# Liquidity-saving mechanisms and Economic Incentives

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This talk is based on "A Study of Competing Designs of a Liquidity Savings Mechanisms" (2010) JBF, joint with Antoine Martin

"The Welfare Effects of a Liquidity Saving Mechanism,"

"Quantifying the benefits of a Liquidity Savings Mechanism," both 2008, FRBNY, and joint with Enghin Atalay and Antoine Martin.

Enghin Atalay—University of Wisconsin
Antoine Martin—Federal Reserve Bank of New York

# LSMs

- LSMs are queues to which payments can be submitted and in which they remain pending until some pre-specified event

- Our interest is to understand the economic principles that should guide the design of LSMs

# LSMs

- We abstract from a lot of real-world complexities of possible LSM designs.
    - 1) limits on the amount of central bank balances that can be committed to a particular bank or set of banks,
    - 2) a time before or after which a payment should be sent,
    - 3) different payment priorities that can change the ordering of payments submitted to the queue away from first in, first out, and
    - 4) queues may or may not be transparent.

# Large-value payment systems (LVPS)

- When banks want to make payments to each other, then use a large-value payment system

- Payments typically must be made on a particular day, but not at a particular time

- This gives banks the option to choose the time at which the payment is sent

# Why study LSMs?

- In standard theory of intertemporal trade, agents borrow and lend to and from each other

- There are typically no organized markets for intraday credit in interbank settlement systems

- Banks have the choice between borrowing from CB at a fixed price or delaying payments

# CBs care about flow of payments

- This has led to undesirable and unpredictable surges of payments toward the end of the day

- Improving the flow of payments during the day is an important policy concern for central bankers

- The traditional approach, netting of payments across banks, is seen as too prone to cascades of defaults

# From netting to RTGS to LSM

- Over the last 30 years, netting systems have been replaced by RTGS systems.

- Because they require large amounts of liquidity, RTGS systems are prone to delay of payments

- LSMs have been developed as an alternative that aims to combine the best elements of netting and RTGS systems

# Literature

- Angellini (1998, 2000), Bech and Garratt (2003), Kahn, McAndrews, and Roberds (2003), Mills and Nesmith (2006) analyze the coordination in RTGS

- Roberds (1999) considers the risk-taking incentives in netting, RTGS, and LSM environments

- Kahn and Roberds (2001) consider the benefits of coordination in CLS

- Willison (2004), Martin and McAndrews (2008) compare equilibria with RTGS and with LSM

- We study the solution to the planner's problem with and without an LSM

- We compare planner's and equilibrium allocations

- We calibrate the model using Fedwire data and compare equilibria with and without an LSM

- I won't spend time on the comparison of *balance-reactive* and *receipt-reactive* LSMs, which was the subject of the *JBF* paper.
  - Technical reason: we changed the timing of the liquidity shock between that paper and the papers that examine the welfare from *ex post* to *ex ante* relative to the decision to queue
  - General results: RR always at least as good as RTGS, while BR can produce an inferior outcome inferior to RTGS. BR and RR can each be preferred under different circumstances.

# In this talk, focus on the planner

- The planner's allocation corresponds to equilibrium with *commitment*

- LSM allows to release a payment *conditional* on the receipt of an offsetting payment

- We highlight the role of commitment and conditionality and their interactions

# Preview

- For some parameter values, the planner can achieve strictly higher welfare with an LSM

- For some parameter values, the equilibrium and the planner's allocation are the same with an LSM, but <u>not</u> with an RTGS

- The welfare gains of an LSM can be large

# Outline

- The Environment
  - LSM queue
- The planner's problem
- The planner's allocation under RTGS
  - Comparison with equilibrium
- The planner's allocation with an LSM
  - Comparison with equilibrium
- Calibration exercise
- Conclusion

# The Environment

- Two periods: morning and afternoon

- Mass 1 of risk neutral core system participants

- Each participant sends (and receives) a payment to (and from) another participant

- Three factors influence banks decision to delay

# Factor 1: Liquidity shocks

- Participants can receive a positive, a negative, or no liquidity shock
  - Thought of as a payment to or a receipt from a *non-strategic* agent, such as CLS
- The size of the liquidity shock is smaller than the size of payments between participants.

