A Specialized Inventory Problem in Banks – Optimizing Sweeps

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Outline

- Background of Sweep Programs
- Popularity of Sweep Programs
- Existing Sweep Methods
  - Cushion
  - Threshold
- Critique of Existing Sweep Methods
- Stochastic DP Model
- Results and Take-Aways

Background of Sweep Programs

- **Monetary Control Act (1980) authorized Fed Reserve to require banks to hold 8-14% of transaction deposits as reserves.**
  - Reserves held as deposits with Fed or as vault cash
  - No reserve requirement for time deposits (savings, money market)
  - Reserves earn no interest for bank
- **Banks had an incentive to keep deposits as time deposits**

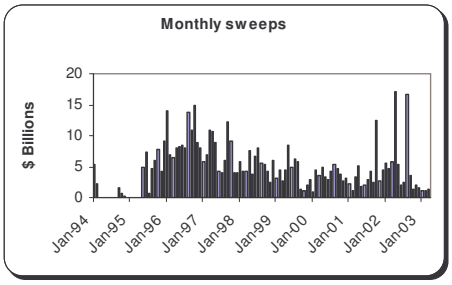
Background of Sweep Programs

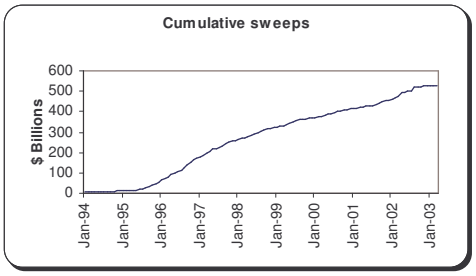
- **In 1994 Fed Reserve did not object to banks sweeping funds between transaction and time deposits.**
  - Banks could maintain two accounts for every customer [a Bank Transaction Account (BTA) and a Money Market Deposit Account (MMDA)]
  - These sweep accounts are transparent to customer
  - By sweeping funds frequently from BTA into MMDA, banks can keep transaction deposits to a minimum
    - Win-win for both banks and customers
    - Banks reserve requirements reduce
    - Customers get higher interest in MMDA accounts

Background of Sweep Programs

- **There are limitations to sweep programs**
  - Debits only serviced from transaction accounts – need some BTA balance to cover check writing, etc.
  - Regulation D limits the number of withdrawals from savings accounts.
- **Regulation D**
  - No more than 6 withdrawals from MMDA to BTA in a calendar month.
  - If a 6th transfer becomes necessary, the entire MMDA balance is transferred to BTA. Until the end of the month all balances are in BTA. This is very expensive.

Popularity of Sweep Programs





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Popularity of Sweep Programs

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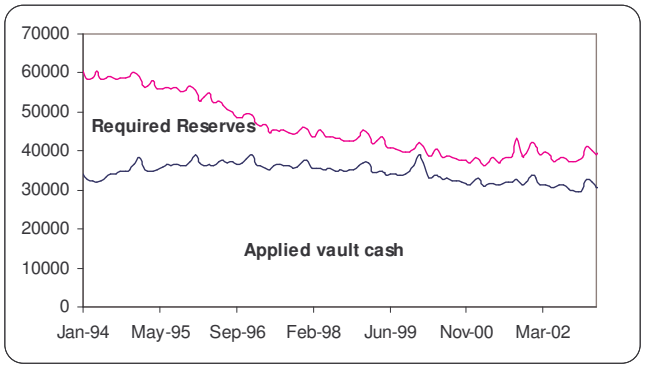


Existing Sweep Methods - Cushion

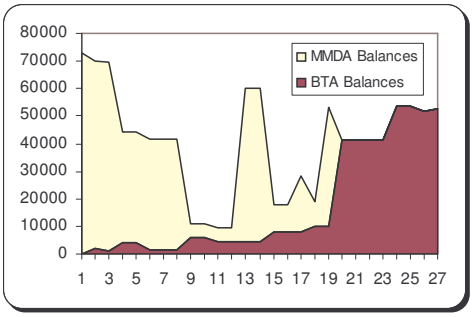
- Cushion method
  - Set cushion amounts for each transfer (1 through 5)
  - If BTA balance after servicing withdrawal is negative, transfer funds from MMDA to BTA
    - Amount transferred – Minimum required + Cushion
    - Idea – leave sufficient funds in BTA to service a few more transactions
  - The challenge is to determine appropriate cushion amounts such that the chance of the 6th transfer is minimized, while reducing average BTA balances

