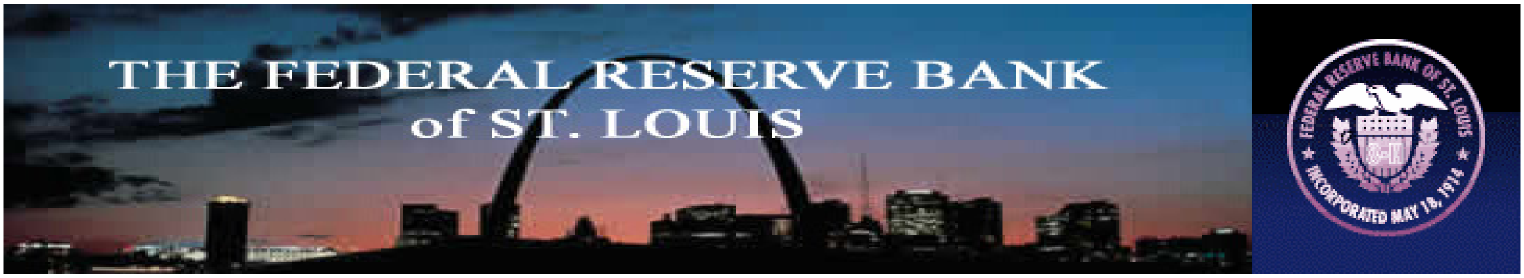

WORKING PAPER SERIES

A Specialized Inventory Problem in Banks: Optimizing Retail Sweeps

Suresh K. Nair
and
Richard G. Anderson

Working Paper 2005-023A
http://research.stlouisfed.org/wp/2005/2005-023.pdf

April 2005

FEDERAL RESERVE BANK OF ST. LOUIS
Research Division
411 Locust Street
St. Louis, MO 63102

A Specialized Inventory Problem in Banks: Optimizing Retail Sweeps

Suresh K. Nair* • Richard G. Anderson**

School of Business, University of Connecticut, Storrs, CT 06269
Federal Reserve Bank of St. Louis, St. Louis, MO 63102

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Deposits held at Federal Reserve Banks are an essential input to the business activity of most depository institutions in the United States. Managing these deposits is an important and complex inventory problem, for two reasons. First, Federal Reserve regulations require that depository institutions hold certain amounts of such deposits at the Federal Reserve Banks to satisfy statutory reserve requirements against customers' transaction accounts (demand deposits and other checkable deposits). Second, some inventory of such deposits is essential for banks to operate one of their core lines of business: furnishing payment services to households and firms. including wire transfers, ACH payments, and check clearing settlement. Because the Federal Reserve does not pay interest on such deposits used to satisfy statutory reserve requirements, banks seek to minimize their inventory of such deposits. In 1994, the banking industry introduced a new inventory management tool for such deposits, the *retail deposit sweep program*, which avoids the statutory requirement by reclassifying transaction deposits as savings deposits. In this analysis, we examine two algorithms for operating such sweeps programs within the limits of Federal Reserve regulations.

JEL Codes: D20, G21

Keywords: *Retail Banking; Deposit Sweeps; Regulation D; Required Reserves; Stochastic Dynamic Programming*

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*Professor and Ackerman Scholar, Operations and Information Management Department, School of Business, University of Connecticut. Contact: suresh.nair@uconn.edu

**Economist and vice president, Research Division, Federal Reserve Bank of St. Louis. Contact: anderson@stls.frb.org

(This is Federal Reserve Bank of St. Louis Research Division Working Paper 2005-023)

