Illiquidity in the Interbank Payment System following Wide-Scale Disruptions

4th Joint Central Bank Conference on Risk Management and Systemic Risk
European Central Bank
Frankfurt – November 8-9, 2005

Morten L. Bech
Federal Reserve Bank of New York

Rod Garratt
University of California, Santa Barbara

The views expressed in this presentation do not necessarily reflect those of the Federal Reserve Bank of New York or the Federal Reserve System
Ronald Reagan on Economists

An economist is someone who sees something [that works] in practice and wonders if it would work in theory.
A Break Down in Coordination

Payments Sent \( t \) = \( \alpha + \beta \cdot \) Payments Received \( t \) + \( \epsilon_t \)

Slope of Reaction Function of Payments Sent to Payments Received: Fixed-Effects Tobit Model

Source: Federal Reserve Bank of New York

McAndrews and Potter (2002)
Game Plan

• Extend a non-stochastic version of the intraday liquidity management game of Bech and Garratt (2003) to $n$ players

• Use the concept of a potential function to characterize the equilibria of the game

• Use the simple adjustment process suggested by Monderer and Shapley (1996) to describe the off equilibrium dynamics of the game
Fee $F$ charged by central bank for overdrafts

<table>
<thead>
<tr>
<th></th>
<th>Bank B</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Morning</td>
<td>Afternoon</td>
</tr>
<tr>
<td>Bank A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning</td>
<td>0, 0</td>
<td>F, D</td>
</tr>
<tr>
<td>Afternoon</td>
<td>D, F</td>
<td>D, D</td>
</tr>
</tbody>
</table>

Time is money (also intraday) so delay is costly. The cost is $D > 0$ per dollar.

F < $D$

F > $D$

Total cost = 0 (FIRST BEST)

<table>
<thead>
<tr>
<th></th>
<th>Bank B</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Morning</td>
<td>Afternoon</td>
</tr>
<tr>
<td>Bank A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning</td>
<td>0, 0</td>
<td>3, 4</td>
</tr>
<tr>
<td>Afternoon</td>
<td>4, 3</td>
<td>4, 4</td>
</tr>
</tbody>
</table>

Stag Hunt

Total cost = 0 or (6)

<table>
<thead>
<tr>
<th></th>
<th>Bank B</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Morning</td>
<td>Afternoon</td>
</tr>
<tr>
<td>Bank A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning</td>
<td>0, 0</td>
<td>4, 3</td>
</tr>
<tr>
<td>Afternoon</td>
<td>3, 4</td>
<td>3, 3</td>
</tr>
</tbody>
</table>

Rational players are pulled in one direction by considerations of mutual benefit and in the other by considerations of personal risk.
Model

- *n* identical banks
- Two periods; morning and afternoon.
- At dawn each bank receives *(n-1)* requests from customers to pay a customer of each of the other *(n-1)* banks $1
- Banks can choose to either process all the requests in the morning period or postpone them all until the afternoon period
- Banks have to trade-off the cost of mobilizing liquidity against the cost of customer dissatisfaction.
Potential Function

- In physics potential-energy functions are used …
- Related concept to summarize \( n \)-player game
- The potential function contains all info needed to compute the NE
- A game with a potential function is called a potential game but not all games are potential games.
- Local maxima of a potential function correspond to Nash Equilibria
- Definition:

A function satisfying for every \( s_i, s_{-i} \in S_i, \ s_{-i} \in S_{-i} \ and \ i \in N \)

\[
\pi_i(s_i, s_{-i}) - \pi_i(s'_i, s_{-i}) = P(s_i, s_{-i}) - P(s'_i, s_{-i})
\]
Potential Function - Example

\[
\pi_1(\text{Top,Left}) - \pi_1(\text{Bottom,Left}) = P(\text{Top,Left}) - P(\text{Bottom,Left}) = 2
\]

\[
\pi_1(\text{Top,Right}) - \pi_1(\text{Bottom,Right}) = P(\text{Top,Right}) - P(\text{Bottom,Right}) = -1
\]
Math Trickery

\[ P(s_1, \ldots, s_n) \xrightarrow{\text{aggregation game}} P(x) \xrightarrow{\text{simplification}} P(\theta) \]

\( x \): no. banks playing morning

\( \theta \): share of banks playing afternoon
Adjustment Process

- Monderer and Shapley (1996): A simple adjustment process that converges to a Nash eqm. of a potential game in a finite number of steps.
- Whenever the strategy profile is not a NE, one player deviates to a strategy that makes him better off. Unilateral deviations that increase the payoff of the deviator raise the value of the potential and vice versa.
- Once a NE is reached (there are no more self-improving, unilateral deviations) the process terminates and the potential function will be at a maximum in the sense that its value cannot be increased by varying any single player's strategy.
- Endpoints of the simple adjustment process are local maxima of the potential function.
Adjustment following Wide-Scale Disruption

-1 * Potential

Share of Banks Playing Afternoon
Mergers and Network Topology

\[ 0 < \alpha \leq 1 \]

\[ \alpha = 2 \]

\[ \alpha = 0 \]
Fedwire

Network Characteristics

Nodes: 66
Links (Undirected): 181
Total Value: $1.12 tn. (%75)
Total Volume: 166,577 (%36)
Potential Function, $P(s, \theta)$

- $1 \times$ Potential

$P(m, \theta)$

$P(a, \theta)$

Self-reversing

Share of Small Banks
Potential Function, $P(s, \theta)$

-1 * Potential

Self-Perpetuating

Share of Small Banks
Potential Function, $P(s, \theta)$

- Option 1: Large Bank recover slowly
- Option 2: Large Bank recover quickly

Share of Small Banks
Potential Function, $P(s, \theta)$

Option 1: Large Bank is impatient
Option 2: Large Bank is patient

Likely Self-Perpetuating
Potential Function, $P(s, \theta)$

Too Big to Fail in terms of maintaining payment coordination

-1 * Potential
Conclusion

• We showed that the ability of banks in Fedwire to revert to payment coordination following a wide-scale disruption depends critically on
  - the scale and/or scope of the shock (not to surprising)
  - the cost of delay and the cost of liquidity (informative)
  - the banking structure and network topology of payment flow (interesting)

• We identified an alternative way a bank may be consider Too Big to Fail. If a bank is sufficiently large it maybe crucial to maintaining payment coordination following a wide-scale disruption.
The Big Picture

• At the apex of the U.S. financial system are a number of critical financial markets

• Critical to the smooth functioning are a set of wholesale payments systems and financial infrastructures

• A complex dynamic adaptive system:
  ▲ a large number of micro agents engage repeatedly in local interactions giving rise to global regularities
  ▲ Reactive agents that are capable of exhibiting systematically different attributes in reaction to change environmental conditions
  ▲ When analyzing system risk it is important to account for behavioral changes of participants