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The Federal Reserve's Tools for Policy Normalization in a Preferred Habitat Model of Financial Markets

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Abstract: This paper develops a model of the financial system that provides a framework for analyzing monetary policy implementation in a world with multiple Federal Reserve liabilities and a superabundant supply of reserves. The analysis demonstrates that the Federal Reserve's suite of policy tools including interest on excess reserves (IOER), overnight and term reverse repurchase agreements, and term deposits should allow the Federal Reserve to raise the level of short-term interest rates at the appropriate time. The model also demonstrates that these tools could be used in different ways to achieve any given desired level of interest rates. The choices among alternative combinations of tools, of course, have implications for patterns of financial intermediation. Specifically, the quantity of Federal Reserve liabilities held outside of the banking system is shown to depend importantly on the spread between various policy rates.

[1] The analysis and conclusions set forth are those of the authors and do not indicate concurrence by other members of the research staff or the Board of Governors. We thank Isaac Green, Joe Kachovec, and Wei Zheng for their contributions.

1. Introduction

Over recent years, the size of the Federal Reserve's balance sheet and the associated level of reserves in the banking system have increased dramatically. In the past, the extraordinarily elevated level of reserve balances could have presented challenges for the Federal Reserve in adjusting the stance of monetary policy. However, as noted in the minutes of recent FOMC meetings and the FOMC's Statement of Policy Normalization Principles and Plans, the Federal Reserve now has a number of new tools at its disposal that will allow it to raise the level of short-term interest rates at the appropriate time even with a very elevated level of reserves. While these tools are quite powerful, there is relatively little work that provides an integrated framework for analyzing monetary policy implementation in a world with multiple Federal Reserve liabilities.[2]

Traditionally, the analysis of monetary policy implementation issues focused on the supply and demand for reserves (see, for example, Hamilton (1997) and Goodfriend (2002)). The traditional framework is very useful in understanding determinants of the federal funds rate and other money market rates at times when Federal Reserve liabilities in the form of reserves are relatively scarce and the demand for reserves is driven largely by banks' need to meet reserve requirements or clearing needs. In that environment, the FOMC can implement changes in the stance of monetary policy through fairly modest changes in the supply of reserves. While still useful, this type of analysis is not well suited to address the full range of issues associated with the Federal Reserve's new policy tools and the current environment in which the supply of reserves is superabundant.

This paper constructs a model that examines how the Federal Reserve's tools can be used to remove monetary policy accommodation at the appropriate time even while the balance sheet remains large. In addition, the model illustrates how the tools may affect patterns of intermediation and the pattern of rates in money markets.[3]

As a step toward understanding the implementation of monetary policy in this environment, we develop a simple "preferred habitat" model of financial markets similar in spirit to the work of Brainard and Tobin (1968). The Brainard/Tobin framework is based on a set of balance sheets for various sectors of the economy and some assumed behavioral relationships. Below, we follow a similar approach by focusing on the balance sheets of financial and nonfinancial sectors. In effect, the analysis develops a set of interrelated demand and supply curves for a range of financial assets and uses those demand and supply relationships to determine the equilibrium structure of interest rates and the response of interest rates to changes in Federal Reserve policy actions.

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[2] Bech and Klee (2011) and Martin, McAndrews, Palida, and Skeie (2013) also focus on the structure of Federal Reserve liabilities.

[3] Another approach not discussed in this paper would be to sell securities. There are numerous academic studies estimating the interest rate and macroeconomic effects of the large-scale asset purchases (LSAPs). A few studies that focus on the interest rate effect include Gagnon et al. (2011) on the effects of LSAP I, Krishnamurthy and Vissing-Jorgensen (2011) of LSAP II, and Ihrig et al. (2013) for a summary of all four purchase programs. The resulting macro effects of the programs are reported in Chen, Cúrdia and Ferrero (2012), Chung et al (2011), and Baumeister and Benati (2011).

As discussed in more detail below, when the Federal Reserve has only reserves as a liability, the model generates a version of the traditional reserve demand curve.[4] In that case, the demand for reserves is driven importantly by an opportunity cost of holding reserves, measured as the spread between market interest rates and the rate of interest on reserves. In cases in which the Federal Reserve issues multiple liabilities, the model generates an analogous relationship that focuses on the demand for total Federal Reserve liabilities. The relevant opportunity cost in this generalized demand curve is the spread between market rates and a weighted average rate paid on all Federal Reserve liabilities.

The model results suggest that equilibrium interest rates are determined by two basic factors—a weighted average level of administered rates set by the Federal Reserve on its own liabilities and the quantity of Federal Reserve liabilities relative to the underlying private sector demand for these assets. If the quantity of Federal Reserve liabilities is quite large relative to private sector demand for these assets, the level of money market rates may be pushed below the Federal Reserve's administered rates. In most cases, however, the level of market interest rates responds nearly one for one to changes in the weighted average level of the Federal Reserve's administered rates. As a result, the model suggests that the Federal Reserve can achieve any desired level of market rates through suitable adjustments of its administered rates even when the level of total Federal Reserve liabilities is very large.

The model also generates predictions regarding the effects of the Federal Reserve's policy tools on patterns of financial intermediation. In general, the private sector will tend to favor Federal Reserve liabilities that are closer substitutes for private sector assets and, in equilibrium, these liabilities will tend to be a larger share of total Federal Reserve liabilities. For example, if GSEs view overnight investments in Federal Reserve ON RRP operations to be a close substitute for investments in the federal funds market, then raising the administered rate on ON RRP relative to IOER can generate a substantial decline in the volume of activity in the federal funds market.

These results are consistent with those of other models on this topic, which all indicate that the Federal Reserve will be able to effectively manage money market interest rates with the tools at its disposal. Previous work has addressed the interplay of these tools. Gagnon and Sack (2014) provide a thought piece focusing on the potential role of ON RRP operations, while Martin, McAndrews, Palida, and Skeie (MMPS, 2013) provide a theoretical model incorporating a range of Federal Reserve liabilities. Each model, however, has its own channels through which the various policy tools work—Bech and Klee (2011) focus on limited competition and bargaining cost, MMPS (2013) incorporate balance sheet costs and interbank frictions, and the model here focuses on preferred habitat considerations in a portfolio balance framework. All of these models conclude that money market rates will be lower than the IOER rate in an environment with high reserve balances. And, although the models employ quite different frameworks, all indicate how the various policy tools can be used effectively to put upward pressure on the level of market interest rates.

[4] For simplicity, the model developed here abstracts from Federal Reserve liabilities in the form of currency.

The remainder of this paper discusses the model and results in more detail. Section 2 provides some background on the new monetary policy tools. Section 3 below discusses the basic structure of the financial and nonfinancial sector balance sheets. Section 4 provides an overview of the structure of the model. Section 5 describes how the market equilibrium is determined. Section 6 considers some important special cases of the full model. Section 7 discusses some numerical results from the full model for a range of possible scenarios and section 8 concludes.

2. Background: Monetary Policy Tools

Over the past few years, the Federal Reserve has been testing new tools that can be used to help raise short-term interest rates at the appropriate time.[5] These tools expand the set of Federal Reserve liabilities and the types of counterparties that can hold Federal Reserve liabilities beyond the traditional framework. For example, the counterparties for term reverse repurchase agreement (RRP) operations have been expanded to include a number of money funds and government sponsored entities (GSEs).[6] In addition, fixed-rate, overnight reverse repurchase agreements have been introduced with an expanded set of counterparties.[7] And the Federal Reserve established a term deposit facility through which it can issue term deposits to depository institutions as a way of reducing the quantity of reserves in the system.[8]

All of these new tools drain reserves from the banking system, which can put some upward pressure on short-term interest rates. In addition, the administered rates established for these Federal Reserve liabilities are likely to be quite important in influencing conditions in money markets. The administered rates for these tools can affect money market rates by introducing alternative investment opportunities for financial institutions, which affects arbitrage across markets, even while reserve balances remain elevated.

The July 2014 Monetary Policy Report included a special box titled "Monetary Policy Implementation During Normalization" that provided a discussion of the tools. Specifically, it mentioned that:

> Adjustments to the IOER rate will be a particularly important tool during the normalization period. Banks should be unwilling to lend to any private counterparty at a rate lower than the rate they can earn on balances maintained at the Federal

[5] A list of policy tools to implement monetary policy can be found at: http://www.federalreserve.gov/monetarypolicy/policytools.htm
[6] The Federal Reserve Bank of New York discusses the eligibility restrictions at: http://www.newyorkfed.org/markets/rrp_counterparties.html
[7] More details of overnight RRPs can be found at: http://www.federalreserve.gov/monetarypolicy/overnight-reverse-repurchase-agreements.htm
[8] Authority to operate the TDF comes from section 19(b)(12) of the Federal Reserve Act, which allows eligible institutions to receive earnings on balances maintained at Federal Reserve Banks and authorizes the Board of Governors to prescribe such regulations concerning the payment of such earnings. More details of the TDF can be found at: http://www.federalreserve.gov/monetarypolicy/tdf.htm

Reserve. As a result, an increase in the IOER rate will put upward pressure on a range of short-term interest rates. In effect, raising the IOER rate allows the Federal Reserve to increase the value that banks place on reserve balances, which will have market effects similar to those associated with a reduction in the quantity of reserves in the traditional, quantity-based mechanism for tightening the stance of monetary policy.