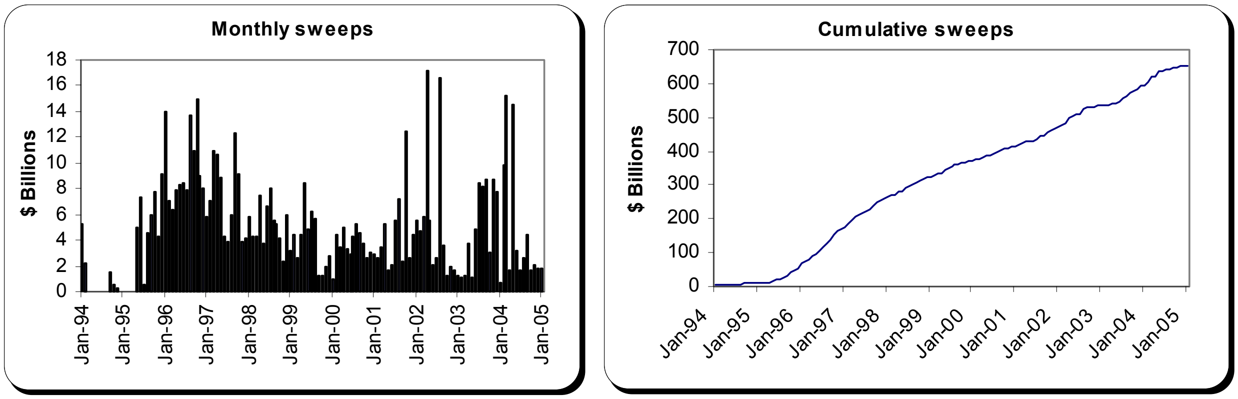
1. Introduction

Deposits held at Federal Reserve Banks are an essential input to the business activity of most depository institutions in the United States. Managing these deposits is an important and complex inventory problem, for two reasons. First, Federal Reserve regulations require that depository institutions hold certain amounts of such deposits at the Federal Reserve Banks to satisfy statutory reserve requirements. Second, an inventory of such transaction deposits is essential for banks to operate one of their core lines of business: furnishing payments services to households and firms, including wire transfers, automated clearing house (ACH) payments, and check clearing settlement.

As competitive firms, banks seek to maximize their profits while complying with applicable laws and regulations. The Monetary Control Act of 1980 authorized the Federal Reserve to require banks and depository institutions to hold statutory reserves against transaction deposits (e.g., checking accounts); since early 1992, a 10 percent reserve-requirement ratio has applied to deposit balances greater than approximately $50 million. Non-transaction deposits (e.g., savings accounts) and most other bank liabilities are subject to a zero percent reserve-requirement ratio. Federal Reserve regulations stipulate that only two bank assets may be used to satisfy statutory reserve requirements: deposits at the Federal Reserve Banks, and vault cash (cash in banks' central vaults, in ATMs, and in transit, etc.). Neither of these assets earns interest for the bank. Penalties are levied if these requirements are violated.

Clever bank managers seek to minimize their holdings of these "sterile reserves." In 1994, for this purpose, a large commercial bank invented the retail deposit sweep program. In such a program, the bank links two companion accounts—a customer's transaction account (demand deposit or similar checkable account), which we hereafter refer as the bank transaction account, or BTA, and a newly created money market deposit account (MMDA, similar to a savings account). Funds are swept regularly from the BTA, where end of day balances are subject to a 10 percent statutory marginal reserve requirement, to the MMDA, which is not subject to any reserve requirement. The MMDA account is invisible to the customer, and is solely a component of the inventory management scheme; transfers between accounts also are invisible to the customer. Unlike numerous earlier reserve-reduction schemes of banks, the Federal Reserve Board has not, as of this writing, objected to banks reducing their

Figure 1: Monthly sweep amounts and cumulative amount since 1994



Source: Board of Governors of the Federal Reserve System
http://research.stlouisfed.org/aggreg/swdata.html

required reserves via such schemes (see Appendix 1 for more details on Federal Reserve history with respect to sweep programs).

In short, the essence of a retail deposit sweep program is the ability of the bank to reclassify, for reserve-requirement purposes, transaction deposits, subject to a 10 percent reserve requirement, as saving deposits (specifically, MMDA), subject to a zero reserve requirement. A retail deposit sweep, essentially, is keeping two sets of books so as to evade the “reserve requirement” tax collector.