- Idiosyncratic but no aggregate uncertainty

# Factor 2: Time-Critical payments

- A fraction $\theta$ of payments are time-critical (TC)

- Cost of delay for time-critical payments: $\gamma \geq 0$

- Non-time-critical payments have no delay cost

- Participants know the time-criticality of payment they must make but not of the payment they receive
  - May be known to a depositor, but not the receiving bank

# Factor 3: Cost of borrowing

- Participants start (and end) the day with zero reserves and cannot have negative reserves

- Reserves can be borrowed at the CB at cost $R$

- Excess reserves have a return of 0

- Payments made and received in the same period offset each other

# Timeline

Nature chooses
which banks receive
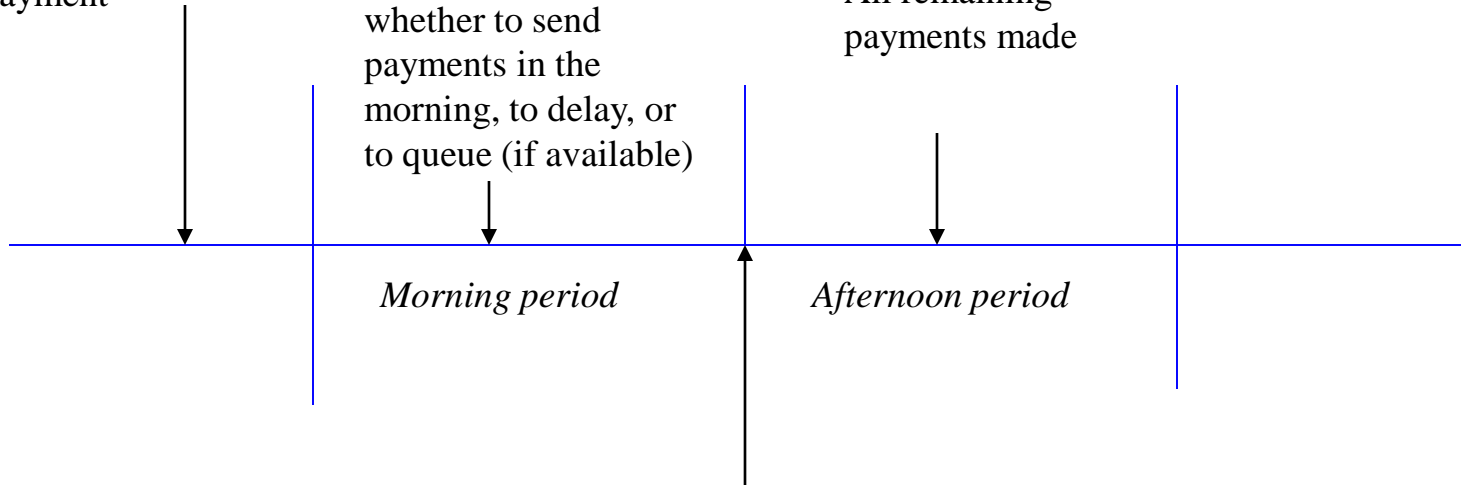a liquidity shock and
a time-sensitive
payment

Banks decide
whether to send
payments in the
morning, to delay, or
to queue (if available)

All remaining
payments made

*Morning period*

*Afternoon period*

Borrowing costs
incurred if balance is
negative, delay costs
if time-critical
payment not made

# Main trade-off

- Cost of borrowing alone provides an incentive to delay and to bunch payments

- Time-critical payments provide an incentive to make payments early

- Liquidity shocks and cost of borrowing provide an incentive to make payments late

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# Liquidity Saving Mechanism