As a complement to the IOER rate, the Federal Reserve could also employ ON RRP operations to put additional upward pressure on short-term interest rates. In an ON RRP operation, eligible Federal Reserve counterparties, importantly including many nonbank financial institutions, may invest funds with the Federal Reserve overnight at a given rate. Consequently, these institutions should be unwilling to lend to private counterparties in money markets at a rate below that available to them on ON RRP transactions with the Federal Reserve. As a result, ON RRP operations should complement the IOER rate in helping to establish a floor on money market interest rates. Finally, the Federal Reserve could also employ term operations—term deposits issued through the TDF and term RRPs—to help drain reserves in the banking system and put further upward pressure on short-term interest rates.

As part of prudent planning, the Federal Reserve has been testing the operational readiness of its new tools. Between December 2009 and April 2013, the Open Market Desk conducted a series of small-scale, term RRP test operations. Those testing operations used a multi-price auction format, a term of two to six days, and accepted collateral included U.S. Treasury securities, direct agency debt, and agency mortgage-backed securities. The number of eligible counterparties was extended over this period. The amount awarded in these test operations peaked at about $3.3 billion.

The Federal Reserve's testing of the TDF has been ongoing since June 2010. The term of the deposits has ranged from 7 to 84 days, and the interest rate offered on these deposits has been determined at auction or fixed by the Board of Governors. Recently, the maximum award amount per institution and the interest rate paid at the facility were raised gradually.[9] As a result, as shown in figure 1, the size of term deposits increased considerably relative to levels in test operations conducted in the past.

Since September 2013, the Desk has been conducting daily fixed-rate, capped-allotment ON RRP operations as authorized by the FOMC. As shown in figure 2, daily take-up of ON RRPs has ranged from under $1 billion up to about $340 billion, with the variation in usage primarily reflecting three factors: (1) changes in the daily counterparty allotment limit; (2) changes in the spread between market repurchase agreement rates and the rate offered in the Federal Reserve's ON RRP operations; and (3) calendar effects, including those related to month- and quarter-ends. Since the

[9] Upcoming TDF tests in October and November 2014 will incorporate an early withdrawal feature that will allow depository institutions to obtain a return of funds prior to the maturity date subject to an early withdrawal penalty. For more detail see http://www.federalreserve.gov/newsevents/press/monetary/20140904a.htm

introduction of the exercise, the daily counterparty allotment limit has been gradually raised and the fixed rate offered on ON RRP operations has been changed within the authorized limits and currently stands at 5 basis points, with the collateral accepted in all the operations being limited to U.S. Treasury securities. As discussed in the FOMC's recent statement on policy normalization principles and plans and the associated operational statement released by the Open Market Desk, the FOMC has authorized testing of various features of ON RRP operations that are aimed maintaining the effectiveness of ON RRP operations in supporting monetary policy implementation while also mitigating potential risks in financial markets.[10]

With these foundational concepts in place, we now move to the model that will help illustrate how these policy tools can remove monetary policy accommodation when the FOMC determines it is the appropriate time to raise interest rates.

3. Structure of Financial and Nonfinancial Sector Balance Sheets

As a point of departure for the analysis, the model focuses on the balance sheets of a number of financial and nonfinancial sectors. Nonfinancial sectors include households, businesses, and government. The financial sectors include banks, dealers, GSEs and the Federal Reserve.

To keep things manageable, the stylized balance sheets for each sector are shown below. Households have net worth that they invest in various financial assets including government securities, private repurchase agreements (repo), bank deposits, Fed RRP, and agency debt. The household sector here encompasses money funds so the investments of households in Fed RRP might be interpreted as money fund investments of cash with the Federal Reserve at an overnight reverse repurchase agreement facility.

Households

Assets	Liabilities
Securities	Net Worth
Private Repo	
Deposits	
Fed RRP	
Agency Debt	

Banks

Assets	Liabilities
Securities	Deposits
Fed RRP	Fed Funds
Reserves	
Agency Debt	
Business Loans	
Term Deposits	

Dealers

Assets	Liabilities
Securities	Private Repo
Agency Debt	

GSEs

Assets	Liabilities
Securities	Agency Debt
Private Repo	
Fed Repo	
Fed Funds	
Reserves	

Fed

Assets	Liabilities
Securities	Reserves
	Fed RRP
	Term Deposits

Businesses

Assets	Liabilities
Inventories	Loans

[10] Statements and operating policies associated with the ON RRP exercise can be found at http://www.ny.frb.org/markets/rrp_op_policies.html

Banks invest in government securities, Fed RRP, reserves, agency debt, business loans, and Fed term deposits; these assets are financed by borrowing in the markets for deposits and federal funds.[11] Dealers invest in government securities and agency debt and finance those assets in repo markets. GSEs hold government securities and invest in a range of short-term assets including private repo, Fed RRP, overnight federal funds, and reserve balances. Those assets in turn are financed with agency debt. The Federal Reserve holds securities as its only asset, and its liabilities include reserves, RRPs, and term deposits. Businesses hold inventories as an asset and finance inventory holdings with bank loans. The government sector issues securities to finance spending. The asset for the government sector is the present discounted value of future taxes revenues.

In this structure, the household sector is the net source of wealth in the economy and the only sector that is a net lender. The government and business sectors are net borrowers. The financial system comprised of banks, GSEs, dealers and the Fed effectively transfer household wealth to the ultimate borrowers. The government supplies securities to meet demand at the prevailing market interest rates.

4. Demand and Supply Curves

Following the basic Brainard/Tobin paradigm, the next step in the analysis is to develop demand and supply curves for all individual financial assets in the economy. To that end, we develop an optimizing framework for all the main actors in this economy that incorporates an element of "preferred habitat." In this setup, households and financial firms have fundamental preferences over the composition of their assets and liabilities but also adjust the composition of assets and liabilities in response to the structure of interest rates. Of course, in a more complete model, one would want to specify the economic factors that give rise to the underlying portfolio preferences. Such factors might include risk diversification, imperfect competition, regulatory incentives and so forth. Here, we simply take these underlying preferences as exogenous. Given these preferences, the framework generates a set of downward sloping demand curves and upward sloping supply curves for all financial claims in the model. These demand and supply curves are linked across markets and institutions through the balance sheet structure described above.

Financial Intermediaries: Financial intermediaries—banks, dealers and the GSEs—maximize profits subject to the costs of deviating from the preferred habitat balance sheet composition as follows

$$\sum_{i=1}^{n} r_i^A A_i - \sum_{j=1}^{k} r_j^L L_j - \frac{\phi}{2} S^2 - \frac{1}{2} \tilde{A}' \Omega \tilde{A} - \frac{1}{2} \tilde{L}' Z \tilde{L} \quad , \qquad (1)$$

where

[11] See Keister and McAndrews (2009) for a primer on bank reserve management in an environment with abundant reserves.

$A_i = quantity\ of\ asset\ i$

$L_j = quantity\ of\ liability\ j$

$S = scale\ of\ balance\ sheet$

$\alpha_i S = preferred\ habitat\ level\ of\ i^{th}\ asset$

$\rho_j S = preferred\ habitat\ level\ of\ j^{th}\ liability$

$\tilde{A}_i = habitat\ deviation\ for\ i^{th}\ asset = A_i - \alpha_i S$

$\tilde{L}_j = habitat\ deviation\ for\ j^{th}\ liability = L_j - \rho_j S$

$r_i^A = rate\ on\ i^{th}\ asset$

$r_j^L = rate\ on\ j^{th}\ liability$

The parameters α_i and ρ_j define the "preferred habit" shares of total assets and total liabilities for each individual asset and liability category. The "habit deviations" are then just the differences between the actual quantities for each individual asset and liability and the preferred habitat quantities. The individual habit deviations are written in matrix notation as:

$$\tilde{A}' = \left[\tilde{A}_1, ..., \tilde{A}_I \right]$$

$$\tilde{L}' = \left[\tilde{L}_1, ..., \tilde{L}_J \right]$$

The scale of the balance sheet is equal to the sum of individual asset holdings and individual liabilities.

$$S = \sum_{i=1}^{I} A_i = \sum_{j=1}^{J} L_j$$

The matrices Ω and Z define the cost of departing from the preferred habitat quantity of each asset and liability. Given this objective function, intermediaries will choose an optimal scale of the balance sheet given by equation (2).

$$S = (\alpha' r^A - \rho' r^L) / \phi \qquad (2)$$

This expression indicates that the optimal scale of the firm is related to the net interest margin, $\alpha' r^A - \rho' r^L$, divided by a balance sheet cost factor. When the costs of balance sheet expansion increase—perhaps due to a period financial distress or more binding regulatory requirements—the parameter, ϕ, increases and the optimal scale of the balance sheet is reduced.

The solutions for the optimal habit deviations are given by:

$$\tilde{A} = \Omega^{-1}(r^A - \gamma_A u)$$
$$\gamma_A = (u'\Omega^{-1}r^A)/(u'\Omega^{-1}u)$$

$$\tilde{L} = Z^{-1}(\gamma_L u - r^L)$$
$$\gamma_L = (u'Z^{-1}r^L)/(u'Z^{-1}u)$$

Here u is a vector of 1s with the same dimension as the vector of rates, r. The values γ_A and γ_L are just scalars that represent a cost-weighted average of rates on assets and liabilities.

