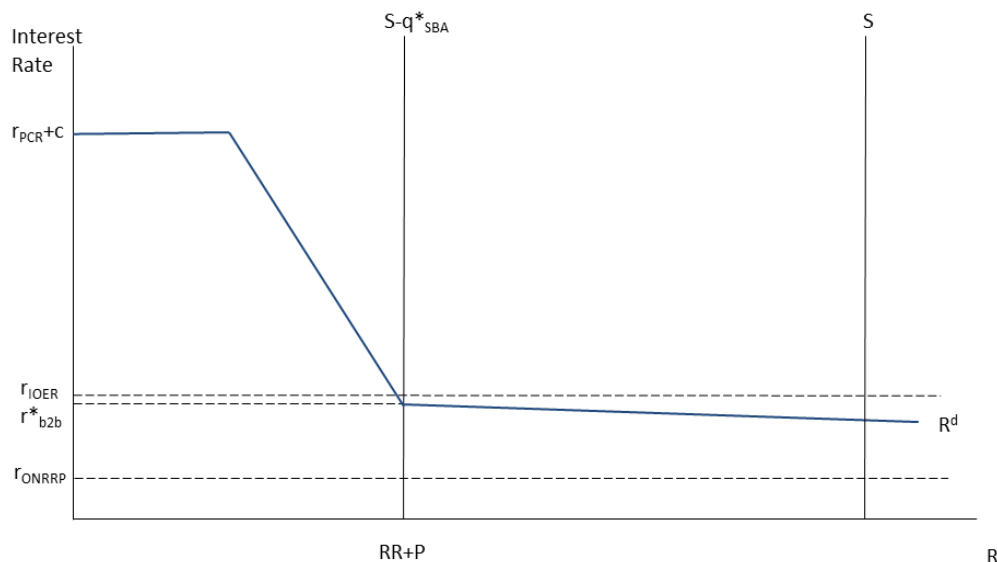


Figure 4: Equilibrium with SBAs

$$r_{FF}^* = r_{b2b}^* = r_{IOER} - a + c. \quad (3)$$

The equilibrium level of SBA balances is given by $q_{SBA}^* = S - RR - P$, as illustrated in Figure 4. Note that this point corresponds to the efficient level of usable reserves. While this quantity is not directly observable, in equilibrium SBAs would identify it.

4.2 Distribution of Reserves

SBAs result in a more favorable distribution of reserves across the banking system, which results in a reduction in aggregate balance sheet costs. We can explicitly compute this savings in the model. After the introduction of SBAs, total balance sheet costs are simply $(S - q_{SBA}^*)a + (\hat{S} + q_{SBA}^*)a = (S + \hat{S})a$. This is because reserve holdings of the creditworthy banks equal $RR + P$ when SBAs are introduced and, as a result, the only balance sheet costs that these banks face is the FDIC assessment fee. The aggregate balance sheet costs before the introduction of SBAs are given by

$$a(S + \hat{S}) + b \frac{(S - RR - P)^2}{2}.$$

Therefore, the aggregate savings in balance sheet costs is

$$b \frac{(S - RR - P)^2}{2}.$$

In other words, all of the costs associated with the leverage ratio compliance is eliminated with the introduction of SBAs.

5 Monetary Policy With SBAs

5.1 Complete Pass Through of Changes in IOER

The competition that SBAs generate improves the transmission of monetary policy in the sense that any increase in the Federal Reserve’s IOER policy rate will be matched by a similar increase in money market rates. To see this, simply note that (3) implies that $\Delta r_{FF}^* = \Delta r_{IOER}$. Moreover, the supply of SBAs is invariant to an increase in IOER rate since $q_{SBA}^* = S - (RR + P)$.

Complete pass-through of changes in the IOER rate into changes of the federal funds rate does not occur in the model in the absence of SBAs. This is because the creditworthy borrowing banks have little incentive to bid up rates since they have all of the bargaining power. In this situation, our model suggests that the federal funds rates is determined by the floor created by ON RRP, and that raising the IOER “ceiling” will have little impact on the federal funds rate.