Since debits (e.g., check writing) can only be serviced from transaction accounts, it is optimal to always leave some funds in the transaction account and replenish the account from the companion MMDA, as required. To discourage the use of the MMDA (a type of savings account) as if it were a checking account, Federal Reserve regulations (Regulation D) limit to a maximum of 6 the number of withdrawals that can be made from an MMDA account during a calendar month. These limits do not apply to transfers made by personally visiting a branch, or by ATM, or by phone. The consequence of violating the six transfer limit is harsh: the entire amount that has been swept between the BTA and the MMDA becomes subject to the same statutory reserve requirement as if no sweep had been attempted at all. Thus, it is generally optimal to move all remaining balances from the MMDA to the transaction account on the sixth transfer out of the MMDA account.

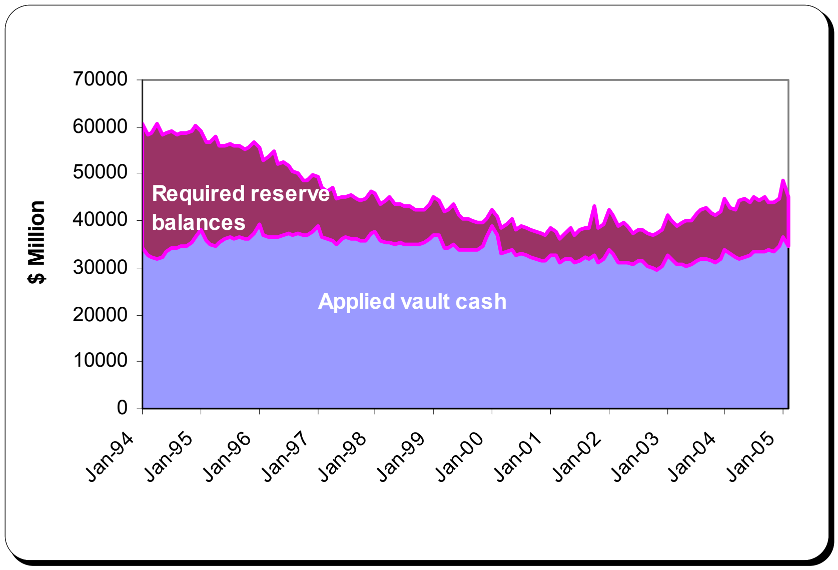
Numerous legal interpretations (e.g., Ireland 1996) from the Federal Reserve emphasize the 6 transfers limit. For a brokerage client with a balance of a million dollars, that would mean a hundred thousand dollars in additional reserves. Therefore, the sweep mechanism would have to ensure that no more than five transfers were necessary from MMDA to BTA every month. This need for judicious sweeping requires sophisticated computer software and algorithms.

Data on the aggregate amount of deposits affected by retail deposit sweep activity is of modest quality, at best. Commercial banks are not required to report data on sweep activity to the Federal Reserve. Hence, in most cases, Federal Reserve staff have imputed the amount being swept from other deposit and reserves data. Sweep activity grew slowly from its inception in January 1994 through mid-1995, and thereafter grew rapidly as banks concluded that the Federal Reserve would not move to prohibit such reserve-requirement reduction schemes. As seen in Figure 1, the cumulative amount of sweep since 1994 reached about $654 billion by January 2005, or more than 50 percent of the total amount of transaction balances at banks and thrift institutions.

Widespread use of sweep programs has significantly reduced the amount of required reserve balances that banks maintain at the Federal Reserve. As a result, even as aggregate transaction deposits (including the amounts in sweeps) has increased, the portion of total require reserves satisfied by vault cash has held almost steady, while the portion satisfied by Federal Reserve Bank deposits (so-called “required reserve balances”) has fallen; see Figure 2. In the past couple of years there has been a slight increase in reserve balances due to low interest rates. There is some concern among economists that this trend can increase volatility in the federal funds rate as the banks try to manage their accounts with very low balances (Bennett and Hilton 1997, Wrase 1998, Anderson and Rasche 2001, Anderson 2002a).