Given the optimal scale of the balance sheet determined by (2), intermediaries choose the optimal composition of their assets and liabilities according to equations below. These equations indicate that the deviations of actual holdings of any particular asset or liability relative to the preferred habitat quantities are a function of the spreads of rates on assets or liabilities relative to a weighted average rate of return on assets or liabilities (γ_A or γ_L).

$$A = \alpha S + \tilde{A}$$
$$L = \rho S + \tilde{L}$$

As an example, it is instructive to take an especially simple case where the matrices Ω and Z are diagonal with the diagonal elements for the *inverse* matrices Ω^{-1} and Z^{-1} are given by $\omega_{i,i}$ and $z_{i,i}$, respectively. In equations (3) and (4), the terms $\omega_{i,j}$ and $z_{i,j}$ capture the possible substitutions across different types of assets and liabilities. When the parameters $\omega_{i,i}$ and $z_{i,i}$ are small, the cost of choosing a quantity for an individual asset or liability that differs from the habit level is very high. In this special case, the matrix expressions above boil down to:

$$A_i = \alpha_i S + \sum_j (\omega_{i,j})(r_j^A - \gamma_A) \quad (3)$$

$$L_i = \tau_i S - \sum_j (z_{i,j})(r_j^L - \gamma_L) \quad (4)$$

And

$$\gamma_A = \sum_{i=1}^{n} m_i r_i^A \quad where \quad m_i = \omega_i / \sum_{i=1}^{n} \omega_i$$

$$\gamma_L = \sum_{i=1}^{n} q_i r_i^L \quad where \quad q_i = z_i / \sum_{i=1}^{n} z_i$$

The optimal choices for individual for assets and liabilities in this special case are given by a term that reflects their "preferred habitat" for an individual asset or liability—the first term in each expression—and the spread of the rate of return on that asset or liability relative to an elasticity weighted average of other asset or liability rates. When the preferred habitat costs are high, the factors $\omega_{i,i}$ and $z_{i,i}$ are small implying small deviations from the preferred habitat values. So the response of the actual choices for individual assets and liabilities to a change in the own rate is smaller when the preferred habitat costs are high. Put another way, the own rate for the particular asset or liabilities must depart substantially from other rates in order to induce a significant deviation from the preferred habitat quantities.

A particularly simple form of (3) results when the cost matrix Ω is diagonal with a constant factor, δ, along the diagonal. In this case, the weighted average return on assets is just the simple arithmetic average of rates $\bar{r}$ and (3) reduces to:

$$A_i = \alpha_i S + (r_i^A - \bar{r}) / \delta \qquad (3')$$

In this case, the firm boosts its holdings of a particular asset whenever the own return on that asset exceeds the arithmetic average of rates on all assets held in the portfolio. The extent of substitution toward the higher yield asset is determined by the cost parameter δ. When the cost of deviating from the preferred habitat quantity is high ($\delta >> 0$), the willingness of the firm to hold larger quantities of the asset is reduced. Put another way, a larger increase in the rate of return on that asset relative to other assets is required to induce the same degree of departure from the preferred habitat holdings.

Households: The household's optimization problem is very similar to the general form assumed for intermediaries except that we assume the size of the household balance sheet is fixed. As a result, the household's optimization problem becomes one of optimal portfolio allocation and the solution to this problem takes the form of equation (3) with the scale of the balance sheet S fixed and equal to household net worth. As in equation (3), households will gravitate toward a generic preferred-habitat composition of their assets across various financial instruments but are willing to deviate from this composition in response to differences in the relative rates of return across different asset categories. The household is assumed to maximize an objective function V defined as the return on its portfolio less preferred habitat costs:

$$V = \sum_{i=1}^{n} r_i A_i - \frac{1}{2} \tilde{A}' \Omega \tilde{A}$$

subject to

$$\sum_{i=1}^{n} A_i = Net\ Worth$$

The solution to this problem is analogous to equation (3) above:

$$A_i = \alpha_i NW + \sum_j (\omega_{i,j})(r_j^A - \gamma_A) \qquad (5)$$

As above, the parameters $\omega_{i,j}$ are elements of the inverse cost matrix Ω^{-1}.

Businesses: Businesses hold inventories as assets and finance those inventories with business loans from banks. In determining the optimal level of inventories and loans, businesses maximize a profit function given by:

$$\pi = C - r_{LN} LN - \frac{(I - I^*)^2}{2b}$$

where

C = constant

LN = business loans

I = inventories

I^* = desired inventories

r_{LN} = business loan rate

Businesses adjust the actual level of inventories relative to the target level based on the level of the business loan rate. Since all inventories are financed by business loans, equation (6) also describes the demand for business loans

$$LN = I^* - br_{LN} \qquad (6)$$

5. Equilibrium

Given these demand and supply curves, the equilibrium can be described by setting demand equal to supply in each market. In keeping track of financial instruments, sectors, and assets and liabilities, we use the notation X^A_{Sector}, X^L_{Sector} to designate the quantity of the instrument X held or issued by sector "X" as an asset (A) or liability (L). For example, D^A_{HH} refers to the quantity of deposits held by the household sector as an asset. With this bit of notation, the equilibrium conditions in each market are shown below.

In the deposit market, we have the demand for deposits as an asset by the household sector equal to the desired quantity of deposit liabilities for banks.

$$D^A_{HH} = D^L_{BK} \qquad (7)$$

In the repo market, the demand for repo investments by households and GSEs is equal to the quantity of repo borrowing by dealers.

$$P^A_{HH} + P^A_{GSE} = P^L_{DL} \tag{8}$$

In the agency debt market, the demand for agency debt investments by households, banks, and dealers is equal to borrowing in agency debt markets by the GSEs.

$$AD^A_{HH} + AD^A_{BK} + AD^A_{DL} = AD^L_{GSE} \tag{9}$$

In the federal funds market, the desired amount of lending in the fed funds market by GSEs is equal to the desired quantity of fed funds borrowing by banks.

$$FF^A_{GSE} = FF^L_{BK} \tag{10}$$

In the loan market, business demand for loans is equal to the supply of business loans from banks.

$$BL^A_{BK} = BL^L_{BS} \tag{11}$$

Finally, the demand for reserves from banks and GSEs, the demand for Fed repo by households, banks and GSEs, and the demand for term deposits from banks must equal the Fed's securities portfolio.

$$RS^A_{BK} + RS^A_{GSE} + RRP^A_{HH} + RRP^A_{BK} + RRP^A_{GSE} + TD^A_{BK} = SEC^A_{FED} \tag{12}$$

When each of the equilibrium conditions above is satisfied, holdings of government securities and bank loans across the system will equal household net worth. That is,

$$S^A_{BK} + S^A_{GSE} + S^A_{HH} + S^A_{DL} + S^A_{FED} + LN^A_{BK} = NW_{HH} = S^L_{GOV} + LN^L_{BUS} \tag{13}$$

Equation (13) illustrates the underlying structure of the model—the household sector is the source of all wealth available for lending and the government sector and the business sector are the source of all net borrowing. A portion of household lending is direct in the form of holdings of government securities. The remaining portion of household lending is intermediated through the financial sector.

The interest rates for all financial claims are denoted as:

r_D = deposit rate
r_L = loan rate
r_S = securities rate
r_P = repo rate
r_{GSE} = agency debt rate
r_{FF} = fed funds rate
r_{RRP} = fed RRP rate
r_{TDF} = term deposit rate
r_{RES} = IOER

The first six private sector rates are endogenous while the rates on Fed RRP, term deposits and reserves are set by the Federal Reserve. Together, equations (7)-(12) determine the equilibrium levels of the private sector rates and the associated split of Federal Reserve liabilities between reserves, Fed RRP, and term deposits.

6. Some Benchmark Cases

The number of sectors in the model described above and the linkages among them introduce a considerable degree of complexity in the analysis for the full model. However, many of the basic features of the model can be gleaned from two special cases that include only a household sector and banking sector along with the Federal Reserve.

Case 1: Reserves as the Only Federal Reserve Liability

In a particularly simple special case, the preferred habitat model reduces to traditional analysis based on a reserve demand curve. In this special case, households hold only deposits and securities and their demands for these assets are exogenous. Banks hold securities and reserve balances and finance these holdings with deposits. In that case, the size of the banking sector is also exogenous and determined by households' desired deposit holdings. Banks optimize over the composition of their assets between securities and reserves as described above. The demand for reserves determined as shown in equation (3) is given by:

$$RS_{BK}^{A} = \alpha_{RES}\beta_D - \tau(r_S - r_{RES}) \qquad (14)$$

Equation (14) is a version of the traditional reserve demand curve. Banks wish to hold some quantity of reserves that is a function of the opportunity cost of holding reserves given by $r_S - r_{RES}$. There is a fundamental "preferred habitat" demand for reserves given by banks' preferred habitat parameter α_{RES} times household's desired deposit holdings β_D. This fundamental demand could derive from various factors including reserve requirements, regulatory requirements, or from demands for reserves to meet clearing needs. The downward slope of the reserve demand curve determined by the parameter τ is directly associated with the costs of deviating from the bank's

"preferred habitat" quantity of reserves. In order to induce banks to willingly hold a quantity of reserves that exceeds the fundamental demand, $\alpha_{RES}\beta_D$, the rate of return on alternative assets must decline relative to the rate paid on reserves.