5.2 Automatic Reserve Management

Historically, when the balance sheet size of the Federal Reserve was much smaller and reserves were scarce, variations in autonomous factors—such as currency demanded by the public—led to potential fluctuations in the federal funds rate that were offset by open market operations. Even though excess reserve balances are now in the trillions, the above analysis indicates that SBAs could reduce usable reserves to the point of scarcity where, once again, fluctuations in autonomous factors are relevant. The equilibrium described in Figure 4, however, has nice stability properties that automatically offset fluctuations in autonomous factors and, as such, costly actions by the Federal Reserve to counteract them would not be necessary.

When SBAs exist, fluctuations in currency demand by the public are offset by flows into and out of SBAs. If currency demand increases by, say, ΔC in Figure 5, usable reserves become more scarce; they decrease from $S - q_{SBA}^*$ to $S - q_{SBA}^* - \Delta C$. If aggregate SBAs remain fixed, this implies that the federal funds rate must rise. But an increase in the federal funds rate results in the liquidation of some SBAs into federal funds. The decrease in SBA holdings increases the level of usable reserves and this puts downward pressure on federal funds rates. Ultimately, the equilibrium is restored at the initial federal funds rate. In Figure 5, the new equilibrium is described by the intersection of the usable reserves supply curve and the demand for reserves curve: $R^d = S - q_{SBA}^* - \Delta C - \Delta q_{SBA}$, where $-\Delta q_{SBA} = \Delta C$. In short, the increase in currency demand is matched by an equivalent decrease in SBAs. If, on the other hand, currency demand decreases, so that the supply of usable reserves increases to

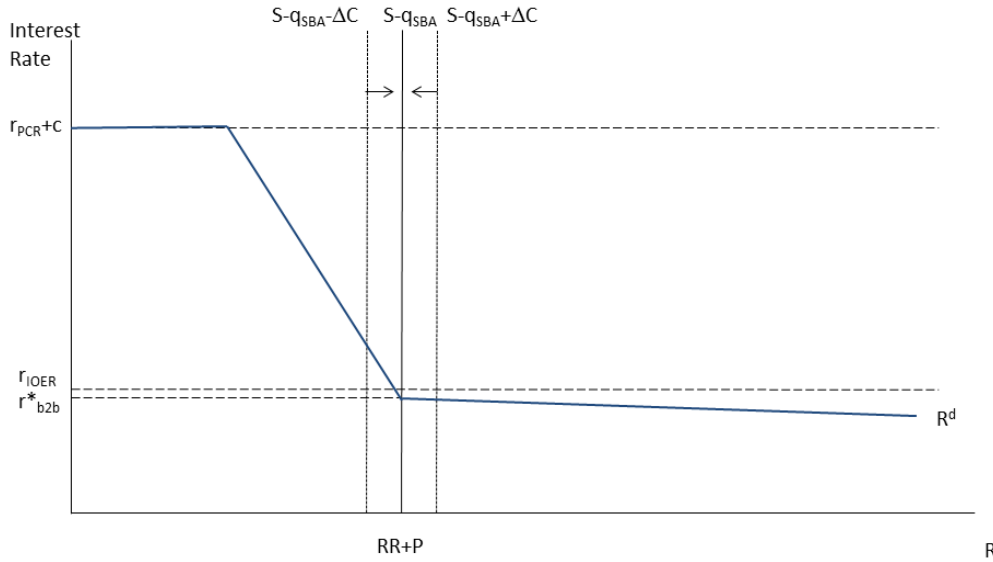


Figure 5: Changes in Currency Demand

$S - q_{SBA}^* + \Delta C$ in Figure 5, then the opposite set of events occur. In particular, the decrease in currency demand is matched by an equivalent increase in SBAs, which leaves both the federal funds rate and usable reserves unchanged.

5.3 SBAs in a World With Low Excess Reserves

Over time, the amount of excess reserves in the banking system will likely decline as the size of the Federal Reserve’s portfolio is reduced. As usable reserves shrink, the aggregate level of SBAs would also be expected to shrink, just as in the case where currency demand increases. The reduction in reserves (induced by the reduction in the size of the Federal Reserve’s portfolio) will be matched by a reduction in SBAs, leaving the amount of usable reserves and the federal funds rate unchanged.