- Payments can be put in a queue

- A payment in the queue is released if an offsetting payment is received

- Payments in the queue can offset multilaterally

# Queued payments

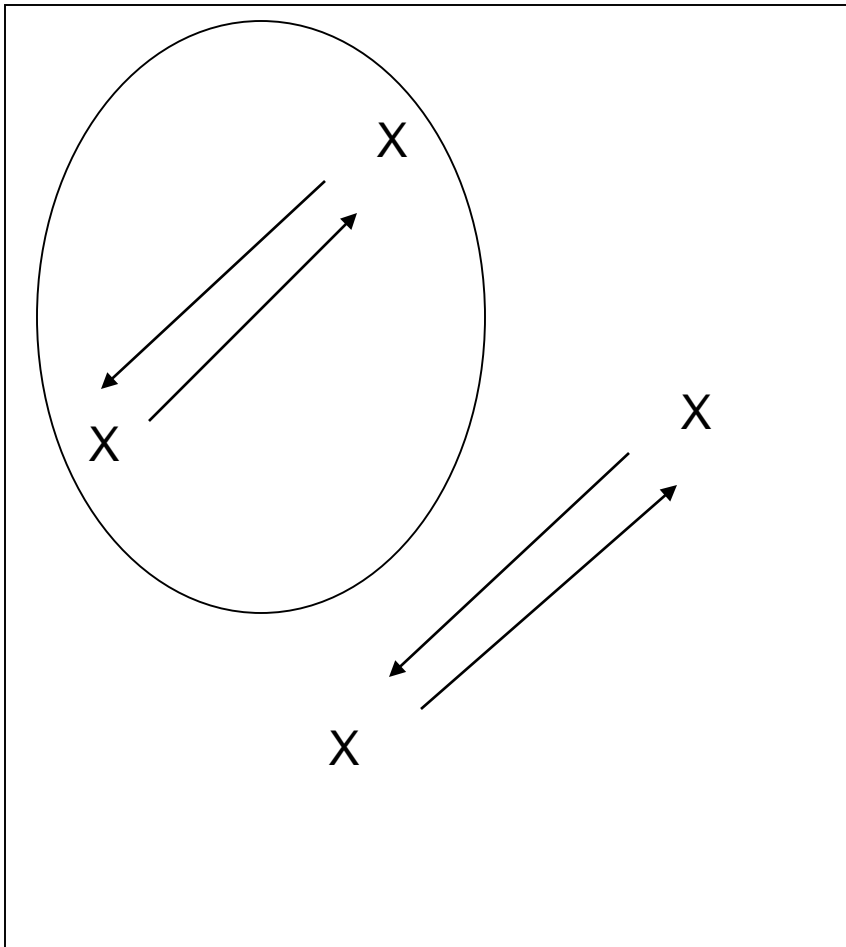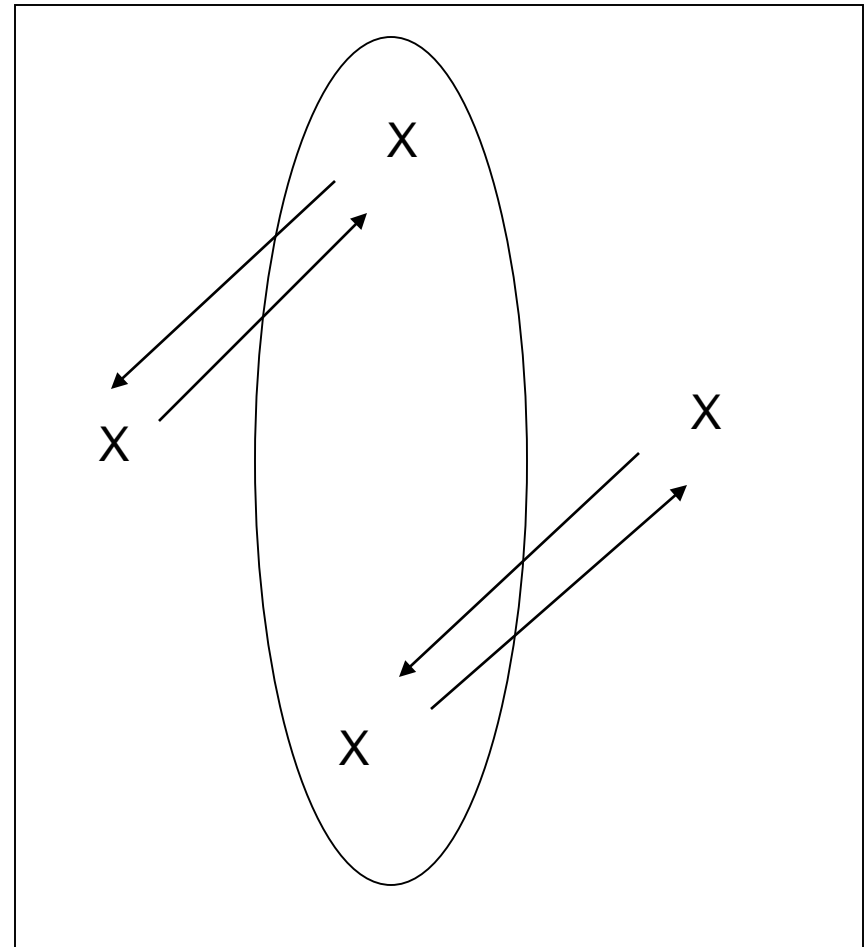Figure 1: Queued payments in a cycle

Figure 2: Queued payment in paths

# Patterns of payments

- Probability that a payment in the queue is settled early depends on overall pattern of payments

- We consider two extreme cases
  - A unique long cycle
  - Many cycles of length 2