Rearranging equation (14) and imposing the equilibrium condition that the aggregate demand for reserves must equal the aggregate quantity of reserves supplied by the Federal Reserve yields:

$$r_S = r_{RES} + (1/\tau)(\alpha_{RES}\beta_D - RS^L_{FED}) \qquad (15)$$

Equation (15) implies that the interest rate on reserves sets a base level for market rates. However, the level of market rates can be driven above or below this level by adjusting the aggregate quantity of reserves, RS^L_{FED}, relative to the fundamental demand for reserves, $\alpha_{RES}\beta_D$. Again, this stems from the basic economics in the preferred habitat framework. If the Federal Reserve provides a level of reserves that exceeds the fundamental demand, banks bid up the prices of securities (and drive down their yields) until they are indifferent at the margin between holding reserves and securities. The upshot of this special case is that the preferred habitat model in its simplest form is fully consistent with the traditional analysis of reserve market issues based on the reserve demand curve.

It is also useful to examine how the deposit rate is determined in this special case. As in equation (2), banks will set the optimal scale of the balance sheet according to:

$$D^L_{BK} = (\alpha_{RES}r_{RES} + \alpha_S r_S - r_D)/\phi$$

With household demand for deposits fixed at β_D, this expression implies that the equilibrium deposit rate will be determined as:

$$r_D = \alpha_{RES}r_{RES} + \alpha_S r_S - \phi\beta_D$$

The deposit rate will generally be set at a level below the weighted average rate of return on other assets by a factor reflecting the marginal cost of balance sheet expansion. This factor, in turn, is a function of the size of the balance sheet β_D and the parameter ϕ that influences the marginal cost of balance sheet expansion. Combining this expression with the equilibrium relationship for the rate on securities in (15), we have:

$$r_D = r_{RES} + (\alpha_S/\tau)(\alpha_{RES}\beta_D - RS^L_{FED}) - \phi\beta_D$$

As in equation (15), an increase in the interest rate on reserves passes through one for one to the level of deposit rates. Changes in the quantity of reserves affect deposit rates in the same direction as rates on securities but by somewhat less. As a result, open market operations that increase the supply of reserves tend to depress market rates by somewhat more than deposit rates and cause the spread between market rates and deposit rates to narrow. By contrast, an increase in the interest rate on reserves leaves the spread between the rate on securities and the deposit rate unchanged.

One final point to note is that the equilibrium relationship in the reserve market is the mirror image of the equilibrium relationship in the securities market. Total demand for securities is given by:

$$\{\beta_S\}+\{\alpha_S\beta_D+\tau(r_S-r_{RES})\}+\{S_{FED}\}=1$$

The three terms in brackets represent the demand for securities by households, banks, and the Federal Reserve, respectively. The sum of their securities holdings equals household net worth, normalized here to a quantity of 1. Using the fact that Federal Reserve securities holdings, S_{FED}, equal reserve liabilities and the fact that the household portfolio shares, β_S and β_D, sum to 1, this expression is identical to equation 15. Rearranging this expression, we have:

$$r_S = r_{RES} + (1/\tau)((1-S_{FED})-(\beta_S+\alpha_S\beta_D))$$

In this version of equation (15), the rate on securities is a function of the supply of securities available to the market $(1-S_{FED})$ relative to the private sector demand for securities $(\beta_S+\alpha_S\beta_D)$. In particular, as the Federal Reserve increases its holdings of securities, the supply available to the private sector falls and that puts downward pressure on yields. This basic logic underlies analysis of the effects of large scale asset purchases working through the so-called "portfolio balance" channel.

Case 2: Multiple Federal Reserve Liabilities

A modest extension of this special case incorporates two additional Federal Reserve liabilities—term deposits and ON RRP—and allows households some scope to choose among different asset categories. In this variation, households hold securities, deposits, and Fed RRP. Banks hold securities, reserves, and term deposits and these assets again are financed entirely by deposits. To keep things simple, we again assume that household demand for deposits is exogenous, but households are allowed to substitute between Fed RRP and securities. In addition, we assume the preferred habitat cost functions are diagonal with identical elements. In this case, equations analogous to (14) above can be developed to describe the demand curves for each type of Fed liability:

$$RS_{BK}^{A} = \alpha_{RES}\beta_D - \tau(r_S - r_{RES}) - \tau(r_{TD} - r_{RES}) \quad (16)$$

$$TD_{BK}^{A} = \alpha_{TD}\beta_D - \tau(r_S - r_{TD}) - \tau(r_{RES} - r_{TD}) \quad (17)$$

$$RRP_{H}^{A} = \beta_{RRP} - \mu(r_S - r_{RRP}) \quad (18)$$

Banks' demands for reserves and term deposits given in (16) and (17) include fundamental components associated with their "preferred habitats" for these liabilities. In addition, banks weigh two margins of substitution in determining their desired holdings of reserves and term deposits. As in the traditional reserve demand analysis in (14), the demand curves for both reserves and term deposits include an interest rate spread term that captures the incentives for banks to substitute between Federal Reserve liabilities and securities. In addition, each equation includes a spread term

capturing the potential for substitution between term deposits and reserves. Household's desired holdings of Fed RRP in equation (18) similarly involve a component of fundamental demand and a component representing the substitution between holding securities versus Fed RRP.

The total demand for Federal Reserve liabilities is given by the sum of these equations as:

$$RS_{BK}^{A} + TD_{BK}^{A} + RRP_{H}^{A} = (\beta_{RRP} + \alpha_{RES}\beta_{D} + \alpha_{TD}\beta_{D}) - \tau(r_{S} - r_{RES}) - \tau(r_{S} - r_{TD}) - \mu(r_{S} - r_{RRP}) \quad (19)$$

Similar to the simplest case, this demand for total Federal Reserve liabilities incorporates a term representing fundamental demands in addition to interest rate spread terms capturing substitutions between each type of Federal Reserve liability and securities holdings. As before, assuming that the Federal Reserve can fix the total quantity of its liabilities, this expression can be rearranged to yield an equilibrium expression for the rate of interest on securities as:

$$r_{S} = (\frac{\mu}{\mu + 2\tau})r_{RRP} + (\frac{\tau}{\mu + 2\tau})r_{RES} + (\frac{\tau}{\mu + 2\tau})r_{TD} + (\frac{1}{\mu + 2\tau})(\beta_{RRP} + \alpha_{RES}\beta_{D} + \alpha_{TD}\beta_{D} - L_{FED}) \quad (20)$$

In the preferred habitat model with multiple Federal Reserve liabilities, equation (20) indicates that it is the balance of the aggregate demand and supply of *all* Federal Reserve liabilities that influences the level of market rates rather than just the level of reserves. The three administered rates on Federal Reserve liabilities establish a base level of rates. The coefficients on the individual administered rates sum to 1, so this weighted average of administered rates sets the base for market rates. As in the traditional reserve demand curve shown in equation (14), the level of market rates can be driven away from this base level if the Federal Reserve expands or contracts the total quantity of its liabilities, L_{FED}, relative to the fundamental demands for Fed liabilities given by $\beta_{RRP} + \alpha_{RES}\beta_{D} + \alpha_{TD}\beta_{D}$. As noted above, equation 20 is the mirror image of the equilibrium condition in the securities market.

As in the case discussed above, the deposit rate is again determined as a weighted average rate of return on other assets minus the marginal cost of balance sheet expansion associated with deposits:

$$r_{D} = \alpha_{RES}r_{RES} + \alpha_{TD}r_{TD} + \alpha_{S}r_{S} - \phi\beta_{D} \quad (21)$$

Combining this expression with the equilibrium expression for the rate on securities results in

$$r_{D} = (\frac{\mu\alpha_{S}}{\mu + 2\tau})r_{RRP} + (\frac{\alpha_{RES}(\mu + 2\tau) + \alpha_{S}\tau}{\mu + 2\tau})r_{RES} + (\frac{\alpha_{TD}(\mu + 2\tau) + \alpha_{S}\tau}{\mu + 2\tau})r_{TD} + (\frac{\alpha_{S}}{\mu + 2\tau})(\beta_{RRP} + \alpha_{RES}\beta_{D} + \alpha_{TD}\beta_{D} - L_{FED}) - \phi\beta_{D} \quad (22)$$

The coefficients on the administered rates in this expression sum to 1, so the deposit rate is also determined by a weighted average of the administered rates, and an increase in all three rates passes through one for one to a change in deposit rates. However, an increase in all three administered

rates leaves the spread between the rate on securities and the rate on deposits unchanged. Changes in the aggregate supply of Fed liabilities affect deposit rates in the same direction as the rate on securities, but by somewhat less.

General Issues in a World with Multiple Federal Reserve Liabilities

A number of important issues arise in connection with monetary policy implementation in a world in which the Federal Reserve can independently set administered rates on multiple liabilities. Many of the issues are highlighted in equations (20) and (22) describing the equilibrium values of the rate on securities and deposits.

