

# Illiquidity in the Interbank Payment System following Wide-Scale Disruptions

4<sup>th</sup> Joint Central Bank Conference on Risk Management and Systemic Risk  
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Frankfurt – November 8-9, 2005

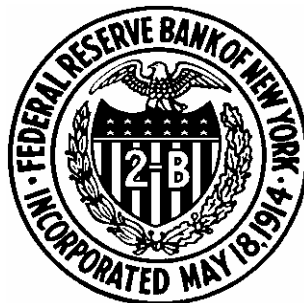
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*The views expressed in this presentation do not necessarily reflect those of the Federal Reserve Bank of New York or the Federal Reserve System*

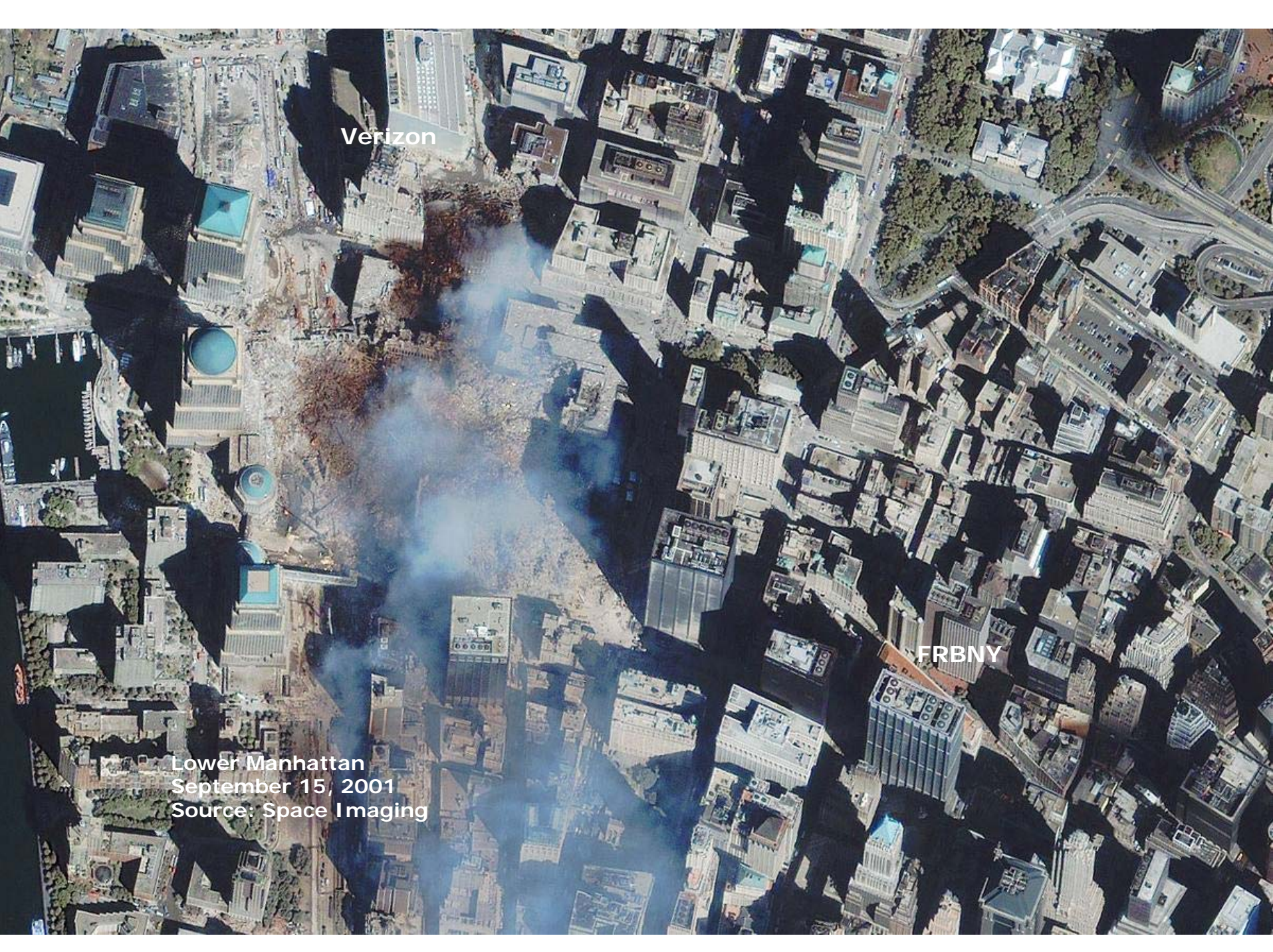


# Ronald Reagan on Economists

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





Verizon

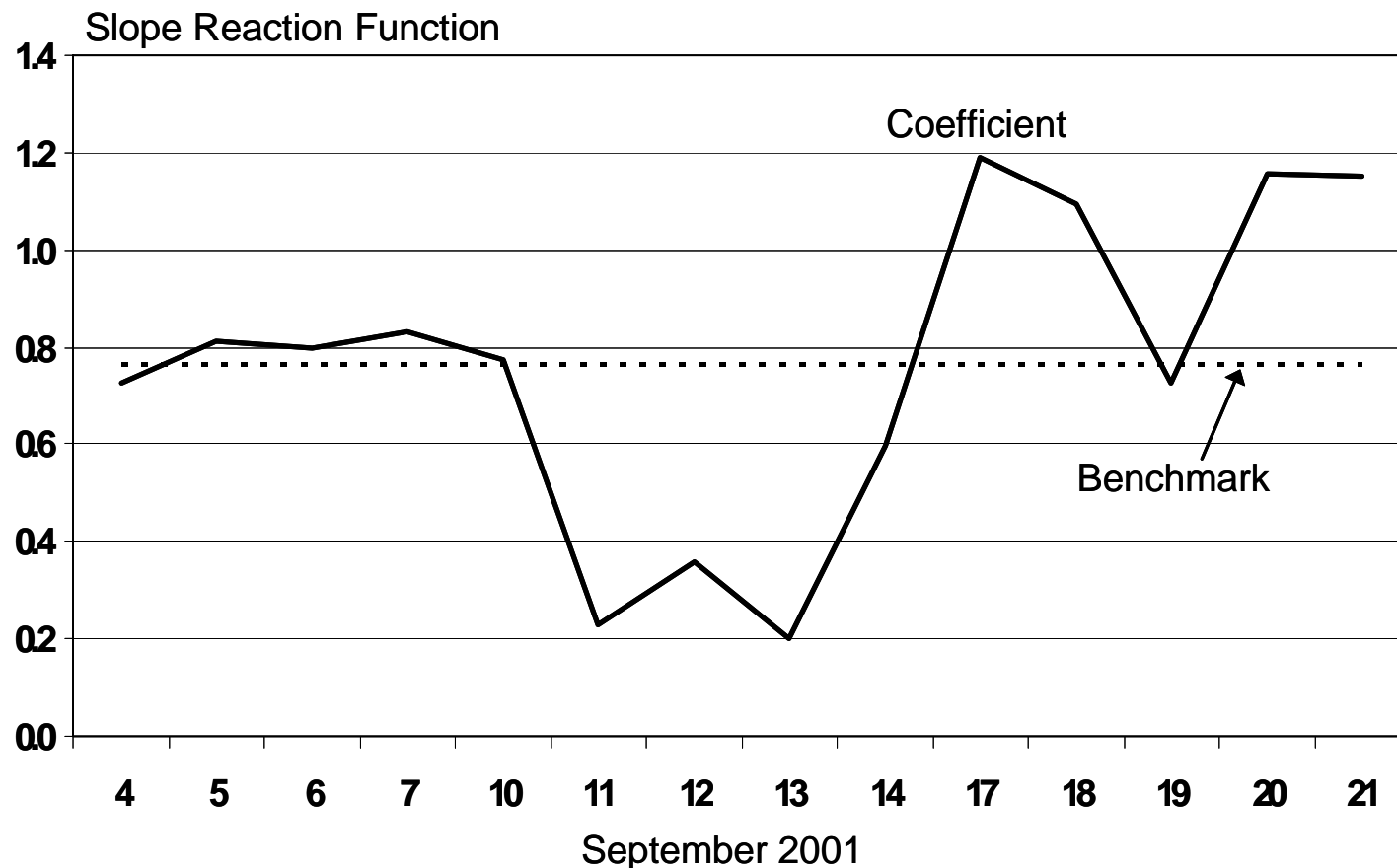
FRBNY

Lower Manhattan  
September 15, 2001  
Source: Space Imaging

# A Break Down in Coordination

$$\text{Payments Sent}_t = \alpha + \beta \cdot \text{Payments Received}_t + \varepsilon_t$$

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



# 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



# Bech and Garratt (2003)

Fee  $F$  charged by central bank for overdrafts

		Bank B	
		Morning	Afternoon
Bank A	Morning	0, 0	$F, D$
	Afternoon	$D, F$	$D, D$

$F < D$

Bank A

		Bank B	
		Morning	Afternoon
Bank A	Morning	<u>0</u> , <u>0</u>	<u>3</u> , 4
	Afternoon	4, <u>3</u>	4, 4

Total cost = 0 (FIRST BEST)

$F > D$

Bank A

		Bank B	
		Morning	Afternoon
Bank A	Morning	<u>0</u> , <u>0</u>	4, 3
	Afternoon	3, 4	<u>3</u> , <u>3</u>

Total cost = 0 or (6)