Some economists have expressed concern that aggressive management of deposits of held at Federal Reserve Banks via sweep programs might increase federal funds rate volatility, an outcome regarded by the Federal Open Market Committee as harmful to monetary policy’s effectiveness. According to Furfine (2000), “As recently as a decade ago, relatively high statutory reserve requirements created a fairly predictable demand for bank reserves, making interest rate targeting a relatively easy-to-implement policy choice for the Federal Reserve. Over the last 10 years, however, lower reserve requirements and the widespread adoption of

Figure 2: Components of Reserves and Account Balances at the Fed



Source: Board of Governors of the Federal Reserve System
http://www.federalreserve.gov/releases/H3/hist/h3hist2.txt
http://www.federalreserve.gov/releases/h3/hist/h3hist3.txt

sweep accounts have precipitated a dramatic fall in required reserve balances. These lower reserve balances may increase uncertainty in reserve demand, possibly complicating the Fed's ability to achieve the goals of monetary policy." And Clouse and Dow (2002) state, "Several countries have already moved to monetary systems without reserve requirements so that their demand for reserves is entirely a demand for excess reserves. The United States is also moving in that direction due to the adoption of retail sweep programs by commercial banks. These programs have resulted in significantly lower levels of required reserves, leaving some banks in the position of not needing to hold reserve balances to meet their reserve requirements. Understanding how this demand behaves is becoming an important issue in applied monetary economics."

Some events in recent years have portended an end to retail deposit sweep accounts. But, in our opinion, such events are not likely to reach fruition. In a late 1990s Federal Reserve survey, a sample of sweeping banks responded they would discontinue retail deposit sweep programs if the Federal Reserve paid interest on deposits at the Federal Reserve Banks. Legislation to require the Federal Reserve to start paying interest on sterile reserve balances at the Fed has been introduced but failed to pass the Congress, e.g., the Bank Reserves

Modernization Act of 2000, and the more recent HR 758, The Business Checking Freedom Act of 2003. The latter passed the House of Representatives but was not acted on in the Senate. The Treasury has not endorsed the proposals due to its potential budgetary burden (Abernathy 2003). Certain small community banks are supporting the proposal (Maus 2003) on the grounds that sweep programs are expensive and complicated for small banks to implement, while others (Menzies 2003) like an alternative proposal (HR 974) which would allow 24 transfers from MMDA to BTA each month instead of the present 6.

Although retail deposit sweep programs have been operating for more than a decade — and banks have earned millions of dollars by their use—there are no published papers modeling their implementation, operation, or optimal tuning. These programs have reduced the amount of banks' sterile reserves from $26.3 billion in Jan 1994 to about $10.7 billion in February 2005 (Figure 2). Even assuming a conservative 100 basis points spread on interest rates, the implied earnings are $156 million per year. Clearly this is an interesting optimization problem, with high earnings potential. This paper attempts to begin to bridge this gap in literature.

2. Systems for Sweep Programs

There are a number of algorithms for operating retail deposit sweep programs. Perhaps the earliest algorithm was the simplest: sweep funds from the transaction deposit into the MMDA at the close of business on Friday, and reverse the sweep at the opening of business on Monday; if Monday is a federal banking holiday, postpone the reverse transfer to Tuesday. Because the Federal Reserve's statutory reserve requirements are calculated from end-of-day balances on a 7-day week, this algorithm immediately reduces the amount of transaction deposits subject to reserve requirements. Considerable improvement, however, can be obtained by more sophisticated methods that we discuss next.