Interest Rate Control: One implication of equations (20) and (22) is that the Federal Reserve can choose levels of administered rates to achieve any desired level of the rate on securities and deposits. That is, these policy tools affect money market rates by introducing alternative investment opportunities for financial institutions, which affects arbitrage across markets. However, the administered rates do not establish a firm floor on the level of market rates. Unexpected changes in the supply of total Federal Reserve liabilities can still push these market rates above or below the Federal Reserve's desired level. The inability to establish a firm floor on rates stems directly from the quadratic specification of the preferred habitat costs. In particular, once the total supply of Federal Reserve liabilities exceeds the fundamental demands, each additional dollar of Federal Reserve liabilities increases preferred habitat costs and the "all in" return on Federal Reserve liabilities falls below the weighted average administered rate. As a result, households and banks are willing to accept lower rates of return on securities and deposits in order to avoid bearing the marginal preferred habitat cost of holding excess quantities of Federal Reserve liabilities. Of course, in aggregate, the private sector must hold the quantity of liabilities the Federal Reserve supplies. So the rates of return on securities and deposits continue to fall until households and banks are just indifferent at the margin between holding securities and deposits versus Federal Reserve liabilities.

Differential Effects of Administered Rates: Equation (20) also indicates that raising any one of the administered rates while holding the other rates fixed does not generate a one for one pass through to the level of market rates. However, given that the coefficients on these terms sum to 1, raising all rates by the same amount will generate a one for one pass through to the level of market rates. Another feature of this framework is that the marginal effects of changing individual administered rates are not the same. For example, the marginal effect of changing the RRP rate is different than the marginal effect of changing the rate on reserves. Examining the coefficients in equation (20) indicates that the relative weight attached to the RRP rate hinges on the ratio of the substitution parameters μ, τ. In more complicated examples, the weights on reserves and term deposits may also differ so there can be differences in the market effects of changes in the interest rate on reserves and the interest rate on term deposits. The key factor that determines the relative importance of one administered rate versus another in affecting the level of market rates is the strength of the substitution between the corresponding Federal Reserve liability and securities. The rates on Federal Reserve liabilities that are relatively strong substitutes for securities will have a larger effect on market rates than those that are not close substitutes with securities.

The Role of Reserve Draining: Equation (20) also provides some perspective on the role of "reserve draining" in putting upward pressure on market interest rates. With a traditional reserve demand curve as presented in equation (14) in mind, it is natural to view the effect of increasing term deposits or overnight RRP as putting upward pressure on market interest rates by reducing the quantity of reserves. Equation (20) makes it clear that this is not the right intuition in a model with multiple Federal Reserve liabilities. It is true that the individual demand curves for each liability are downward sloping. So the effect of issuing term deposits does reduce reserves and does tend to push up the level of market rates along the reserve demand curve (16). However, there is an offsetting effect because issuing more term deposits also puts downward pressure on market rates by increasing the supply of term deposits through equation (17). Indeed, equation (20) indicates that the individual quantities of particular Federal Reserve liabilities do not matter in determining the level of market interest rates. What matters is the total quantity of Federal Reserve liabilities, L_{FED}, relative to the total "fundamental" demand for Federal Reserve liabilities given by $\beta_{RRP} + \alpha_{RES}\beta_D + \alpha_{TD}\beta_D$. Of course, if the Federal Reserve offers term deposits at a higher rate, the quantity of term deposits will go up and the quantity of reserves will go down and the level of market interest rates will rise as indicated by equation (20). However, these effects are not generated fundamentally by creating scarcity of reserves but rather by inducing banks to substitute out of securities and thereby generating upward pressure on their yields.

Quantity-Based Operations: Equation (20) assumes that the Federal Reserve establishes administered rates for all of its liabilities and allows the private sector to determine the composition of Federal Reserve liabilities. Of course, the Federal Reserve could also conduct quantity based operations if it wished. In this case, equation (20) would still hold but one or more of the administered rates on the right hand side of the equation would be endogenous. As one example, it's useful to consider the case when the Federal Reserve offers a fixed quantity of term deposits $\bar{T}$. In this case, equation (17) describing the demand for term deposits together with the fixed supply of term deposits would define the endogenous level of the term deposit rate as a function of the interest rate on securities and reserves as:

$$r_{TD} = (\bar{T} - \alpha_{TD}\beta_D)/2\tau + \frac{1}{2}(r_S + r_{RES})$$

This relationship can be combined with equation (20) to arrive at:

$$r_S = (\frac{\mu}{\mu + 1.5\tau})r_{RRP} + (\frac{1.5\tau}{\mu + 1.5\tau})r_{RES} +$$
$$(\frac{1}{\mu + 1.5\tau})(\beta_{RRP} + \alpha_{RES}\beta_D + \alpha_{TD}\beta_D - L_{FED}) + (\frac{.5}{\mu + 1.5\tau})(\bar{T} - \alpha_{TD}\beta_D)$$

In this case, the equilibrium level of the market interest rates is again a weighted average of the two exogenous administered rates. As before, the equilibrium rate on securities responds to the gap between total Federal Reserve liabilities and the fundamental demand for Federal Reserve liabilities.

The last term shows that increasing the quantity of term deposits over and above the fundamental demand for term deposits also puts upward pressure on market rates. This effect stems from the resulting upward pressure on the equilibrium term deposit rate and the associated response by banks to higher rates on term deposits.

The Variance of Interest Rates: Equation (20) provides some insight on model implications for variability of market rates. If the so-called fundamental demands for Federal Reserve liabilities are stochastic, and the total quantity of Federal Reserve liabilities is fixed then the variance of market rates would be given by:

$$Var(r_S) = (\frac{1}{\mu + 2\tau})^2 Var((\beta_{RRP} + \beta_D(\alpha_{RES} + \alpha_{TD})) =$$

$$(\frac{1}{\mu + 2\tau})^2 (Var(\beta_{RRP}) + Var(\beta_D(\alpha_{RES} + \alpha_{TD})) + 2Cov(\beta_{RRP,}\beta_D(\alpha_{RES} + \alpha_{TD}))$$

The variance of market rates would thus reflect the variance in household demand for Fed RRP and the variance in bank demands for reserves and term deposits. Moreover, the coefficient on the outside of this variance term, $\mu + 2\tau$, becomes smaller when households and banks become less willing to substitute across assets and that leads to greater volatility in interest rates. To minimize this variability, the Federal Reserve would need to make appropriate adjustments to the levels of administered rates or to the size of the balance sheet to offset the shocks to these fundamental demands.

The Footprint Effects of Various Tools: Although different combinations of tools may be used to achieve the same level of interest rates, the implications for patterns of financial intermediation across banks and nonbanks can be quite different. Combining equation (18) describing household demand for Fed RRP with equation (20) for the equilibrium rate on securities, we have:

$$RRP_H^A = \beta_{RRP} - \mu(r_S - r_{RRP}) =$$

$$\beta_{RRP} + (\frac{\mu\tau}{\mu + 2\tau})(r_{RRP} - r_{RES}) + (\frac{\mu\tau}{\mu + 2\tau})(r_{RRP} - r_{TD}) + (\frac{\mu}{\mu + 2\tau})(L_{FED} - (\beta_{RRP} + \alpha_{RES}\beta_D + \alpha_{TD}\beta_D))$$

Not surprisingly, the quantity of Federal Reserve liabilities held outside of the banking system depends importantly on the spread between the Fed RRP rate and the rate offered on Federal Reserve liabilities held by the banking sector. If these rate spreads are zero as proposed recently by Gagnon and Sack (2014), the quantity of liabilities held by the nonbank sector is equal to the fundamental demand for these liabilities β_{RRP} plus a share of total Federal Reserve liabilities L_{FED} in excess of the fundamental demand for total Federal Reserve liabilities. The magnitude of the last component depends importantly on the magnitude of the parameter μ that captures the willingness of households to substitute between securities and Fed RRP. If the degree of substitution is high,

then a large portion of total Federal Reserve liabilities in excess of fundamental demands will be held by the nonbank sector.

7. Full Model

With some of the core features of the model outlined in the special cases examined above, we now turn to an analysis of the full model. As noted above in section 3, the full model incorporates additional assets (federal funds, private repo, agency debt, and bank loans) and additional sectors (dealers, GSEs and businesses). Those additions provide a richer set of interactions than the special cases in section 6 but also introduce a good deal of complexity in the model solutions. Rather than focusing on the explicit analytical solution, below we report numerical results to illustrate key features of the full model.

7.1 Specification and Calibration

To develop reasonable numerical examples, we must first choose parameter values for all of the key behavioral relationships. The parameters for the model are loosely based on the relative asset holdings for each sector from the Federal Reserve's Z.1 statistical release on Financial Accounts of the United States for 2013Q2.[12] In addition, when setting preferred habitat target holdings for each sector, costs of departing from the preferred-habitat quantity of each variable (the diagonal elements of the preferred habitat cost matrices, Ω and Z), and balance sheet cost parameters, we attempted to roughly match the equilibrium asset and liability holdings for each sector to the patterns in the 2013:Q2 Flow of Funds data and have the resulting endogenous rates display basic patterns that are similar to those of observed market rates. Additional details of the parameterization are provided in Appendix 1.