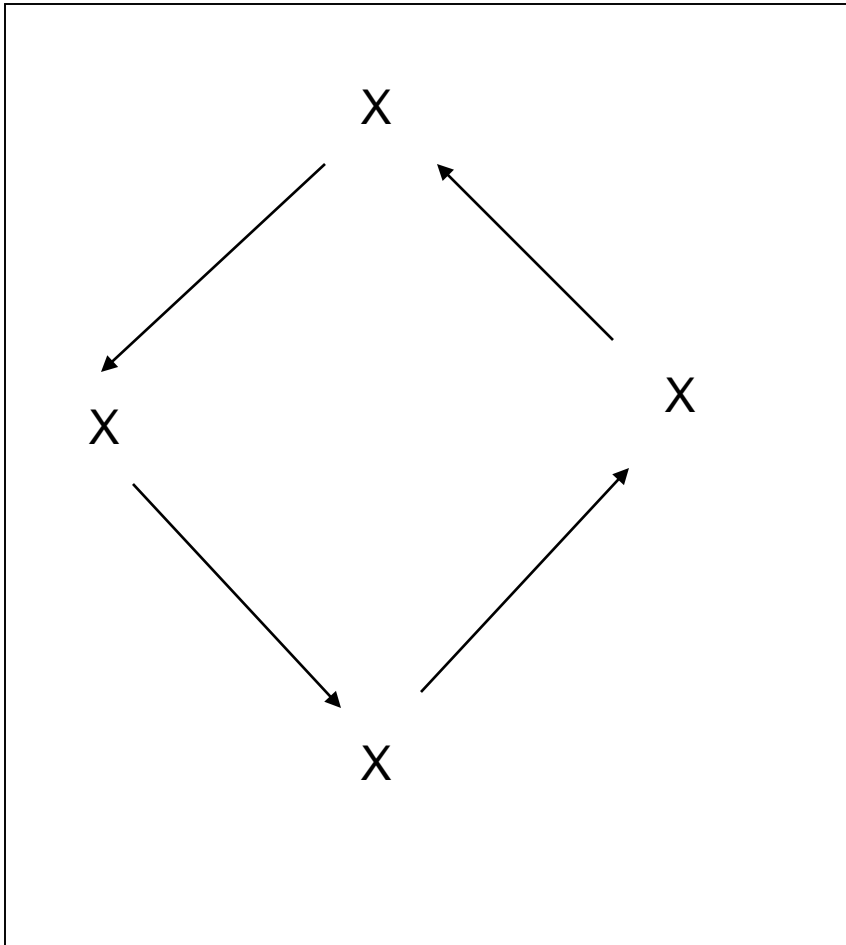# Patterns we consider

Figure 3: A unique cycle

Figure 4: Cycles of length 2
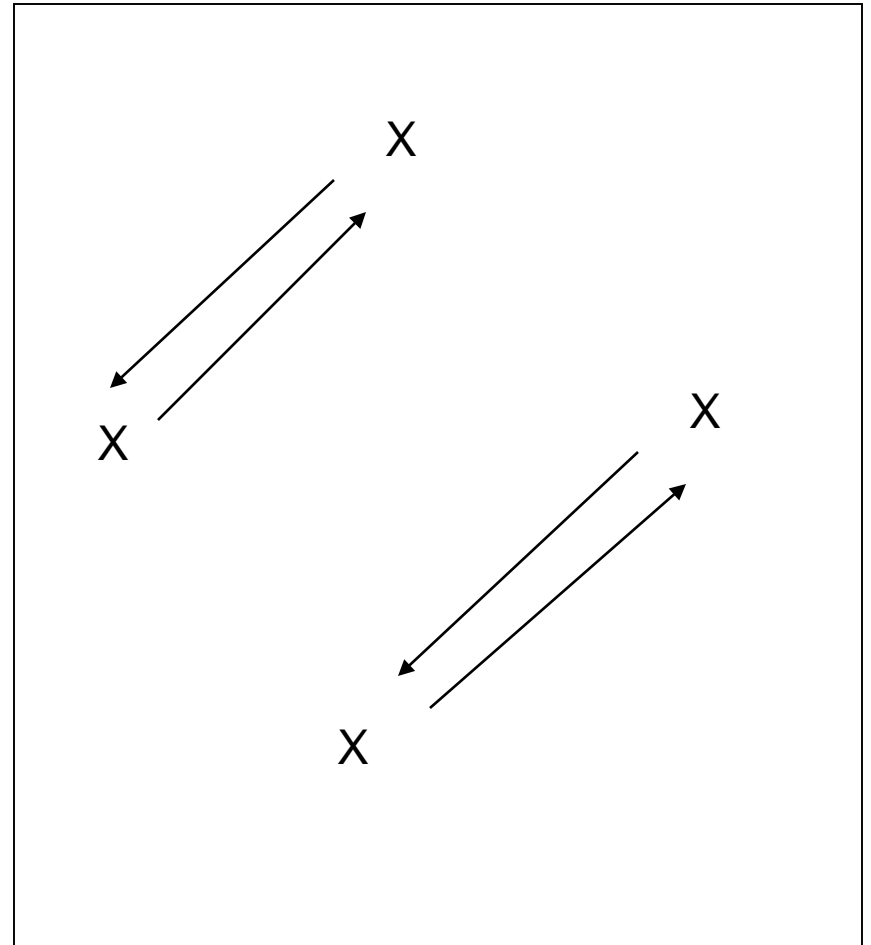
# Probability of receiving payment early

- For either assumption about the pattern of payments, we can calculate:

    - Probability of receiving a payment early if own payment is in the queue, $\pi^q$

    - Probability of receiving payment early if own payment is not in the queue, $\pi^o$

# Economic role of the queue

- The queue allows a bank to condition the release of their payment on the receipt of another payment

- It provides some insurance against the risk of having to borrow at the CB

# Where are we now?

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# Planner's objective

- Maximize the expected utility of a bank before the bank's type is known

- This is equivalent to a weighted average of banks' welfare where weights are given by the population sizes

