Congestion and Cascades in Payment Systems

Walt Beyeler[1]
Kimmo Soramäki[2]
Morten L. Bech[3]
Robert J. Glass[1]
[1]Sandia National Laboratories
[2]European Central Bank
[3]Federal Reserve Bank of New York

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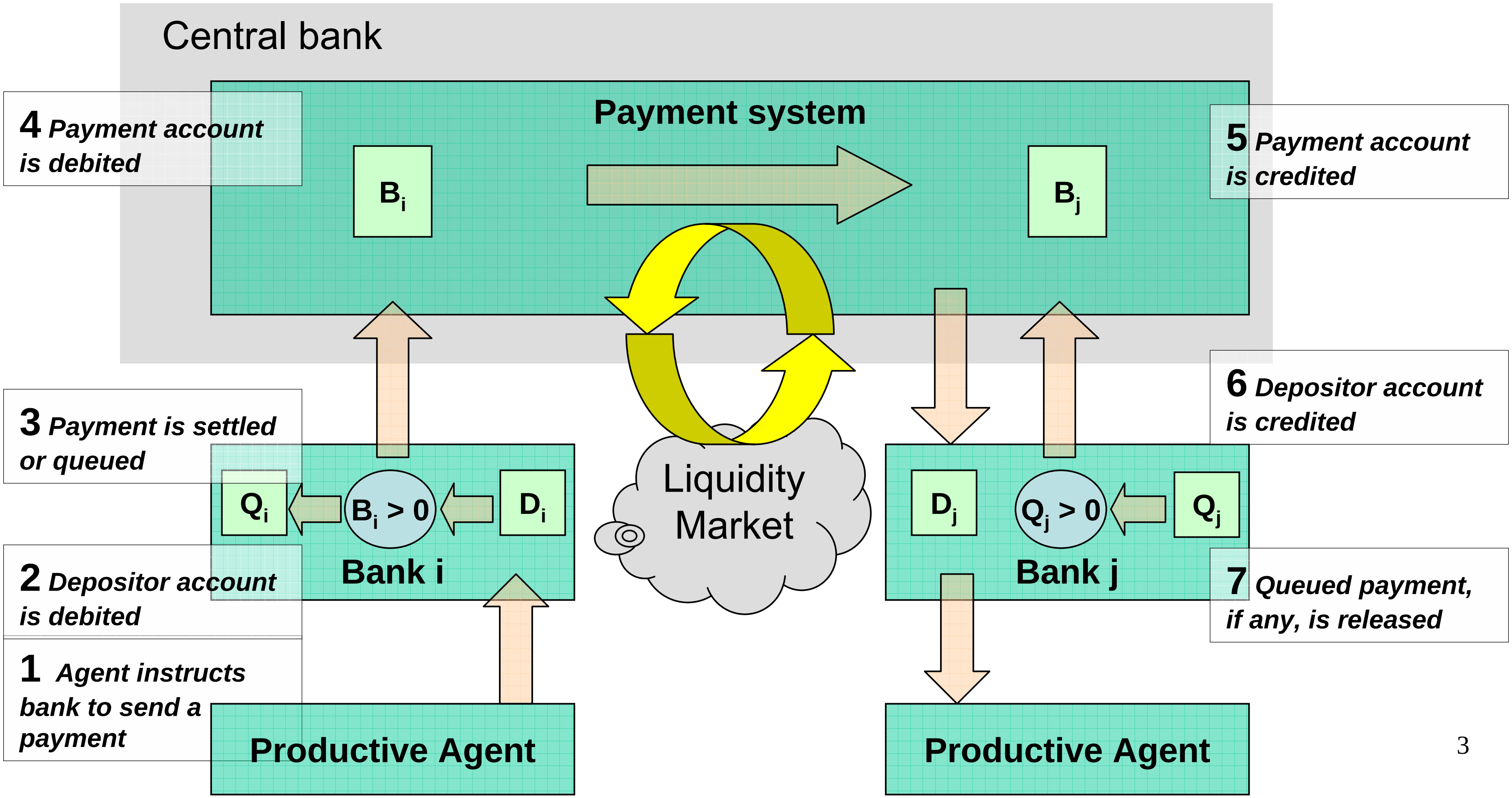
Physics of Payment Systems

- Purpose of “complexity” models
  - Understand how interactions among many agents can generate system-level behavior
  - Understand regimes of behavior and what governs transitions among them
- *Models are accordingly abstract and usually very simple because accurate simulation of a specific system or situation is not the goal*
- Payment systems as complex systems
  - Understand how liquidity controls congestion
  - Characterize congested state
  - Understand how liquidity markets relieve congestion