7.2 Numerical Results

Based on the calibration described above, this section examines the full model results for alternative monetary policy implementation regimes. Although we have made a modest attempt at calibration, the scenarios discussed below are intended only to illustrate some of the qualitative features of the full model; the quantitative results are not intended as forecasts of what would actually happen in these scenarios. Indeed, the results in various scenarios can be quite sensitive to particular parameter settings. That said, the particular scenarios reviewed below help highlight a number of issues associated with the various tools available to policymakers for raising short-term interest rates.

We start with a base case, which resembles the current situation in which the Federal Reserve implements IOER at 25 basis points but draining tools are not in place. Sequentially, we consider the implications of increasing the IOER rate, introducing an ON RRP facility, and using term deposits. Each scenario will provide intuition for how the tool can affect market interest rates and asset allocations.

[12] However, relative to the household sector, the sizes of banks and GSEs are small compared to the data.

7.2.1 Base Case (IOER=25 basis points, No Other Policy Tools)

In the base case, the Federal Reserve does not issue ON RRPs or term deposits and relies exclusively on IOER to manage the level of interest rates. As noted in Table 1, the model results generate patterns of intermediation that are similar to those in the flow of funds accounts. The cells highlighted in orange in this table report liabilities of the entities in the columns, while all other cells report asset holdings of the entities. As described above, households are a major actor in the model. The household sector (which includes money funds, shown in column 1) holds about 85 percent of its assets in securities with the remainder spread between deposits, agency debt, and private repo. Focusing on the balance sheet of the banking sector, reserve balances account for roughly 25 percent of total assets, while securities holdings and loans as a share of total assets are about 10 percent and 60 percent, respectively. The federal funds market (row 3 in the table) is very small relative to the size of other markets. As is currently the case, the lenders in this market are the GSEs and the borrowers are banks that find it profitable to maintain a small share of their total liabilities in the form of federal funds borrowing.

Table 2, row 1, reports the money market rates for this scenario. In order to induce the private sector to hold a quantity of Federal Reserve liabilities that exceeds the preferred habitat levels, most money market rates fall well below IOER. As noted in section 6, IOER does not set a floor on short-term money market rates in general and, in the base case, total reserves are very large relative to the fundamental or preferred habitat demand for reserves, putting downward pressure on rates across the financial system.

7.2.2 Effects of an Increase IOER

Table 3 reports the effect of a 10 basis point increase in IOER on the level of the various endogenous rates. The endogenous rates rise nearly one for one with the assumed increase in IOER. This is consistent with the discussion in section 6; the model generally delivers solutions in which the endogenous variables are determined importantly by a weighted average of the Federal Reserve's administered rates. When reserves are the Federal Reserve's only liability and IOER is the only administered rate, an increase in IOER passes through one for one to the level of market rates. In the model then, policymakers can increase market rates predictably with this policy tool alone. However, the *level* of market rates following an increase in IOER would remain below the administered rate.

7.2.3 Effects of Introducing an ON RRP Facility along with IOER

Introducing an ON RRP facility that would work along with IOER as an additional lever to influence market rates is another option that could be employed in removing policy accommodation. The ON RRP facility interacts with both banks and non-banks (households, dealers, and GSEs). Given the bank-GSE federal funds arbitrage that we see in markets today (see Bech and Klee (2011) for further discussion), the impact of this tool on the federal funds market depends on the setting of the ON RRP rate relative to the IOER rate. Results, of course, also depend on the willingness of counterparties to substitute between ON RRPs and other assets.

We begin with the model adjusted to incorporate two Federal Reserve liabilities—ON RRPs and reserves.[13] As an example, the IOER is set at 25 basis points and the fixed rate on ON RRPs is set at 15 basis points. Table 4 reports how each endogenous interest rate responds to a 10 basis point change of IOER or the ON RRP rate. In general, the implicit weights on IOER and ON RRP sum to 1. As discussed in section 6, with the introduction of an ON RRP facility, the marginal effect of IOER on the level of market interest rates is reduced relative to the base case; the relative size of the two coefficients is determined by the degree of substitutability across the Fed's tools and with other assets in the economy. In our calibration, the marginal effect of a change in the ON RRP rate on market interest rates is a little larger than that of IOER. As discussed above, the relatively large marginal effect of the ON RRP rate on market rates stems from the fact that it is available to a broad array of counterparties while IOER is available only to the banking sector.

Table 5 reports the asset allocations for this scenario. Households and financial firms respond to the introduction of the ON RRP facility in a way that results in a restructuring of the Federal Reserve's balance sheet. After the introduction of the ON RRP facility, a significant portion of Federal Reserve liabilities (more than 15 percent) is in the form of ON RRPs rather than reserve balances.[14] The household sector (money funds) and GSEs account for almost all of the participation in the Federal Reserve's ON RRP facility, and households reduce their holdings of deposits, repo, agency debt and securities. With a 10 basis point spread between IOER and the ON RRP rate, the size of the federal funds market falls relative to the base case. As shown in second row of Table 2, money market yields in this case rise appreciably relative to the base case. Some observers have suggested that the IOER-ON RRP rate spread should be zero at lift off, with the IOER and ON RRP rates both set at 25 basis points (see Gagnon and Sack (2014)). As shown in row 3 of table 2, relative to the base case, the increase in the ON RRP rate pushes money market rates up. However, these settings do not result in a hard floor on the level of money market rates. As reported in Table 6, an even larger portion of the Federal Reserve's liabilities takes the form of ON RRP. Relative to the base case, as shown in figures 3 and 4 respectively, the size of bank balance sheets declines by about 4 percent and volume in the federal funds market declines by about 70 percent. The continued existence of a federal funds market in this scenario reflects the fact that banks have preferences over the amount of borrowing they wish to conduct in the federal funds market and GSEs likewise have preferences over their volume of lending in this market.

[13] When we introduce ON RRPs as an available asset in the model, we assume the preferred habitat holding is zero. This assumption implies that we are providing a lower bound for the effects on interest rates and asset allocations. That is, the resulting demand for ON RRP is smaller than would otherwise result if counterparties to the facility wanted to shift their asset allocation toward this new asset.

[14] We maintain the preferred habitat asset targets from the base case, implying zero weight on ON RRP assets. Even in this case, we find a desire to hold ON RRPs, as market interest rates adjust and the sectors maximize profits. If sector participants would prefer non-zero holdings of these Federal Reserve liabilities, then the change in asset allocations would be larger than reported here.

Of course, in the July 2014 FOMC minutes, it was noted that almost all participants supported an approach to liftoff that included a 25-basis-points range for the federal funds rate, with the IOER rate set at the top of the range and the ON RRP rate set at the bottom. With this wider spread, the model would suggest that trading in the federal funds market would be more sizable than in the previous two scenarios.

Overall, these cases highlight how the ON RRP facility can affect asset allocations in the economy. As shown in figure 5, the household sector (which includes money funds) chooses to increase its holdings of Fed ON RRPs while paring the holdings of most other assets. For a 25 basis point increase in the ON RRP rate, deposits decline by about 2 percent, repo holdings decline by 5 percent, agency debt shrinks by nearly 4 percent, and securities decline slightly. The decline in deposits results in smaller bank balance sheets and a reduction in bank balance sheet costs; this result is also found in MMPS.[15] If counterparties to the ON RRP facility view RRP claims on the Federal Reserve as a close substitute for other assets on their balance sheets, the volumes of the funds market (and other markets) can be very different than portrayed here. For example, if GSEs have a high degree of substitution between investing in Fed ON RRPs and lending in the funds market, volume in the funds market essentially falls to zero (see table 6a).

7.2.4 Effects of Relying on IOER and Term Deposits

Term deposits are another tool that can work along with IOER to influence market rates. We consider a scenario in which IOER is set at 25 basis points and the term deposit facility (TDF) rate is set at 30 basis points.[16] As shown in Table 7, a term deposit rate set above IOER will encourage banks to move reserves into term deposits. More importantly, as noted above, the higher rate on term deposits will induce banks to arbitrage this rate against other investment options, putting upward pressure on market rates and affecting asset allocations. Figure 3 shows that with the model's calibration, deposits decline slightly, which reduces banks' balance sheets. Households' balance sheets are roughly unchanged, with the decline in deposits roughly offset by an increase in repo and agency debt holdings.

Table 8 reports how market rates will move with changes in IOER and TDF. Both tools affect short-term rates about equally, similar to the effect found in MMPS when reserves are superabundant. The extent to which the TDF rate would need to increase relative to IOER to bring the level of money market rates up to the IOER rate is sensitive to the parameterization of the model. In this example, the federal funds rate lies 12 basis points below IOER when the TDF rate is set at 30 basis points (row 4 of Table 2). Given the marginal effect of the TDF rate on the federal

[15] MMPS explicitly models money funds, who internalize the ON RRP rate. When the ON RRP rate rises, money funds offer depositors a rate that is more attractive than the bank. As depositors leave the bank, the bank's balance sheet cost decreases.

[16] When we introduce term deposits, we assume the preferred habitat holding is zero. This assumption implies that we are providing a lower bound for the effects on interest rates and asset allocations. That is, the resulting demand for term deposits is smaller than would otherwise result if banks wanted to shift their asset allocation toward this new asset.

funds rate shown in Table 8, the TDF rate would need to rise to about 55 basis points, or 30 basis points above IOER, in order to pull the level of the federal funds rate and other short-term rates up to the IOER rate.