Stag Hunt

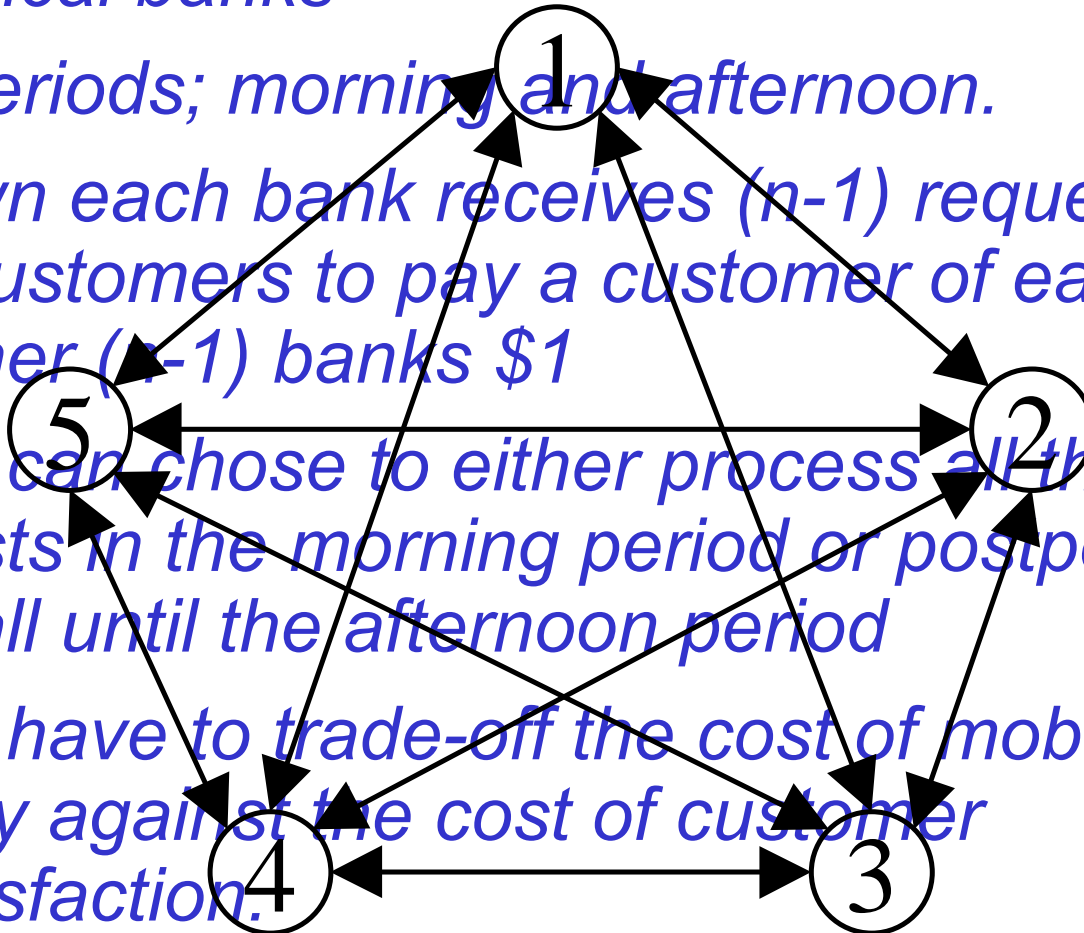
Time is money (also intraday) so delay is costly. The cost is  $D > 0$  per dollar

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

		Player 2				Player 2		
		Left	Right			Left	Right	
Player 1	Top	<u>2</u> , <u>2</u>	0, 0	One Candidate →	Player 1	Top	2	0
	Bottom	0, 0	<u>1</u> , <u>1</u>			Bottom	0	1

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

$$\pi_1(\text{Top,Right}) - \pi_1(\text{Bottom,Right}) = P(\text{Top,Right}) - P(\text{Bottom,Right}) = -1$$



# Math Trickery

$$P(s_1, \dots, s_n) \xrightarrow{\text{aggregation game}} P(x) \xrightarrow{\text{simplification}} P(\theta)$$