If reserves become sufficiently scarce, then SBA balances should fall to zero and we would be back in a corridor system, where the federal funds rate can be “significantly” higher than the IOER rate.¹⁸ Even though SBA usage would be *de minimis* in a corridor system, their existence would still contribute to supporting the IOER rate as the lower bound. For example, should overnight market rates drop close to the

¹⁸An appealing feature of SBAs is that they are a new technology and not a facility. If market participants no longer demand SBAs, then their use simply ends. There would be no need to impose an end to their use. Similarly, if they were to become desirable again, at some point in the future, the market could reemerge without requiring official intervention.

IOER rate, we would expect that investment in SBAs would resume, which would prevent overnight rates from dropping below floor set by the IOER rate (net of any balance sheet costs).

6 Potential Risks

6.1 Flight to Quality

In recent crises, there has been a flight to quality in financial markets.¹⁹ In 2008, while substantial funds attempted to shift into Treasury securities, especially bills,²⁰ there was also a huge flow of funds into U.S. commercial bank deposits, most notably into custody banks. While such a brisk removal of liquidity from key markets is problematic, economists have argued that there is a silver lining because big banks become flush with deposits, which allows their customers to draw down lines of credit.²¹

Recently, market observers and policy makers have expressed concerns that uncapped ON RRP facilities could exacerbate flight-to-quality flows, by providing a risk-free alternative to bank deposits, thereby causing a removal of much needed liquidity from the financial system.²² For these reasons, an aggregate cap on the amount that can be invested at the ON RRP facility has been imposed and an auction pricing mechanism has been introduced to ration ON RRPs in the event that bids exceed the aggregate cap.

A similar concern could arise with SBAs. During a crisis, SBAs might be seen by lenders as an attractive near risk-free investment. However, a “surge” into SBAs—i.e., an increased supply of funds by lenders for SBA collateral arrangements—would be accommodated by counterbalancing price movements. Suppose that, in our model, take up in SBAs rises above equilibrium levels depicted in Figure 4. Then, as described in Figure 5, this would trigger an increase in the federal funds rate, as usable reserve become scarce. Further, because SBAs are supplied competitively, their rate would not adjust, since the rate is “competitively tied” to the IOER rate. The result would be an increase in the spread between the federal funds rate and the rate paid on SBA balances, which would help to arrest the surge and mitigate potential dislocations in funding markets.

Additional factors could limit the ability of investors to suddenly place large sums of money into loans secured by SBAs. SBA collateral arrangements would likely specify caps on balances at the insistence of the borrowing banks. Banks have a desired leverage ratio and typically want to stay below it. As a result, banks would

¹⁹See Gatev and Strahan (2006).

²⁰This necessarily led to a rise in their price, since the supply of bills is fixed in the short run. The fixed supply of bills and consequently their yield in such situations may help to reduce the shift into safe assets and so limit the risk of disruptions in existing funding patterns

²¹See Strahan and Gatev (2006).

²²See Frost, Logan, Martin, McCabe, Natalucci, and Remache (2015).

only demand loans secured by SBA balances up to a point that keeps them below that target. It is difficult to predict whether usage in non-stress times would approach these caps, leaving little room for a surge in balances during times of stress, or whether caps would be far from binding on a daily basis. But this is something that the Federal Reserve would have influence over. As a party to the SBA agreement, it could impose caps.

6.2 Effect on the Federal Funds Market

The current situation, where the federal funds rate lies below the IOER rate and the federal funds market is dominated by FHLB lending to foreign banks, is somewhat unusual and it is strongly affected by the frictions of balance sheet costs and imperfect competition. SBAs could lead to a significant reduction in the FHLBs' federal funds lending to foreign banks. The likely result would be that federal funds arbitrage transactions would diminish and arbitrage would most likely take place in loans secured by SBAs. If SBAs attract FHLB funds from the federal funds market, then the federal funds volume could decline from its current level and the federal funds rate could come to reflect only a few idiosyncratic trades. However, as more reserves move into SBAs, some banks could find themselves short of reserve balances. These banks would have stronger incentives to borrow in the federal funds market and the share of interbank transactions could rise. Since the interest rate on interbank transactions is typically above the IOER rate, the federal funds effective rate would be expected to increase as the share of these transactions increase, and could eventually lie above the IOER rate. Overall, SBAs could hasten the day when the federal funds trades occur above the IOER rate and are comprised primarily of interbank trades.