7.2.5 IOER + ON RRP + Term Deposits

Finally, we consider a scenario in which the Federal Reserve establishes a fixed-rate ON RRP facility and also issues term deposits. The ON RRP, IOER, and TDF rates are set at 15 basis points, 25 basis points, and 30 basis points, respectively. In this scenario, banks shift a relatively large portion of their reserves to term deposits and take-up of ON RRPs is relatively modest. Relative to the scenario shown in row 2 of Table 2 and in Table 5 (same settings of IOER and ON RRP rates but no TDF), this option boosts rates a bit. Bank balance sheets are somewhat larger and the level of activity in the federal funds market is a bit higher. The effect of the Fed's administered rates on market rates is shown in Table 10. As expected, the effect of the Fed's tools on the level of interest rates sums to one. The parameterization suggests that the ON RRP again has the largest marginal effect on market rates, with a 10 basis point rise in the ON RRP rate boosting most endogenous rates by about 5 basis points. As one might expect, the marginal effect of an increase in ON RRP on private repo rates and securities is quite strong but less notable for deposits and loans. In contrast, the combined effect of IOER and TDF rates is largest for deposits and bank loans and somewhat smaller for other market rates.

The second column of table 10 makes it clear that the marginal effect of the TDF rate in raising interest rates is only about half of that reported in table 8 for the comparable scenario without an ON RRP facility. As a result, if policymakers wished to push the funds rate up to the level of IOER in this scenario, the TDF rate would need to increase to about 80 basis points (55 basis points above IOER). On the other hand, if policymakers were content to have the funds rate and other short-term rates just a little above the ON RRP rate, the TDF rate might need to be raised only modestly above 30 basis points.

Finally, comparing the second and third columns of table 10, one sees that the calibrated model implies a 1 basis point increase in the rate on term deposits is slightly less effective at raising money market rates than a 1 basis point increase in the ON RRP rate. MMPS argue that when reserves are drained substantially, so that there is reserve scarcity, the TDF is effective in raising market rates; however we show here that the TDF can be effective at pulling up money market rates through arbitrage even if reserves are still appreciable.

8. Conclusion

Though the model developed here is simplistic, the analysis highlights how the Federal Reserve's tools for monetary policy normalization can affect short-term interest rates and asset allocations. First, the administered rates on Federal Reserve liabilities are very important factors in determining the overall level of money market rates across markets and institutions. While the marginal effect of each policy tool can differ somewhat, the model suggests that the Federal Reserve's policy tools will be effective in raising the level of money market rates when policymakers judge that it is time to

begin removing policy accommodation. Another general feature of the model worth emphasizing is that different settings of the Federal Reserve's administered rates can have very important consequences for patterns of financial intermediation. The nature of these effects depends importantly on the possible substitutions between Federal Reserve liabilities and private sector financial assets.

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10. Appendix 1: Model Parameterization

Below is the parameterization of the base-case model. Note that when ON RRP and TDF are introduced, the preferred habitat targets are set to zero. This setting ensures that changes in interest rates and asset allocations are not driven by adjustments to the target values. In essence, the results are a lower bound to changes in interest rates and asset allocations. If sector participants would prefer non-zero holdings of these Federal Reserve liabilities, then the results reported in the paper would be larger.

Target holdings

Households	
securities	0.85
private repo	0.01
deposits	0.12
Fed repo	0
agency debt	0.02

Banks Liabilities	
deposits	0.95
Fed funds	0.05

Banks Assets	
securities	0.15
Fed repo	0
reserves	0.14
agency debt	0.14
loan	0.57
term deposits	0

GSE Assets	
securities	0.68
private repo	0.27
Fed repo	0
Fed funds	0.05
reserves	0

Deals Assets	
securities	0.5
agency debt	0.5

Diagonal Cost parameters

Households				
securities	private repo	deposits	Fed repo	agency debt
20	0	0	0	0
0	20	0	0	0
0	0	20	0	0
0	0	0	20	0
0	0	0	0	20

Bank Liabilities	
deposits	Fed funds
5	0
0	5

Bank Assets					
securities	Fed ON RRP	reserves	agency debt	loans	term deposits
20	0	0	0	0	0
0	2000	0	0	0	0
0	0	5	0	0	0
0	0	0	20	0	0
0	0	0	0	20	0
0	0	0	0	0	5

GSE				
securities	private repo	Fed repo	Fed funds	reserves
10	0	0	0	0
0	10	0	0	0
0	0	10	0	0
0	0	0	10	0
0	0	0	0	5000

Dealers	
Securities	Agency debt
5	0
0	5

Other parameters

Other Parameters	
Household Balance Sheet Cost Parameter	1
GSEs Balance Sheet Cost Parameter	1
Dealers Balance Sheet Cost Parameter	1
Business loan demand curve intercept	0.075
Business loan demand curve slope	0.01
Fed Balance Sheet Size	0.03
Bank Balance Sheet Cost Parameter	1

11. Tables

Table 1 – Base Case (IOER = 25 bp, no ON RRP or TDF)						
	Households	Banks	Dealers	GSEs	FED	Business
(1) Deposits	120.5	120.5				
(2) Repo	9.3		15.1	5.7		
(3) Fed Funds		3.7		3.7		
(4) Agency Debt	19.1	9.1	3.5	31.6		
(5) Securities	851.1	12.4	11.6	22.2	30.0	
(6) Loans		72.7				72.7
(7) Reserves		30.0		0	30.0	
(8) Fed RRP						
(9) Term Deposits						
(10) Assets	1000	124.2	15.1	31.6	30.0	

Note. The cells highlighted in orange in this table report liabilities of the entities in the columns, while all other cells report asset holdings of the entities

Table 2 – Interest Rates Across Scenarios (Percent)							
Scenario		Securities (1)	Private Repo (2)	Deposit (3)	Agency Debt (4)	Fed Funds (5)	Business Loans (6)
IOER = 25 bp	(1)	0.062	0.026	0.050	0.021	0.076	0.226
IOER = 25 bp ON RRP = 15 bp	(2)	0.121	0.087	0.094	0.080	0.130	0.268
IOER = 25 bp ON RRP = 25 bp	(3)	0.181	0.147	0.136	0.139	0.185	0.310
IOER = 25bp TDF = 30bp	(4)	0.118	0.082	0.098	0.077	0.126	0.279
IOER = 15bp ON RRP = 25bp TDF = 30bp	(5)	0.143	0.108	0.115	0.102	0.149	0.295

Table 3 - Basis points change in endogenous rates for 10 bps change in IOER rate (IOER increase from 25bp to 35bp)

	IOER
(1) Deposits	9.5
(2) Repo	10.3
(3) Fed Funds	9.8
(4) Agency Debt	10.3
(5) Securities	10.4
(6) Loans	8.9

Table 4 - Basis points change in endogenous rates for 10 bps change in IOER or ON RRP rate

	IOER	ON RRP
(1) Deposits	5.2	4.3
(2) Repo	4.2	6.0
(3) Fed Funds	4.2	5.5
(4) Agency Debt	4.3	5.9
(5) Securities	4.3	6.0
(6) Loans	4.6	4.2

Table 5–ON RRP= 15 bps; IOER = 25 bps ; No TDF						
	Households	Banks	Dealers	GSEs	FED	Business
(1) Deposits	119.4	119.4				
(2) Repo	9.0		14.2	5.2		
(3) Fed Funds		2.4		2.4		
(4) Agency Debt	18.7	10.6	3.0	32.2		
(5) Securities	850.8	13.8	11.2	21.9	30.0	
(6) Loans		72.3				72.3
(7) Reserves		25.1		0.0	25.1	
(8) Fed RRP	2.2	0.0		2.8	4.9	
(9) Term Deposits						
(10) Assets	1000	121.8	14.2	32.2	30.0	

Table 6–ON RRP = IOER = 25 bps; No TDF						
	Households	Banks	Dealers	GSEs	FED	Business
(1) Deposits	118.3	118.3				
(2) Repo	8.8		13.3	4.5		
(3) Fed Funds		1.1		1.1		
(4) Agency Debt	18.4	12.0	2.5	32.9		
(5) Securities	850.5	15.3	10.8	21.4	30.0	
(6) Loans		71.9				71.9
(7) Reserves		20.1		0.0	20.1	
(8) Fed RRP	4.0	0.0		5.9	9.9	
(9) Term Deposits						
(10) Assets	1000	119.4	13.3	32.9	30.0	

Table 6a - GSEs view ON RRP as Close Substitute for Lending in the Funds Market						
	Households	Banks	Dealers	GSEs	FED	Business
(1) Deposits	118.5	118.5				
(2) Repo	8.8		13.5	4.7		
(3) Fed Funds		0.1		0.1		
(4) Agency Debt	18.4	11.9	2.6	33.0		
(5) Securities	850.5	15.2	10.9	21.6	30.0	
(6) Loans		71.8				71.8
(7) Reserves		19.6		0.0	19.6	
(8) Fed RRP	3.8	0.0		6.6	10.4	
(9) Term Deposits						
(10) Assets	1000	118.6	13.5	39.9	30.0	