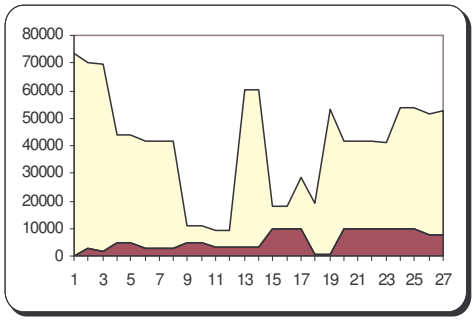
Existing Sweep Methods - Cushion

Day	MMDA	BTA	Withdrawal	Min Transfer MMDA to BTA	Cushion	Actual Transfer MMDA to BTA	Comments
1	50,000	-	1,000	1,000	1,000	2,000	Transfer #1
2	48,000	1,000	-				
3	48,000	1,000	-				
:							
6	48,000	1,000	7,000	6,000	2,000	8,000	Transfer #2
7	40,000	2,000	-				
:							
10	40,000	2,000	3,000	1,000	3,000	4,000	Transfer #3
11	36,000	3,000	-				
:							
15	36,000	3,000	4,000	1,000	4,000	5,000	Transfer #4
16	31,000	4,000	-				
:							
18	31,000	4,000	6,000	2,000	5,000	7,000	Transfer #5
19	24,000	7,000	-				
20	24,000	7,000	8,000	1,000	Dump	24,000	MMDA Dumped
21	-	23,000					
:							
30	-	23,000					

Existing Sweep Methods - Cushion

- Bad and Good cushions





Existing Sweep Methods - Threshold

- **Threshold methods**
  - Set threshold level of funds to maintain in BTA, say $2000
  - If BTA balance over threshold, sweep excess funds daily into MMDA
    - Since there is no limit to transfers out of BTA, these transfers may be made daily.
  - If BTA balance after servicing withdrawal is less than threshold
    - But positive, then do nothing.
    - Negative, then transfer sufficient amount from MMDA to BTA to leave threshold amount after withdrawal is serviced.
  - The challenge is to set X such that the chance of the 6th transfer is minimized, while reducing average BTA balances.

Existing Sweep Methods - Threshold

- **Suppose threshold is $2000**

BTA Balance	Action
2000	Do Nothing
2500	Transfer 500 to MMDA
1500	Do Nothing
-600	Transfer 2600 from MMDA to BTA

- There is no limit to transfers out of BTA. These transfers may be made daily.

Existing Sweep Methods - Threshold

Suppose threshold is $3000

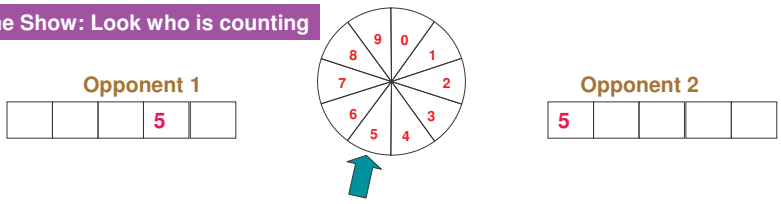
	Start of day			5 mins before EOB	Transfer to		End of day		Transfer
Day	MMDA	BTA (5 mins before EOB)	Net transaction	BTA	MMDA	BTA	MMDA	BTA (5 mins before EOB)	Count
1	75000	0	-3000	-3000	0	6000	69000	3000	1
2	69000	3000	-750	2250	0	0	69000	2250	1
3	69000	2250	-25500	-23250	0	26250	42750	3000	2
:	:	:	:	:	:	:	:	:	:
10	43750	1000	-30500	-29500	0	32500	11250	3000	3
:	:	:	:	:	:	:	:	:	:
17	61150	2900	-4200	-1300	0	4300	56850	3000	4
:	:	:	:	:	:	:	:	:	:
21	67350	3000	-9500	-6500	0	9500	57850	3000	5
22	57850	3000	34000	37000	34000	0	91850	3000	5
23	91850	3000	-11500	-8500	0	86350	0	86350	6
:	:	:	:	:	:	:	:	:	:
30	0	98450	-2000	96450	0	0	0	96450	6

Critique of Existing Sweep Methods

- **Cushions and Thresholds used may be too simple**
- **These may be similar for all customers**
  - **Small dollar frequent check writer may need different cushions/threshold than large dollar infrequent check writer.**
- **Fixed irrespective of when during the calendar month the transfers become necessary**
  - **If the 4th transfer is required on day 12, the cushion/threshold should be different from if the 4th transfer becomes necessary on day 25**

Motivation for Model

Game Show: Look who is counting



Whoever gets the larger 5 digit number wins!!