In banks, sweep programs are part of the treasury cash management function. While a variety of algorithms undoubtedly exist, anecdotal evidence suggests that two are the most popular. For discussion, we label them the *threshold method* and the *cushion method*. Both these methods try to leverage high-frequency information on customer behavior (daily patterns of net credits and debits) to optimize the division of funds, over the month, between the BTA and MMDA accounts, subject to the constraint of no more than six transfer limit from MMDA to BTA. Note that there is no limit on transfers from the BTA to the MMDA account, although each such transfer may have a small cost for the bank. Recall that if five transfers have already been made for an account, it generally is optimal on the sixth transfer to move the entire MMDA balance to BTA. This can be expensive. If an institutional customer has $10 million in their account and all of it gets transferred to BTA, the reserves will have to be increased by $1 million, for which no interest is earned by the bank. All subsequent activity after the dumping of all MMDA funds to BTA, both debit and credit, is done via the BTA.

For both methods, it is important to keep in mind that the month-by-month six transfer limit imposes a complex time-dependent structure on the functions that define the optimal outcomes. In general, we will show that the thresholds, cushion amounts, and optimal transfers in both directions depend on the position of each specific business day within the calendar month.

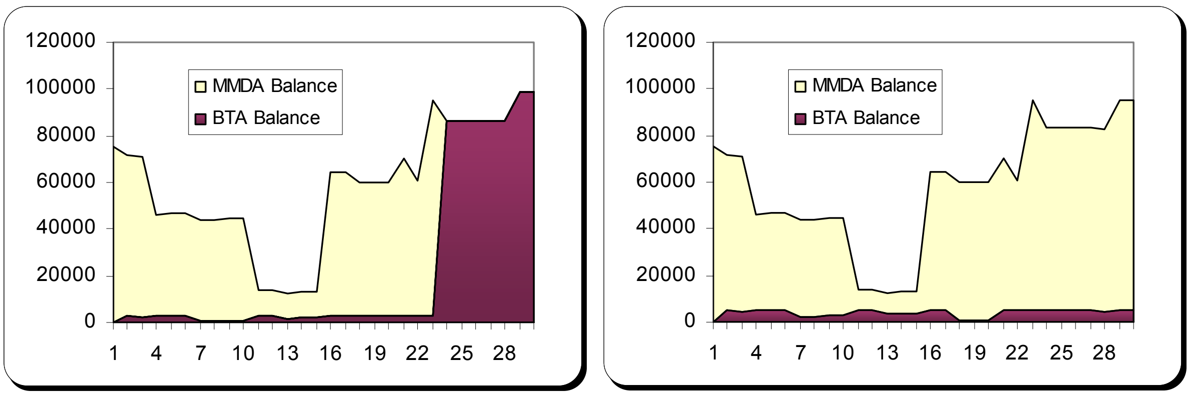
Threshold Method: In this method, for each accountholder, a threshold is set for the BTA account balance. Because there is no restriction on the number of transfers from the BTA to MMDA, and because we assume zero cost of such transfers, optimality always requires that all incoming funds be credited to the BTA. If the account balance in the BTA just prior to the end of the business day exceeds that day's optimal threshold, excess funds are moved from BTA to MMDA before the close of business. If posting incoming debits against the BTA implies a negative balance at the end of business, funds are transferred from the MMDA to the BTA. In our models, we assume that the six transfer rule is a hard constraint. As a result, on the sixth transfer, all funds in the MMDA are moved to the BTA. In fact, this is a stochastic economic decision, and part of the optimal solution. A bank which chooses not to move all funds from the MMDA to the BTA on the sixth transfer is placing a bet that a seventh transfer will not be necessary before the end of the month when a new set of six transfers begins. Determining the correct option price for this bet is beyond the scope of this paper, and part of our current research. In this algorithm, the amount transferred is equal to the threshold plus the amount of negative balance, leaving a balance of the threshold amount in BTA after the transfer. In operation, this method seeks to maintain the BTA balance within an acceptable band. The parameters for this method are the thresholds values. The minimum level here is zero. The method can be generalized to a situation where the minimum level is set to a value greater than zero, in which case the parameters are the minimum and maximum thresholds.