- Equivalent to commitment

# Notation

- The set of types is $I = \{s+, s0, s-, r+, r0, r-\}$

- Let $\lambda^j_i$ denote the mass of banks of type $i$ choosing action $j$, $i \in I$, $j \in \{d, q, e\}$

# Welfare function

$$
\begin{aligned}
W \;=\; & -\sigma \left[ (\theta \lambda_{s+}^{e} + (1-\theta)\lambda_{r+}^{e})(1-\pi^{o})(2\mu-1)R \right] \\
& -\sigma\theta\lambda_{s+}^{q}(1-\pi^{q})\gamma \\
& -\sigma\theta\lambda_{s+}^{d}\gamma \\
& -(1-2\sigma)\left[ (\theta\lambda_{s0}^{e} + (1-\theta)\lambda_{r0}^{e})(1-\pi^{o})\mu R \right] \\
& -(1-2\sigma)\theta\lambda_{s0}^{q}(1-\pi^{q})\gamma \\
& -(1-2\sigma)\theta\lambda_{s0}^{d}\gamma \\
& -\sigma \left[ (\theta\lambda_{s-}^{e} + (1-\theta)\lambda_{r-}^{e})(1-\mu\pi^{o})R \right] \\
& -\sigma \left[ \theta\lambda_{s-}^{q}(1-\pi^{q})\gamma + (\theta\lambda_{s-}^{q} + (1-\theta)\lambda_{r-}^{q})(1-\mu)R \right] \\
& -\sigma \left[ \theta\lambda_{s-}^{d}\gamma + (\theta\lambda_{s-}^{d} + (1-\theta)\lambda_{r-}^{d})(1-\pi^{o})(1-\mu)R \right]
\end{aligned}
$$

Welfare cost for banks with positive liquidity shocks the send early, queue, or delay.

…banks with no liquidity shocks…

…banks with negative shocks.

# Useful lemma

- Lemma: $W$ is convex in $\lambda^j_i$, for all $i$ in $I$, $j$ in $J$

- Idea of proof: Product of two strictly increasing, weakly convex functions is convex

- Consequence: The planner always assigns the same action to banks of the same type

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# Benefit of delay with RTGS

- **Lemma 1**

  Delay reduces expected cost of borrowing

  The benefit of delay is

  - Greater for a bank with a negative liquidity shock than for a bank with no liquidity shock.

  - Greater for a bank with no liquidity shock than for a bank with a positive liquidity shock.

# Idea of proof

- The planner always assigns the same action to banks of the same type

- Cost of delay to society is independent of the type of banks that delay

- Benefit of delay to delaying bank is not independent of type (lemma 1)

- Planner prefers to delay type *r-* than other type and never wants to delay type *r0*

# Equilibria with RTGS

|   | s+ | s0 | s- | r+ | r0 | r- |
|---|----|----|----|----|----|----|
| 1 | E  | E  | E  | D  | D  | D  |
| 2 | E  | E  | D  | D  | D  | D  |
| 3 | E  | D  | D  | D  | D  | D  |
| 4 | D  | D  | D  | D  | D  | D  |

# Planner's solution, RTGS

|   | s+ | s0 | s- | r+ | r0 | r- |
|---|----|----|----|----|----|----|
| 1 | E  | E  | E  | E  | E  | E  |
| 2 | E  | E  | E  | E  | E  | D  |
| 3 | E  | E  | D  | E  | E  | D  |

# Comparison under RTGS

- In equilibrium there are always too few payments settled early
  - Banks with non-time-critical payments delay
  - Planner would like (some of) these banks to pay early
- This can justify "throughput requirements" or increased cost of late payments.

# Welfare with LSM

- As with RTGS, the planner always assigns the same action to banks of the same type
- There are $6^3 = 216$ potential cases to check
- We can eliminate some cases outright

# Actions the planner will not choose

- **Lemma 2**

  The planner will never choose to make banks with a positive or zero liquidity shock delay their payments

- **Lemma 3**

  The planner will never choose to make banks of type $r$- queue, or send early, unless all other payments are being sent early

# Actions the planner will not choose

- **Lemma 4**

  The cost of paying early, relative to queuing or delaying, is smaller for banks with a positive liquidity shock than for banks with no shock, and smaller for these banks than for banks with a negative shock

- **Lemma 5**

  The planner will never choose to have banks of type $s+$ delay or queue payments while other banks send payments early

# Action profiles left to consider

| Type | s+ | s0 | s- | r+ | r0 | r- |
|------|----|----|----|----|----|----|
| 1 | E | E | E | E | E | E |
| 2 | E | E | E | E | Q | D |
| 3 | E | Q | Q | E | Q | D |
| 4 | E | Q | D | E | Q | D |
| A | E | E | E | E | E | D |
| B | E | E | E | Q | Q | D |
| C | E | E | Q | E | E | D |
| D | E | E | Q | E | Q | D |
| E | E | E | Q | Q | Q | D |
| F | E | E | D | E | E | D |
| G | E | E | D | E | Q | D |
| H | E | E | D | Q | Q | D |
| I | E | Q | Q | Q | Q | D |
| J | E | Q | D | Q | Q | D |

# The planner's allocation

- **Proposition 2**

  Depending on parameter values, the planner will choose strategy 1, 2, 3, or 4.