Table 7 – IOER = 25 bps; TDF = 30 bps; No ON RRP;						
	Households	Banks	Dealers	GSEs	FED	Business
(1) Deposits	120.2	120.2				
(2) Repo	9.4		15.3	5.9		
(3) Fed Funds		3.3		3.3		
(4) Agency Debt	19.2	9.0	3.6	31.7		
(5) Securities	851.2	12.3	11.8	22.5	30.0	
(6) Loans		72.2				72.2
(7) Reserves		18.7		0.0	18.6	
(8) Fed RRP						
(9) Term Deposits		11.4			11.4	
(10) Assets	1000	123.5	15.3	31.7	30.0	

Table 8 - Basis Points change in endogenous rates for 10 basis points change in IOER or term deposit rate

	IOER	TDF
(1) Deposits	5.4	4.2
(2) Repo	5.4	5.0
(3) Fed Funds	5.4	4.5
(4) Agency Debt	5.4	5.0
(5) Securities	5.4	5.0
(6) Loans	4.2	4.7

Table 9 – ONRRP = 15 bps; IOER = 25 bps; TDF = 30 bps						
	Households	Banks	Dealers	GSEs	FED	Business
(1) Deposits	119.6	119.6				
(2) Repo	9.2		14.9	5.7		
(3) Fed Funds		2.7		2.7		
(4) Agency Debt	18.9	9.8	3.3	32.0		
(5) Securities	851.0	13.1	11.6	22.3	30.0	
(6) Loans		72.0				72.0
(7) Reserves		17.3		0.0	17.3	
(8) Fed RRP	1.3	0.0		1.3	2.5	
(9) Term Deposits		10.2			10.2	
(10) Assets	1000	122.3	14.9	32.0	30.0	

Table 10 - Basis Points change in endogenous rates for 10 basis points change in Fed administered rate

	IOER	TDF	ON RRP
(1) Deposits	3.3	2.4	3.7
(2) Repo	2.4	2.3	5.5
(3) Fed Funds	2.7	2.1	5.0
(4) Agency Debt	2.5	2.4	5.3
(5) Securities	2.5	2.4	5.4
(6) Loans	2.3	3.1	3.5

12. Figures

Figure 1

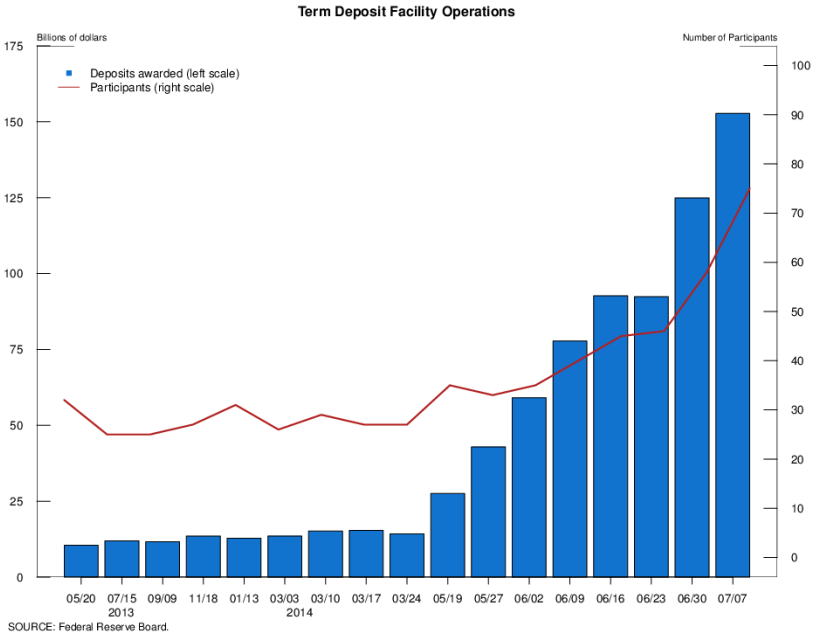

Figure 2

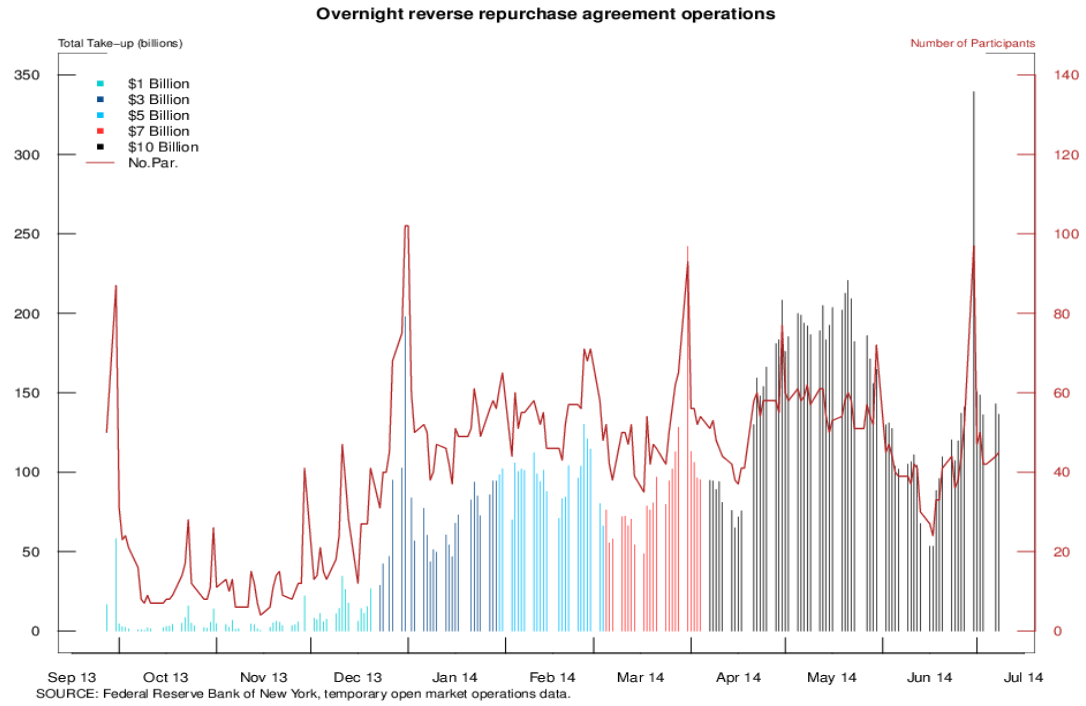

Figure 3 - Change in Bank's Balance Sheet Size

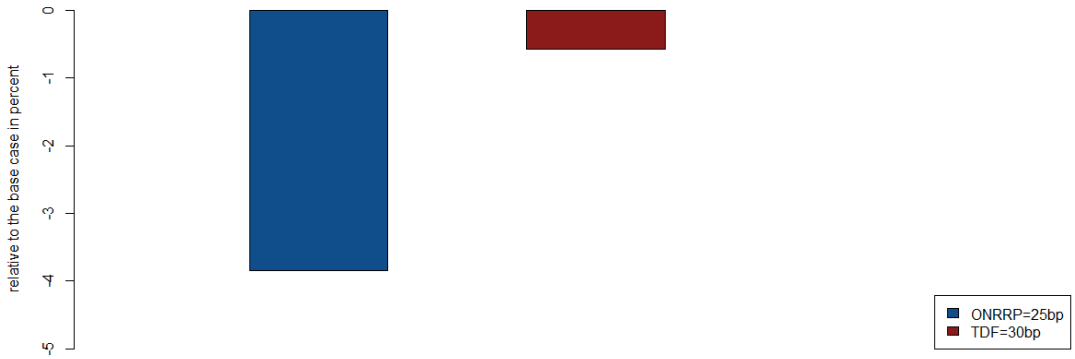

Figure 4 - Change in Fed Funds Market

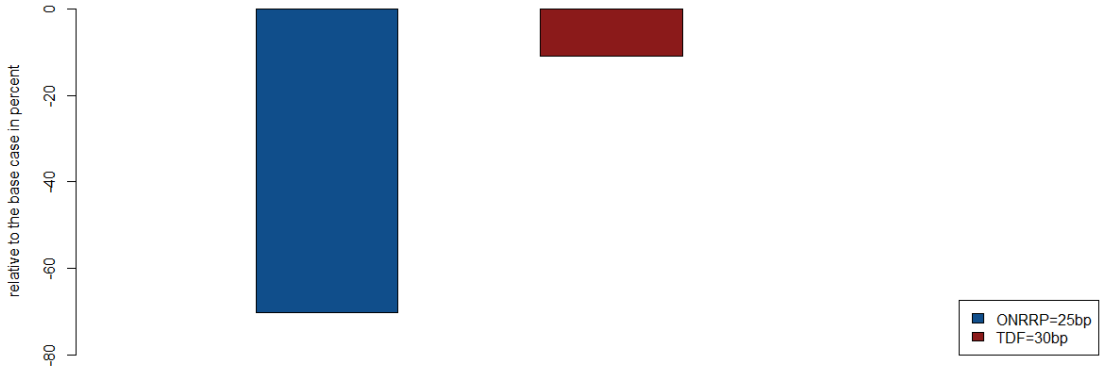

Figure 5 - Change in Household Asset Allocations