Cushion Method: In this approach, incoming customer funds (deposits) throughout the month are credited to the MMDA so long as the transfer count from MMDA to BTA is less than six. Since debits can only be serviced from the BTA account, the first debit transaction initiates a transfer from MMDA to BTA of the debit amount plus a day-specific cushion amount. The optimal amount generally should be large enough to service a few more debit transactions. When the balance in the BTA is not sufficient to service a subsequent debit transaction, another transfer from MMDA to BTA is initiated. This transfer again includes funds to service the current debit transaction and a cushion amount, which, in general, will differ from the first cushion amount. This pattern is repeated as needed up to five transfers. The parameters in this method are the cushion amount for each transfer.

Although these two methods both can be considered similar to the (*s,S*) and (*r,Q*) models in inventory management, the algorithms are not isomorphic, that is, we have been unable to establish (stochastic) circumstances in which the two methods yield the same account balances and profit. In both methods, the item being inventoried is cash, that is, deposits at Federal Reserve Banks. The methods differ primarily in two respects. First, the algorithms differ in where the deposits are made. In the threshold method it is to the BTA, in the cushion method it is to the MMDA. In current work, we are exploring optimal strategies for allocating deposits between the two accounts. Second, they differ in their treatment of the sixth transfer from MMDA to BTA. In further work, we are exploring the optimal handling of the risk incurred by not moving all funds on the sixth transfer. Finally, as noted above, the *s* and *r* are set to zero, though this is not necessary and the methodology could benefit from not restricting these to zero.

Discussions with bank treasury managers suggest that most models used in practice to implement sweep programs are very simplistic. In the threshold method, for example, often little variation is permitted by day; in some cases, managers allow the threshold to vary by transfer count ($1000 for first transfer into BTA, $2000 for second transfer, etc.) but not by day of the month. Further, managers may use the same threshold for all accounts, regardless of size and transaction patterns. In addition, the same threshold sometimes is used for transferring balances out of BTA to MMDA and for moving funds back from the MMDA. In the next section, we show that different thresholds for these two types of transfers yield superior earnings relative to one threshold, and that thresholds which vary by day of month and account activity yield further earnings improvements.

Figure 3: The result on MMDA and BTA balances of using different threshold values for the same account ($3000 and $5000 respectively)



Although not discussed further in this analysis, discussions suggest that managers often use similar methods for the cushion approach, with cushion amounts that vary by transfer count (say a cushion of $1000 for the first transfer, $2000 for the second transfer, etc.), but not vary by customer activity or day of month. In the balance of this paper, we examine the threshold method.

An illustration with two different sets of thresholds for the same account is shown in Figure 3. The detailed transaction data for each day is shown in Appendix 2 and 3 for the two cases shown in Figure 3. In the case on the left, all six transfers become necessary, and therefore the sixth transfer dumps the entire MMDA balance into BTA. All subsequent transactions are in BTA. This is an expensive outcome due to a poor choice of thresholds. In the case on the right, because of a better set of thresholds is used, only five transfers are necessary. Therefore, the BTA balance is kept low.

Figure 4: Transition matrix for net transaction activity for an account

Current day		Next Day					
		Withdrawal		No	Deposit		Average
		Large	Small	activity	Small	Large	Amount
Withdrawal	Large	7%	46%	33%	7%	7%	-$3,500
	Small	5%	49%	35%	6%	5%	-$500
No activity		4%	35%	49%	6%	6%	$0
Deposit	Small	4%	44%	41%	6%	5%	$500
	Large	9%	50%	34%	3%	4%	$5,000