$x$ : no. banks playing morning

$\theta$ : share of banks playing afternoon

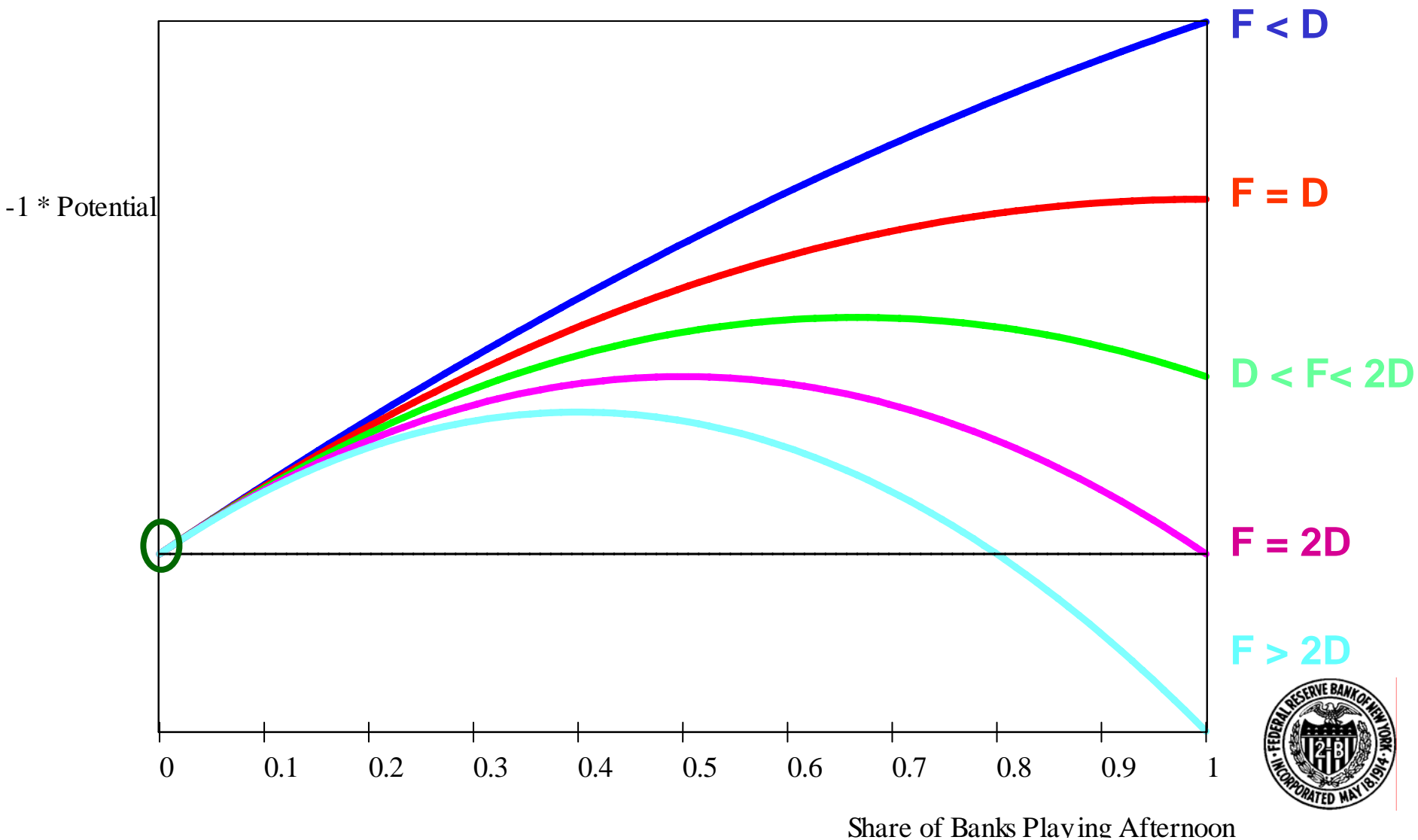


# Adjustment Process

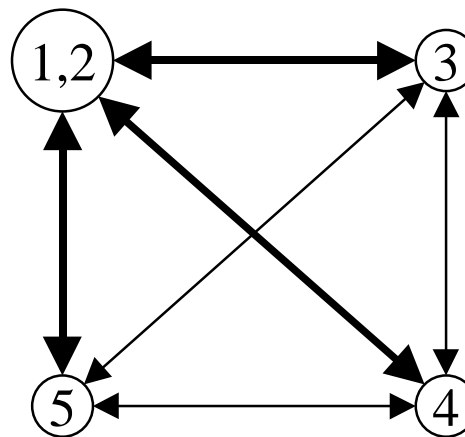
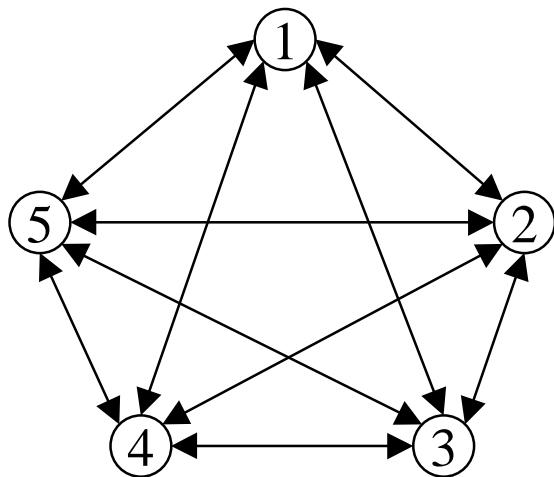
- Monderer and Shapley (1996): A simple adjustment process that converges to a Nash eqm. of a potential game in a finite number of steps.
- Whenever the strategy profile is not a NE, one player deviates to a strategy that makes him better off. Unilateral deviations that increase the payoff of the deviator 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.



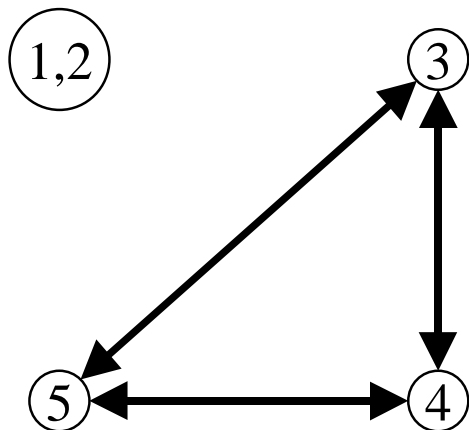
# Adjustment following Wide-Scale Disruption