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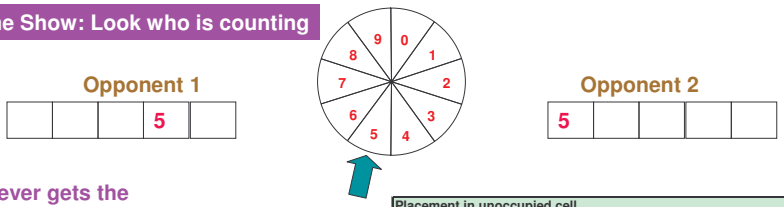

Whoever gets the larger 5 digit number wins!!

Optimal Policy

Placement in unoccupied cell

Number on wheel	Spin Number 1	2	3	4	5
0	5	4	3	2	1
1	5	4	3	2	1
2	5	4	3	2	1
3	4	4	2	2	1
4	3	3	2	1	1
5	3	2	1	1	1
6	2	2	1	1	1
7	1	1	1	1	1
8	1	1	1	1	1
9	1	1	1	1	1

- Source: Puterman, MDP, 1994

This model can be solved using stochastic dynamic programming

Modeling Customer Behavior

- An understanding of customer behavior is critical to determination of optimal Cushions and Thresholds
- For retail banks with predominantly household accounts
  - Income may be deposited biweekly and is predictable.
  - Mortgage payments are predictable
  - Credit card payments are on cycle dates
  - Utility bills are at known dates and fairly stable
  - Only sundry expenses may be unpredictable.

Modeling Customer Behavior

- For investment banks,
  - study customer behavior of withdrawals, deposits and no activity.
- For sundry household expenses, and for investment banking type customers, a transition matrix may be developed to model customer behavior
- Predictable deposits and withdrawals can be super-imposed on the activity subject to uncertainty modeled by the transition matrix

Modeling Customer Behavior

- Divide the population into various segments
- Divide withdrawals and deposits into "transaction intervals." For example, Large withdrawal (<-$1500), Small withdrawal (-$1 to -$1499), no transaction (0), Small deposit ($1-$750) and Large deposit (>$751).
- For each segment create a transition matrix showing the chance of withdrawal and amount of withdrawal every day.

	Next day					
Current day	1	2	3	4	5	Avg Amt
1	11%	44%	32%	8%	5%	-2200
2	5%	49%	35%	8%	3%	-150
3	3%	28%	54%	8%	6%	0
4	4%	47%	37%	8%	4%	325
5	15%	50%	30%	2%	3%	4100

Stochastic DP Model

- The state of the system may be defined as *(m,b,i,x),* where *m* is the balance in MMDA, *b* is the balance in BTA, *i* is the transaction interval, and *x* is the transfer count (*x<6*).
- Suppose r_{mb} is the reward from having a balance of *m* in MMDA and *b* in BTA, then

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

Where δ is the % reserve requirement, and *r* is the return for the bank on funds invested.

Stochastic DP Model - Cushion

- **The functional equation of our model will be**

$$f_t^T(m,b,i,x) = r_{mb} + \max_{c=0,\ldots,c_z} \begin{cases} Cushion = c_z: & \beta[\sum_j p_{ij} f_{t+1}^T(m+b+s_i - c_z, c_z, j, x+1)] \\ \vdots & \\ Cushion = c_1: & \beta[\sum_j p_{ij} f_{t+1}^T(m+b+s_i - c_1, c_1, j, x+1)] \\ Cushion = 0: & \beta[\sum_j p_{ij} f_{t+1}^T(m+b+s_i, 0, j, x+1)] \end{cases}$$

- **Where β is the one period discount factor and p the transition matrix.**
- **The functional equation changes a bit for specific conditions (e.g., $x=6$).**