6.3 Effect on the FDIC

Reserves held in SBAs would not be available to the FDIC if the account holder becomes insolvent. Banks could end up substituting out of uninsured deposits and into borrowing secured by SBAs, and that would weaken the FDIC's position in resolution. From the perspective of the FDIC, this is similar to a situation where investors chose to transfer funds out of the bank and place the funds in repos, including those offered by the Federal Reserve Bank of New York in the form of ON RRP. In each case, the bank's uninsured deposits would decrease and we would see a corresponding decrease in assets available to the FDIC. To provide additional protection to the FDIC the ability to offer SBAs could be restricted to banks with a CAMELS rating of 1, 2, or 3.

6.4 Legal and Regulatory Issues

Several legal and regulatory issues would need to be resolved before SBAs could be implemented. Three issues are essential. First, it would need to be determined that the Federal Reserve System has the authority under Federal Reserve Act to maintain SBAs and recognize the security interest of the lender. Second, to function as near risk-free investments, the FDIC would need to act quickly to permit lenders to gain access to SBAs that collateralize their loans in the event the borrowing DI becomes insolvent and is placed into FDIC receivership. Third, since banks cannot secure deposits, a statement from the Office of the Comptroller of the Currency that the funds acquired from lenders and placed in SBAs would be classified as “money borrowed” would be required. Prior to operationalizing SBAs these and other operational issues would have to be addressed.

7 Concluding Remarks

SBAs are a design for a new type of account that would allow any bank to credibly compete for overnight money market funding, because they are almost completely free of credit risk. Since banks would compete more vigorously for funds using SBAs, the rates paid on borrowings secured by SBAs, along with other money market rates, are likely to move closer to the IOER rate and be more tightly linked to that rate. The rates paid on borrowings secured by SBAs are market-determined and, therefore, may adjust to changing economic circumstances.

While SBAs would not reduce the aggregate supply of reserves in the system, they would reduce the amount of “usable” reserves that banks can use to meet reserve requirements or to make their own payments. In equilibrium, SBAs would be expected to endogenously reduce the amount of usable reserves to the point of scarcity. As such, in the context of our model, SBAs identify the minimum level of reserves consistent with satiation. That is, any additional reserve balances would not be valuable to banks either to fulfill reserve requirements or to use for payments. This quantity of reserves is not otherwise observable. Hence SBAs may help identify an optimal target for reserve levels that may be difficult to achieve using conventional draining tools. Conveniently, if reserve levels are reduced to a point of scarcity through other means, market forces should cause SBA use to decline to zero. Since SBAs are a technology and not a facility, this would not require any action by the central bank. Rather the accounts would simply be inactive unless conditions changed.

If some banks face higher marginal balance sheet costs than others, then the competition induced by SBAs would be expected to redistribute bank reserves in a way that equates the marginal balance sheet cost across all banks. Hence, SBAs also promote an efficient allocation of reserves within the banking sector.

SBAs, should they be created, could be discontinued at any time, if the Federal Reserve judged that it would be appropriate to do so. Indeed, since the Federal

Reserve provides the technology that makes SBAs possible, it would be possible to discontinue their use simply by not signing any new SBA agreements. Existing agreements could be allowed to expire at the agreed term.

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Appendix A: Detailed Description of SBA Mechanics

The SBAs proposal envisions that an account holder of a Federal Reserve Bank (FRB), which must be a type of entity that is eligible to earn interest on excess reserves, would, from time to time, borrow funds from one or more entities (each entity referred to as the “lender of funds”) on a secured basis. To secure its borrowings from a lender of funds, the account holder would enter into an agreement to grant to the lender a security interest in funds deposited in the SBA that the account holder established at its FRB specifically for the purpose of securing borrowings from the lender. Each time the account holder borrows from the lender of funds, the account holder would deposit funds (or cause funds to be deposited) to the SBA in an amount equal to the amount borrowed.