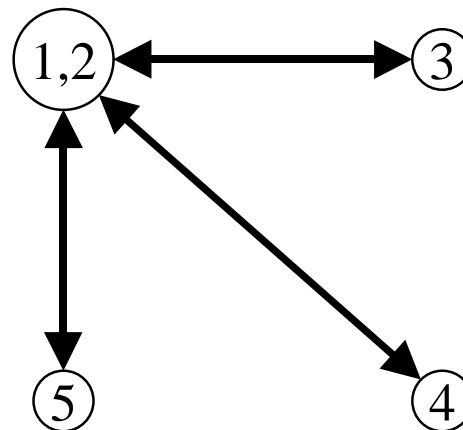
# Mergers and Network Topology



$0 < \alpha \leq 1$



$\alpha = 2$



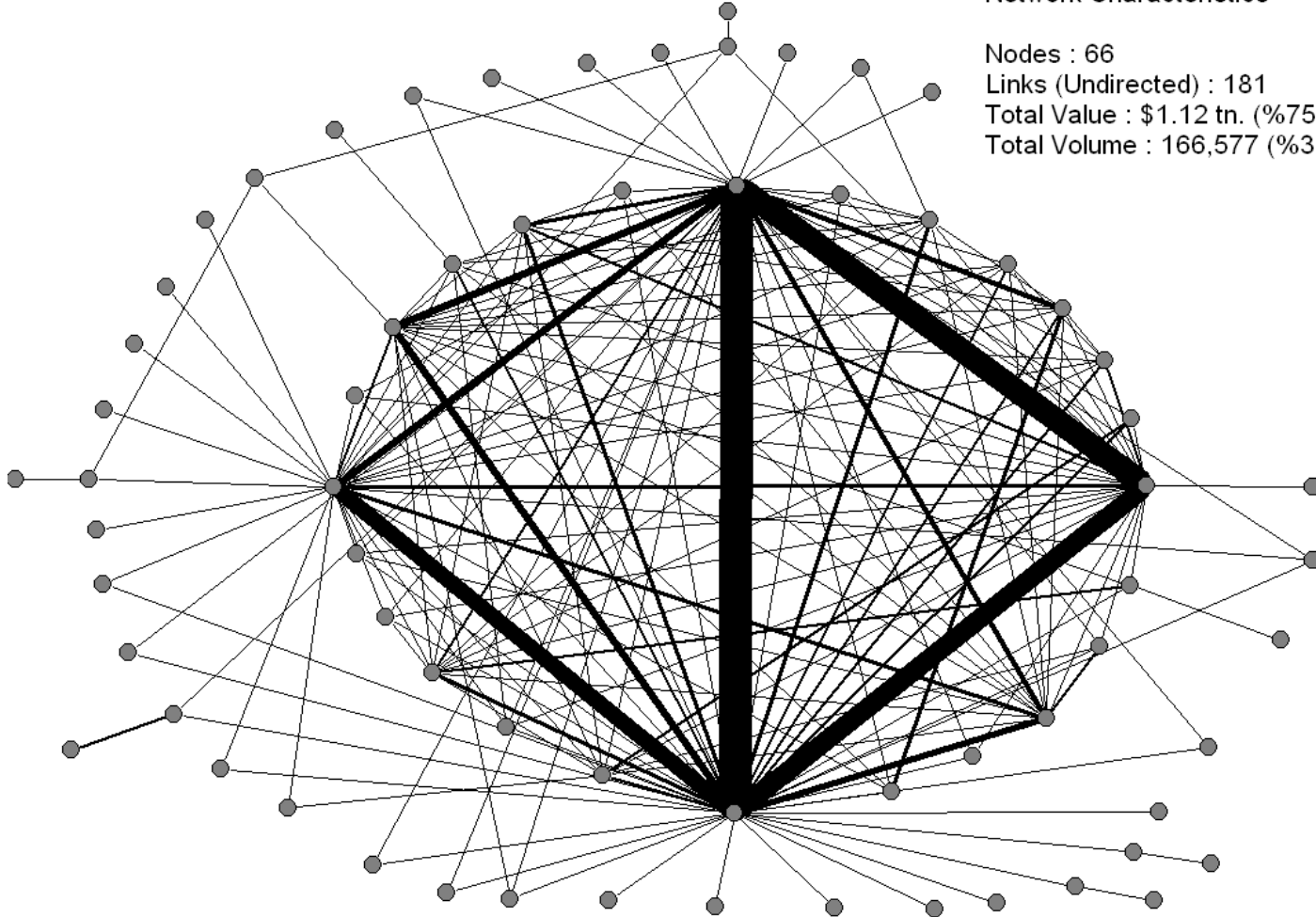
$\alpha = 0$



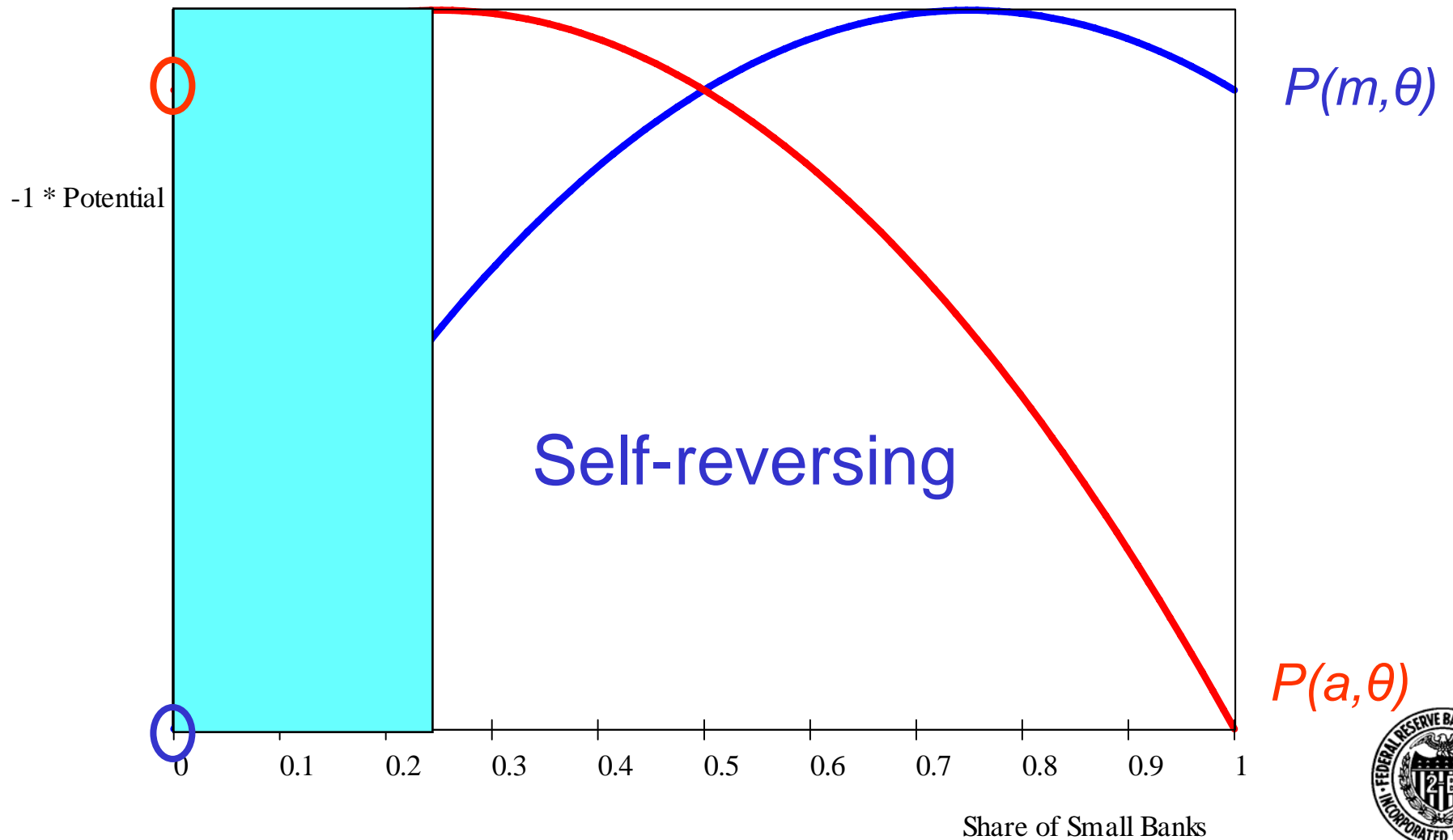