3. A Stochastic Dynamic Programming Model

We develop a stochastic dynamic programming model for this problem. For tractability and presentation here, the data in our model is somewhat less rich than the data that a bank treasury manager would have available for use in such a model. Most banks retain customer account activity (debits and credits) for at least several recent months, including daily account balances and net transaction activity. (The net transaction activity is the net of all deposits and withdrawals posted to the account during the day. Positive numbers correspond to net deposits, negative numbers to net withdrawals, and zeros to no activity during the day.) Because the stochastic model could get very unwieldy if actual real-number dollar transaction values are used, we choose to model using discrete *transaction intervals*. Suppose there are *n* transaction intervals in the model. For example, if we choose to model with 8 transaction intervals for net activity, the intervals may be defined to correspond to daily net transaction activity of <-10000, -10,000 to -5001, -5000 to 1, 0, 1 to 5000, 5001 to 7500, 7501 to 15000, >15000. Note that the interval breakpoints do not need to be symmetric, of equal size, or have as many withdrawal intervals and deposit intervals. However, it is important to have one interval for no activity, 0, since on many days there may not be any net activity.

Using the historical transaction data, a (*nxn*) size transition matrix is created. See Figure 4 for an example with 5 intervals. The entries of the transition matrix, p_{ij}, correspond to the probability of having a net transaction in interval *i* on one day, and a transaction in interval *j* the next day, where $\sum_j p_{ij} = 1$, for all *i*.

Figure 5: MMDA and BTA balances in various cases of account activity.
The transfer into BTA threshold is *g* and the transfer out of BTA threshold is *h*.

	Balance at start of day		Net transaction during day, s_i	BTA balance 5 minutes before end of business	Transfer	Balance at end of day		Transfer count
	MMDA	BTA				MMDA	BTA	
Case 1	m	b	Withdrawal	0 <= b+s_i < g	No transfer	m	b+s_i	
Case 2	m	b	Withdrawal	b+s_i < 0, Transfer count < 6	Transfer g-(b+s_i) from MMDA to BTA	m-[g-(b+s_i)]	g	+1
Case 3	m	b	Withdrawal	Transfer count = 6	Transfer entire MMDA balance to BTA	0	m+b+s_i	
Case 4	m	b	No activity	b	No transfer	m	b	
Case 5	m	b	Deposit	b+s_i <= h	No transfer	m	b+s_i	
Case 6	m	b	Deposit	b+s_i > h	Transfer h-(b+s_i) from BTA to MMDA	m+[(b+s_i)-h]	h	

Let s_i ($i \in \{1,\ldots,n\}$) be the average net transaction amount for each interval (last column of Figure 4), where s_i is negative for withdrawal intervals and positive for deposit intervals, *A* denote the MMDA balance at the beginning of the month, l*m* denote the MMDA balance, and *b* denote the BTA balance on day *t*. Suppose the net transaction on day *t* is in transaction interval *i* and *x* transfers from MMDA to BTA have been made to date. Let *X* be the maximum allowable transfers. As per current Federal Reserve regulations, *X* is 6. At the beginning of the month x=0, and we constrain this number to be less than or equal to *X* at the end of the month. Suppose there are *T* working days in the month. Then the state of the system in day *t* can be specified by *(m,b,i,x)*. Let $f_t^T(m,b,i,x)$ be the maximal discounted net present value of being in state *(m,b,i,x)* in period *t* in the *T* period problem when optimal actions are taken in each day from *t* through *T*. The actions pertain to choosing the correct thresholds when transfers become necessary. We will use different thresholds for transfers *into* BTA and *out of* BTA.

Let r_{mb} be the single-day revenue realized from an MMDA balance of *m* and a BTA balance of *b*,

$$r_{mb} = r(m + [1-\delta]b)$$

where r is the interest rate spread that the bank earns on balances (expected marginal asset yield minus its average cost of funds), and δ is the (marginal) fraction of BTA balances that the bank needs to maintain as sterile reserves. Under current regulations, δ is approximately 0.1, or 10%.