An SBA will be an account established by an account holder that is separate from its Master Account. The SBA account holder will not be able to use the funds in the SBA account for any purpose (e.g., to satisfy reserve requirements) other than to secure its obligation to repay the lender of funds and to earn interest on the account balance. The interest earned on this balance will be at the same rate as IOER. The SBA account holder will not have the right to transfer funds out of the SBA. Instead, the SBA will be established so the funds can be sent into or transferred out of the account through either National Settlement Services or the Fedwire Funds Service. The interest earned on the balance in the SBA will be credited to the SBA account holder master account. It is then anticipated that the SBA owner will transfer an agreed amount of interest earned on the funds in the SBA to their lender. A separate SBA will need to be established by the Administrative Reserve Bank for each relationship (i.e., borrower/lender pair).

It is anticipated that the majority of these funds will be held in the SBA on an overnight basis, but there will be no restrictions to term borrowing by the owner of the SBA. This would be part of the bilateral agreement between the borrower and

lender of the funds. The interest rates paid to the lender by the borrower as part of the SBA agreement would be negotiated bilaterally at the time the contract is initiated and would last the duration of the contract. We anticipate that the interest rate would be tied to the IOER rate. At this point, there is no anticipated minimum or maximum usage levels needed to establish or maintain an SBA. However, if there is an overwhelming demand for account holders to establish these accounts, there could be an operational burden placed upon the Reserve Banks for their set up and maintenance.

Appendix B: g2b Market Equilibrium

This appendix computes the equilibrium described in section 3.2. We begin with a more formal description of the g2b market. There are $i = 1, \dots, n$ lenders and $j = 1, \dots, n$ borrowers. Borrowers and lenders are evenly distributed around a circle so each lender has one borrower to the left and one to the right and each borrower has one lender to the left and one to the right. Borrowers can only monitor adjacent lenders and will not lend to borrowers who they cannot monitor. Let L_j denote the set of (adjacent) lenders that borrower j deals with and B_i denote the set of borrowers that lender i deals with. Each lender has l dollars to lend, where l is even, and has a concentration limit equal to $l/2$ for each borrower. Each borrower j seeks to borrow a total amount $b < l$ from the lenders in L_j . To do so, borrower j broadcasts a take-it-or-leave-it offer r_j to the lenders in L_j .

Each lender i assigns a credit score to borrower j , which we denote by $s_j \in [0, 1]$, where 1 denotes no credit risk and 0 denotes certain failure.²³ We interpret the credit score as $1 -$ (probability of default); hence, the expected profit lender i gets from lending each dollar to borrower j is given by

$$\pi_i = s_j r_j - (1 - s_j).$$

Lenders also have the option of lending to the ON RRP facility at rate r_{ONRRP} . If the expected profit to lending at the ON RRP facility is the same as the expected profit to lending at in the g2b market, the lender strictly prefers the latter.²⁴

Let x_i denote a lending decision of lender i ; x_i is a 2-tuple where component x_{ij} is the amount lender i wishes to lend to borrower $j \in B_i$. Borrowers may be

²³In reality, it is possible that two different lenders will rate the same borrower differently. For instance, FHLBs use the lowest rating from a set of Nationally Recognized Statistical Ratings Organizations (NRSROs) and this set may differ across FHLBs. Moreover, FHLB credit departments may have different practices. For example, some may treat banks on negative watch as if they have already been downgraded. So there may be some discrepancy in terms of how an FHLB rates a potential borrower. However, we expect this discrepancy to be small and hence we ignore it. NRSROs include Moody's Investor Services Inc, Standard and Poor's Inc, Fitch Inc, Dominion Bond Rating Service Limited (DBRS), and A.M. Best Company Inc.