# Fedwire

## Network Characteristics

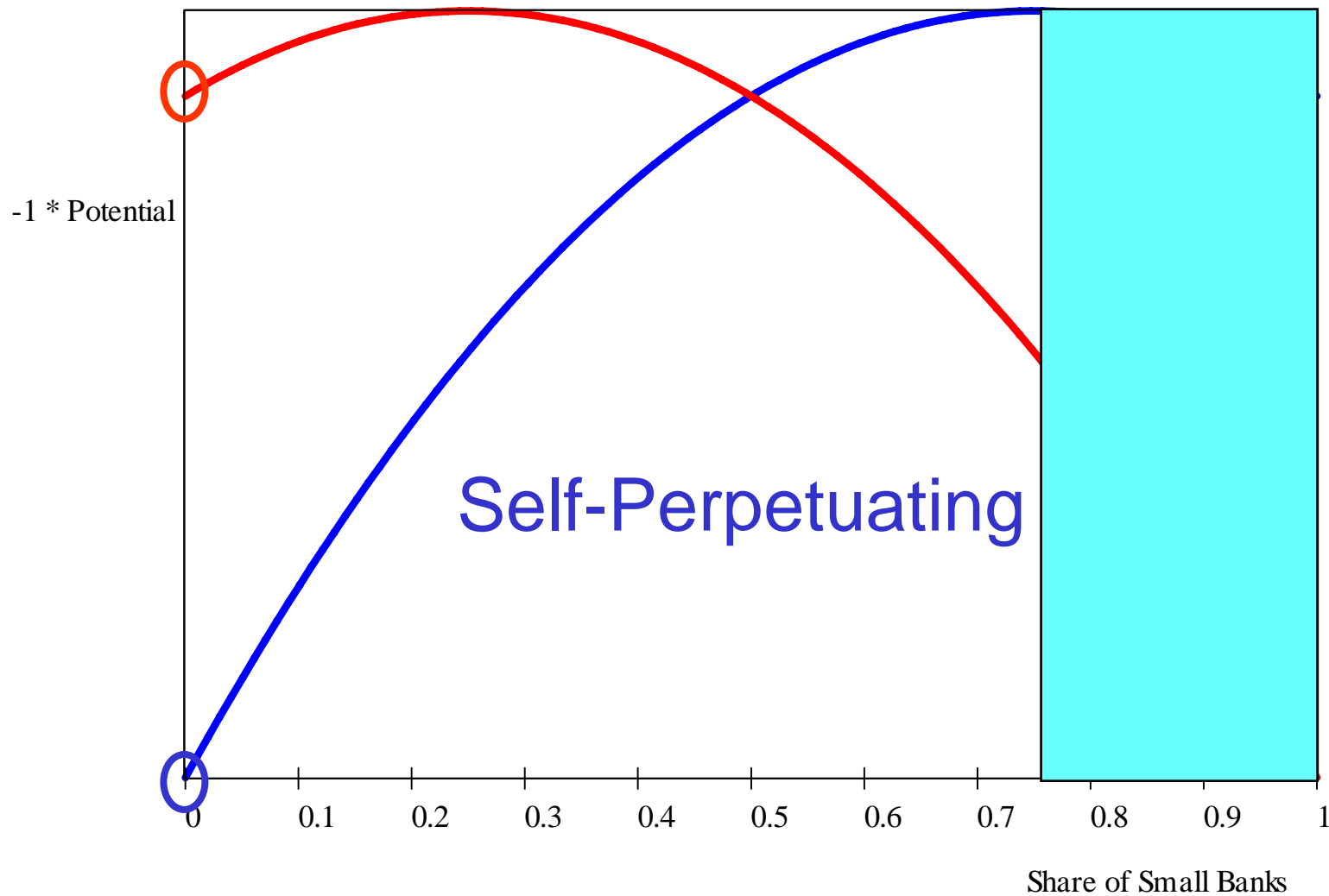
Nodes : 66  
Links (Undirected) : 181  
Total Value : \$1.12 tn. (%75)  
Total Volume : 166,577 (%36)