- **Proposition 3**

  If $\mu > 2/3$, the planner chooses to have all payments sent early for both RTGS and LSM.

- **Proposition 4**

  If the planner chooses delay in the long-cycle case, then she also chooses delay in the short-cycles case.

# Equilibria under LSM

|   | s+ | s0 | s- | r+ | r0 | r- |
|---|----|----|----|----|----|----|
| 1 | E  | E  | E  | E  | E  | E  |
| 2 | E  | E  | E  | Q  | Q  | D  |
| 3 | E  | Q  | Q  | Q  | Q  | D  |
| 4 | E  | Q  | D  | Q  | Q  | D  |

# Planner's solution LSM

|   | s+ | s0 | s- | r+ | r0 | r- |
|---|----|----|----|----|----|----|
| 1 | E  | E  | E  | E  | E  | E  |
| 2 | E  | E  | E  | E  | Q  | D  |
| 3 | E  | Q  | Q  | E  | Q  | D  |
| 4 | E  | Q  | D  | E  | Q  | D  |

# Comparison under LSM

- If $\gamma$ is small, an LSM can achieve the planner's allocation

- In equilibrium there can be too little ($\gamma$ big and $\mu$ small) or too much ($\gamma$ small and $\mu$ big) early settlement

  – Intuition: with small costs of delay and large payment sizes, planner wants to avoid imposing excessive borrowing costs on banks

- The ability to send payments conditionally is a partial substitute to commitment

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# Calibration Exercise

- Would an LSM increase welfare for the participants of *Fedwire?*

- Strategy:
    - Calibrate the RTGS equilibrium of the model using Fedwire Data. We need: $\mu$, $\sigma$, $R$, $\theta$, $\gamma$.
        - *Size of liquidity shock, share with liquidity shock, borrowing costs, share of time-critical payments, cost of delay.*
    - Given these parameters, find welfare associated with the RTGS and the LSM equilibrium.

# The Data

- Fedwire data from 1st and 2nd quarter of 2007

- Approximately 534 thousand payments worth $2.48 trillion were made each day

- We associate liquidity shock with payments on CHIPS, CLS, DTC

# Size of the liquidity Shock, $\mu$

- In the model the size of the shock and of the payment add up to 1

- Bank has either a time-critical payment or not

- In the data, we care about the size of a bank's shock relative to the size of its time-critical payments

# Size of the liquidity Shock, $\mu$

- In the model:

$$\text{Shock} = \frac{\text{Net payment to settlement institutions}}{|\text{Net payment to settlement institutions}| + \text{Core Payments}}$$

- Core Payments: Time-sensitive payments made through Fedwire Funds.