²⁴One could justify this on the grounds that the ON RRP facility may be temporary and lenders want to preserve relationships with borrowers.

oversubscribed. That is, it may be that $\sum_{i \in L_j} x_{ij} > b$. In this case we assume that offers to lend are allocated (or confirmed) on a pro rata basis. Given an n -tuple of lending decisions we define the resulting lending allocation $A(x)$ to be such that $A_{ij}(x) = \frac{b}{\sum_{i \in L_j} x_{ij}} x_{ij}$ if $\sum_{i \in L_j} x_{ij} > b$, and x_{ij} otherwise.

The second-stage (lender) game: $G(r)$

The strategy set of each lender is $S_i = \{x_i \in R^2 : x_{ij} \leq l/2, \forall j \in B_i\}$. Given an interest rate profile r and a strategy profile x , the payoff to lender i , $P_i(x; r)$, is equal to $\sum_{j \in B_i} \pi_i(r_j) A_{ij}(x) + (l - \sum_{j \in B_i} A_{ij}(x)) r_{ONRRP}$.

Definition 1 A Nash equilibrium of the lender game $G(r)$ is x^* such that, for each i , $P_i(x_i^*, x_{-i}^*; r) \geq P_i(x_i, x_{-i}^*; r)$, for all $x_i \in S_i$.

The two-stage (g2b) game

Borrowers earn a rate of return $r_{IOER} - M$ on each dollar borrowed (regardless of the lender), where M represents the borrower j 's marginal balance sheet costs.²⁵ Hence a borrower j 's profit on each dollar borrowed at rate r_j is $r_{IOER} - M - r_j$. Therefore we can define a strategy choice of borrower j to be a rate $r_j \in R_j = [0, r_{IOER} - M]$. Let $r = (r_1, \dots, r_m) \in \times_j R_j = R$ denote the profile of borrower strategies. The payoff to borrower j under rate profile r is $\sum_{i \in L_j} A_{ij}(x(r))(r_{IOER} - M - r_j)$.

Definition 2 A subgame perfect equilibrium of the g2b market is a strategy profile $(x^*(r^*), r^*)$ such that $x^*(r^*)$ is a Nash equilibrium of the subgame $G(r^*)$ and for each j ,

$$\sum_{i \in L_j} A_{ij}(x(r^*))(r_{IOER} - M - r_j^*) \geq \sum_{i \in L_j} A_{ij}(x(r_j, r_{-j}^*))(r_{IOER} - M - r_j)$$

for all $r_j \in R_j$.

Define

$$k_j = \frac{(1 + r_{ONRRP})(1 - s_j)}{s_j}$$

to be the credit risk premium over the ON RRP rate that make lenders indifferent between lending a dollar to borrower j in the b2b market and lending (risklessly) to the ON RRP facility.²⁶

²⁵ M should be a function of total reserve holding for the bank, which would also depend on how much the bank borrows. However, in equilibrium the only thing that will matter is that marginal balance sheet costs are not so high that they make borrowing unprofitable at any rate above the ON RRP rate. We can take M to be the marginal balance sheet costs of the bank when it borrows the full amount b .

²⁶It is easily verified that $r_{ONRRP} = s_j(r_{ONRRP} + k_j) - (1 - s_j)$.

Proposition 1 *Any subgame perfect equilibrium in the $g2b$ market will consist of rates $r_j^* = r_{ONRRP} + k_j$ for all $j = 1, \dots, n$.*

The proof is trivial given the special set-up (a similar result for a more general market structure can be found in Garratt, Nosal and McAndrews, 2015). The proposed equilibrium interest rates make every lender i indifferent between lending to any borrower in B_i . Moreover, for every lender i , lending to any borrower in B_i is strictly preferred to lending to the ON RRP facility. Hence, we can assume the lenders will offer all of their funds to the borrowers in the $b2g$ market and that, due to concentration limits they will offer the same amount, $l/2$, to each borrower. Given the assumption that $b < l$, the resulting allocation will be that each lender lends $b/2$ to each borrower. Since borrowers are making positive profits, no borrower has an incentive to lower its rate, since this would result in rejection and zero profits. Moreover, no borrower has an incentive to increase its offer rate since borrowers are satiated and at their limit b at the proposed equilibrium allocation.

There cannot be an equilibrium in which any borrower j offers a rate greater than $r_{ONRRP} + k_j$ since borrower j could lower its rate without losing any funds.