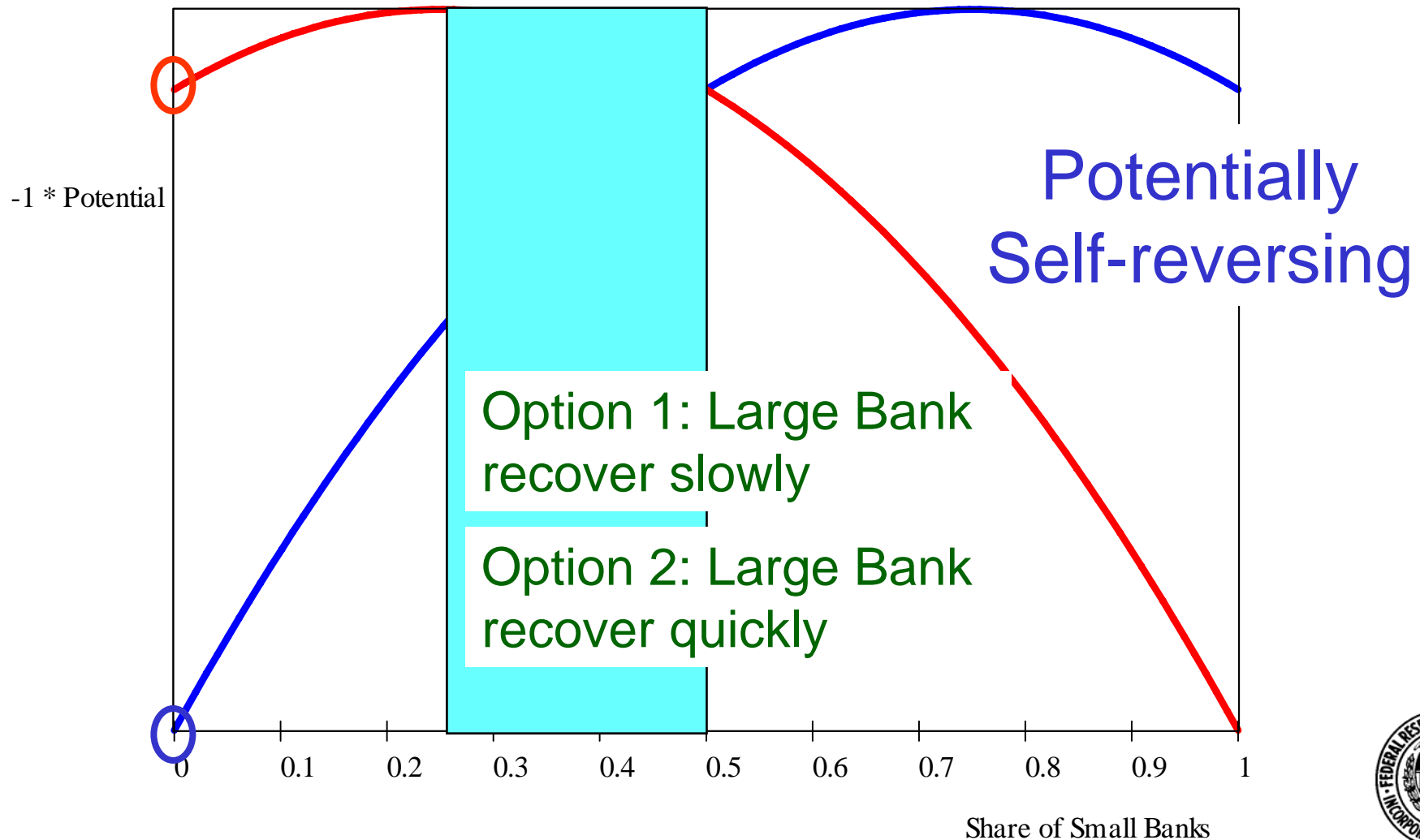
# Potential Function, $P(s, \theta)$



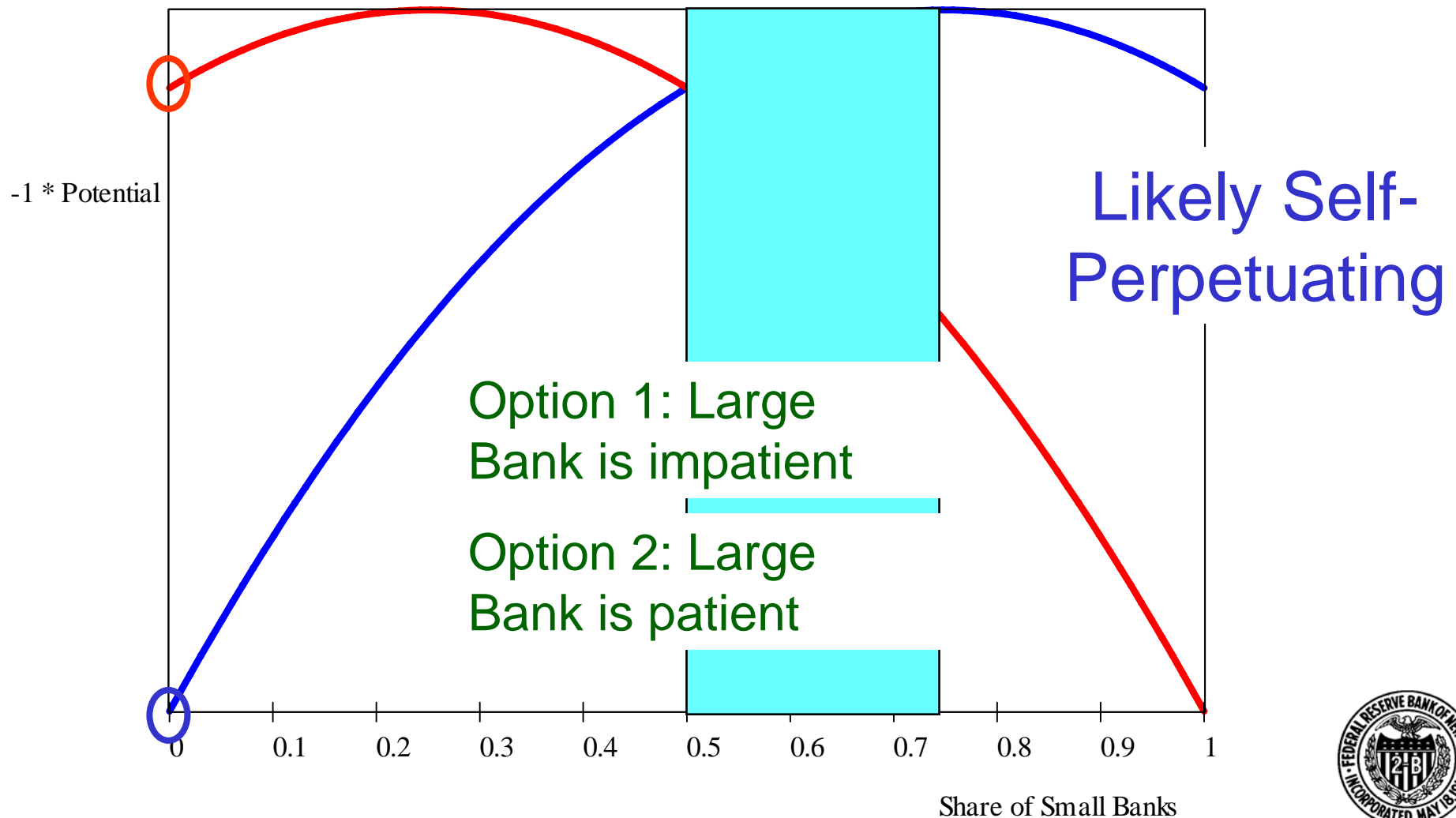
# Potential Function, $P(s, \theta)$



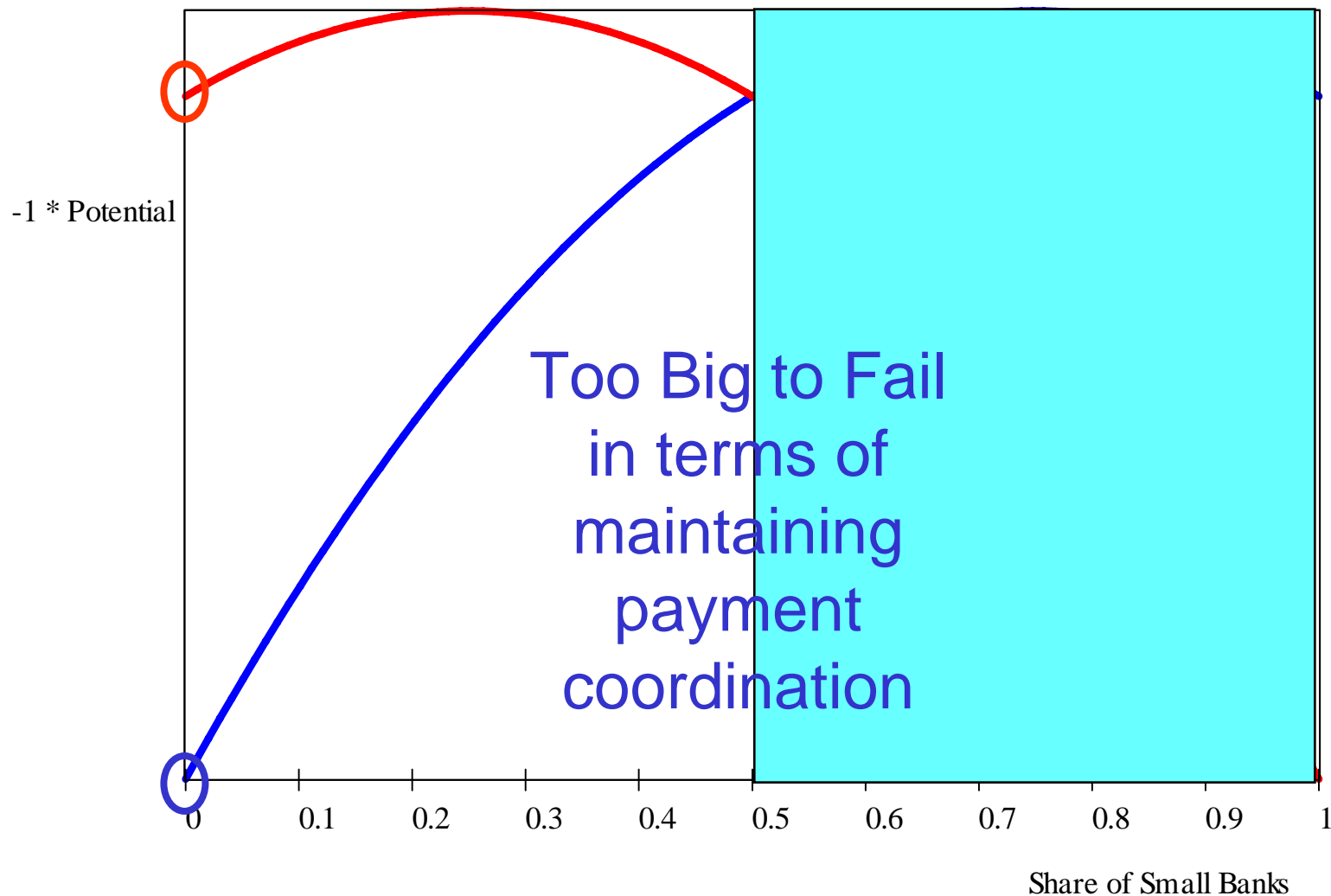
# Potential Function, $P(s, \theta)$



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# Potential Function, $P(s, \theta)$



# 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