- Payment to settlement institutions: Net payments to DTC, CHIPS, CLS, and through Fedwire Securities before noon.
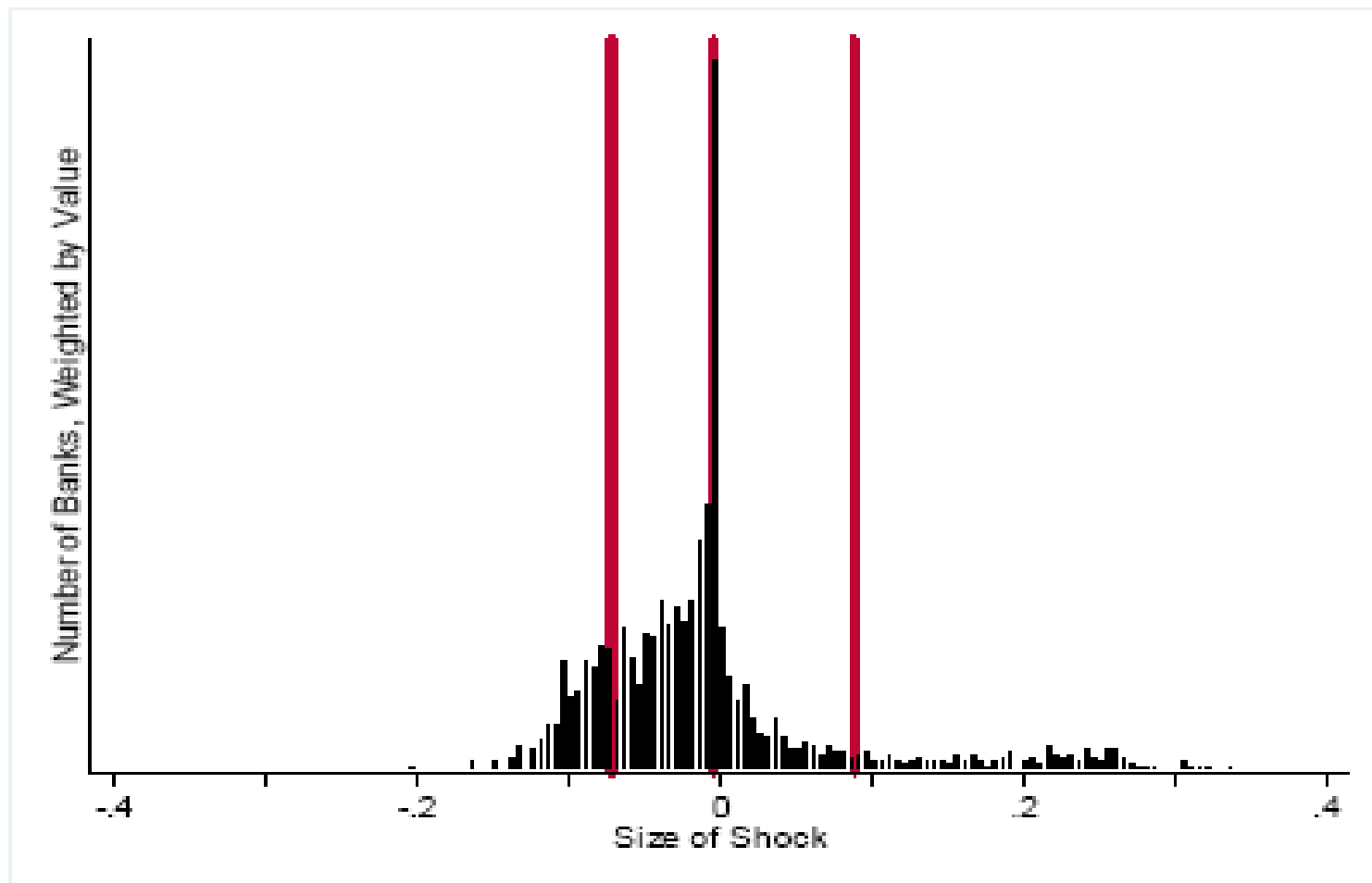
# What payments are time critical?

- We consider two possibilities:

- Only Fed funds deliveries are non-time-sensitive

- Only third-party transactions are time-sensitive

# Fraction of banks with liquidity shock, $\sigma$

- The fraction of banks with a shock depends on how large $\mu$ must be to qualify as a shock

- A shock is defined as a $\mu$ above the mean of the right hand of the distribution

- We "impose" symmetry

# The size of the shock and the share of banks with a liquidity shock

# Calibrated values for $\mu$ and $\sigma$

- Only Fed funds deliveries are non-time-sensitive: $\mu = 0.9$, $\sigma = 0.13$

- Only third-party transactions are time-sensitive: $\mu = 0.825$, $\sigma = 0.17$

# Calibrating $\theta$

- In the data, 20% of time-critical payments are made before noon

- We conclude: Only banks with positive liquidity shock make time critical payments early
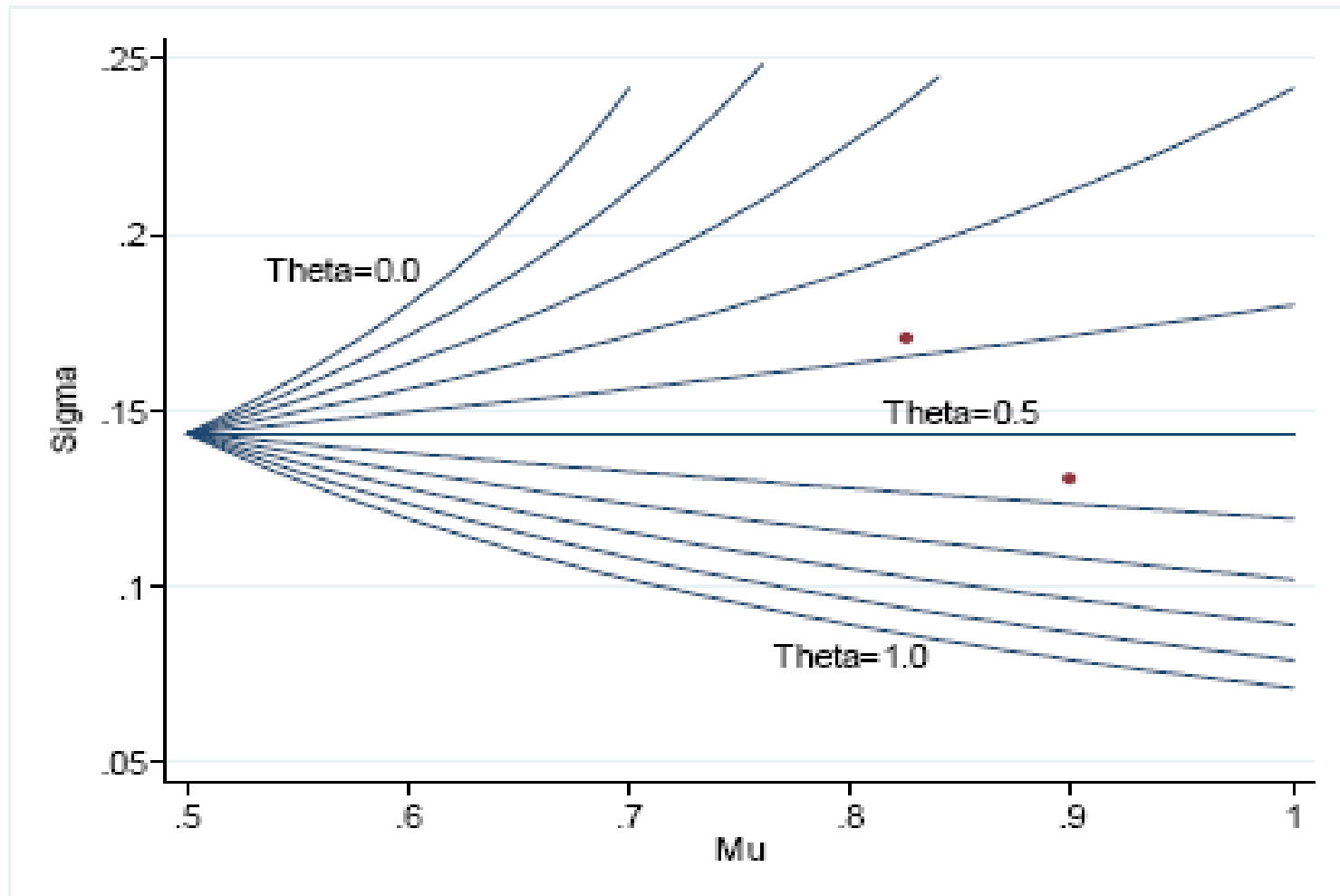
# Calibrating $\theta$ (cont.)