Sample Results - Cushion

Day of Month	MMDA+BTA: 25,000 Transfer #, x					MMDA+BTA: 50,000 Transfer #, x				
	1	2	3	4	5	1	2	3	4	5
1	500					500				
2	500	500				500	750			
3	500	500	1000			500	750	1000		
4	250	500	1000	1500		500	500	1000	2250	
5	250	500	750	1500	3250	500	500	1000	2250	3750
6	250	500	750	1250	3250	250	500	1000	2000	3750
7	250	500	750	1250	3250	250	500	750	2000	3750
8	250	500	750	1250	3250	250	500	750	2000	3750
9	250	500	750	1000	3250	250	500	750	2000	3750
10	250	250	500	1000	3000	250	500	750	2000	3750
11	250	250	500	1000	3000	250	250	750	2000	3750
12	250	250	500	1000	3000	250	250	500	2000	3500
13	0	250	500	750	2750	250	250	500	2000	3500
14	0	250	500	750	2750	0	250	500	2000	3250
15	0	250	250	750	2500	0	250	500	2000	3250
16	0	250	250	500	2500	0	250	500	2000	3250
17	0	0	250	500	2250	0	0	250	2000	3000
18	0	0	250	500	2000	0	0	250	2000	3000
19	0	0	250	500	1750	0	0	250	2000	2750
20	0	0	0	250	1750	0	0	250	2000	2750
21	0	0	0	250	1250	0	0	250	2000	2500
22	0	0	0	250	1000	0	0	250	2000	2500
23	0	0	0	0	500	0	0	0	2000	2000
24	0	0	0	0	250	0	0	0	1750	1750
25	0	0	0	0	0	0	0	0	0	0

Sample Results - Thresholds

Large Withdrawal Thresholds, g^*_{tmb1x}						Small Withdrawal Thresholds, g^*_{tmb2x}				
	Transfer Count, *x*					Transfer Count, *x*				
Days to EOM, 26-*t*	1	2	3	4	5	1	2	3	4	5
25	1000					1000				
24	1000	1000				1000	1000			
23	1000	1000	1500			1000	1000	2000		
22	1000	1000	1500	2500		1000	1000	1500	4500	
21	500	500	1000	2500	3000	1000	1000	1500	4500	6000
20	500	500	1000	2500	3000	1000	1000	1500	4500	6000
:	:	:	:	:	:	:	:	:	:	:
5	0	0	0	500	1000	0	0	0	500	1000
4	0	0	0	0	500	0	0	0	0	500
3	0	0	0	0	500	0	0	0	0	500
2	0	0	0	0	500	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0

Sample Results - Thresholds

Small Deposit Thresholds, h^*_{tmb4x}						Large Deposit Thresholds, h^*_{tmb5x}				
	Transfer Count, *x*					Transfer Count, *x*				
Days to EOM, 26-*t*	1	2	3	4	5	1	2	3	4	5
25	500					1000				
24	500	500				1000	1500			
23	500	500	500			1000	1000	1500		
22	500	500	500	500		1000	1000	1500	2000	
21	500	500	500	500	500	500	1000	1500	2000	5000
20	500	500	500	500	500	500	1000	1500	2000	5000
:	:	:	:	:	:	:	:	:	:	:
5	0	0	0	500	500	0	0	0	500	1000
4	0	0	0	0	500	0	0	0	0	1000
3	0	0	0	0	500	0	0	0	0	500
2	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0

Impact of Model

- The model is scheduled to be implemented in a mid size bank.
- Savings are expected to be about $3 million per year.
- In simulations, reduced BTA balances from 13% to 26% over existing methodology
- Paper downloaded 145 times in 3 days after posting at Fed Reserve.

Similarity with Inventory

- This is a model for fungible assets
  - Financial goods, commodities
- The raw material can be transformed to finished goods and then if demand does not accrue, can be converted back to raw material, at some cost
  - In usual inventory models, this reversal is not possible
- Is a nice complement to inventory postponement strategies.

Key Take-Aways

- There may be big savings in optimizing sweep programs at banks
- Sweeps are transparent to customers, therefore easier to modify
- Modeling customer behavior is critical
- Simple rules may be leaving a lot of money on the table. Need for optimization technology to be brought to bear on this problem

Questions?