- To match the data we find

$$2/3 \geq \theta \geq 1/3$$

# Values of $\mu$, $\sigma$, $\theta$ consistent with model

# Calibrated values for $\mu$, $\sigma$, and $\theta$

- Only Fed funds deliveries are non-time-sensitive: $\mu = 0.9$, $\sigma = 0.13$, $\theta = 0.6$

- Only third-party transactions are time-sensitive: $\mu = 0.825$, $\sigma = 0.17$, $\theta = 0.4$

# Equilibrium outcomes

Given our calibration two kinds of equilibria can occur with an LSM.

1. all payments are made early with an LSM. For these parameters, the cost of using the payment system is $78,000 per day with an LSM but $2.88 million per day with RTGS.

2. banks with positive shocks send time-critical payments early, banks with negative shocks delay their nontime-critical payments, and all other payments are queued. The cost of using the payment system is $1.24 million with an LSM but $3.11 million with RTGS.

# Welfare Implications

- Compare the welfare cost under RTGS and LSM

- If $\gamma/R < 2\mu-1$, cost is at least than 8 times higher with RTGS than LSM

- If $\gamma/R > 2\mu-1$, cost is at least than 5 times higher with RTGS than LSM

# Welfare costs in dollars

- To measure the welfare costs in dollars, we calibrate R to the fee bank must pay

- Depending on parameter, the benefit of an LSM ranges from $1 million and $3.5 million per day

- Cost of delay is approximately 7 times the cost of borrowing

# Conclusion

- For some parameters, the planner uses an LSM
  - Conditionality is complement to commitment

- An LSM can achieve higher welfare than RTGS in equilibrium
  - Conditionality is substitute for commitment

- Welfare benefits of an LSM are likely large

# Some notation

- Mass of payments
  - sent early is denoted by $\lambda_e$
  - in queue is denoted by $\lambda_q$
  - delayed is denoted by $\lambda_d$

- Probability that a queued payment is in a cycle is $\chi$

# Probability of receiving a payment early

- Prob. receiving payment early if not in queue:

$$\pi^o \equiv \frac{\lambda_e}{\lambda_e + \lambda_d} = \frac{\lambda_e}{1 - \lambda_q}$$

- Prob. receiving payment early if in queue:

$$\pi^q \equiv \chi + \left(1 - \chi\right) \frac{\lambda_e}{\lambda_e + \lambda_q} = \chi + \left(1 - \chi\right) \pi^o$$

# Our two cases

- Long-cycle: All payments form a unique cycle
  - If $\lambda_q < 1$, $\chi = 0$ and $\pi^o = \pi^q = \lambda_e / (\lambda_e + \lambda_d)$
  - If $\lambda_q = 1$, $\pi^o = 0$ and $\pi^q = 1$

- Short-cycles: All payments form cycles of length 2
  - $\chi = \lambda_q$
  - $\pi^q = \lambda_q + [1 - \lambda_q] \pi^o$