Payment Physics Model



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Instruction Arrival

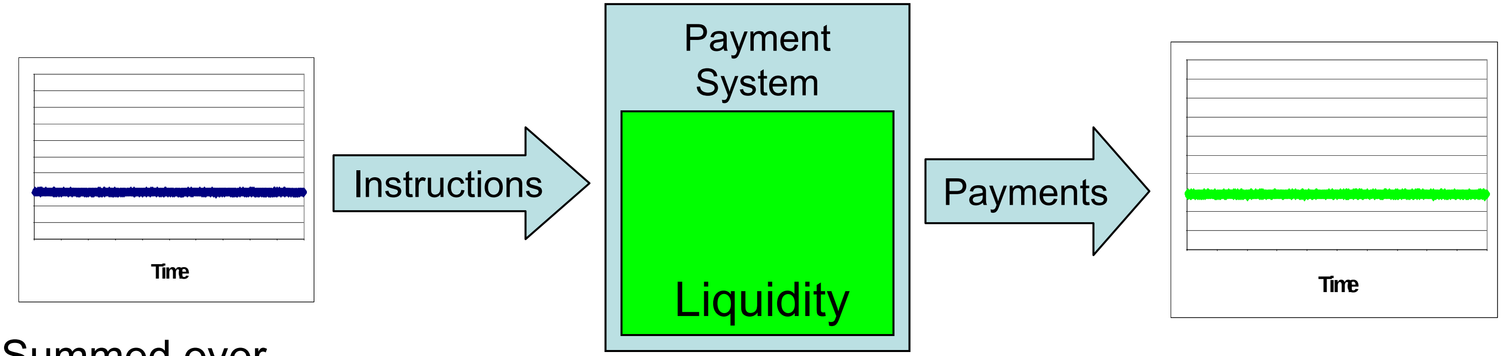
- Each bank has a given level of customer deposits (D_i)
- Each unit of deposits has the same probability of being transformed into a payment instruction

$$\langle I_i(t) \rangle = \lambda_i \cdot \frac{D_i(t)}{D_i(0)}$$

where λ_i is the initial rate

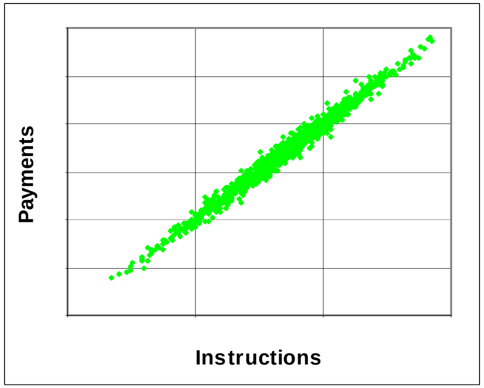
- When a bank receives a payment its deposits increase
- -> the instruction arrival rate increases
- When a bank sends a payment its deposits decrease
- -> the instruction arrival rate decreases

Influence of Liquidity

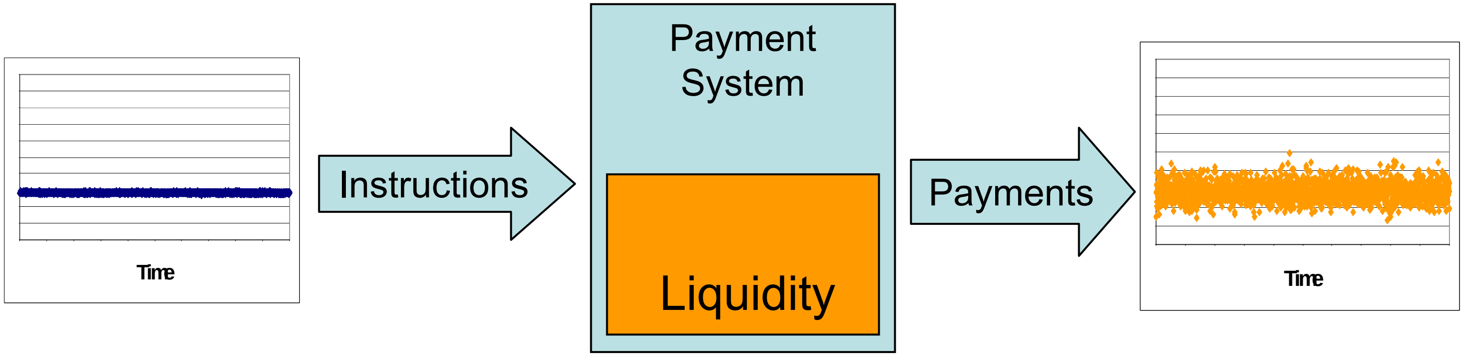


Summed over the network, instructions arrive at a steady rate

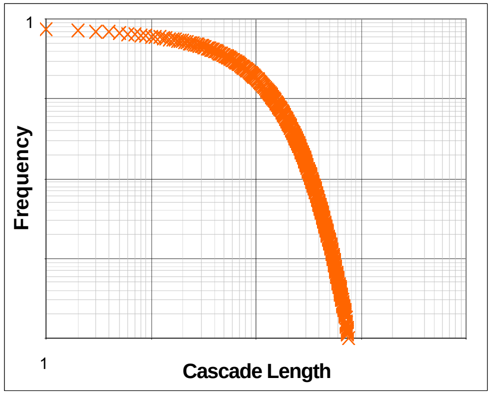
When liquidity is high payments are submitted promptly and banks process payments independently of each other

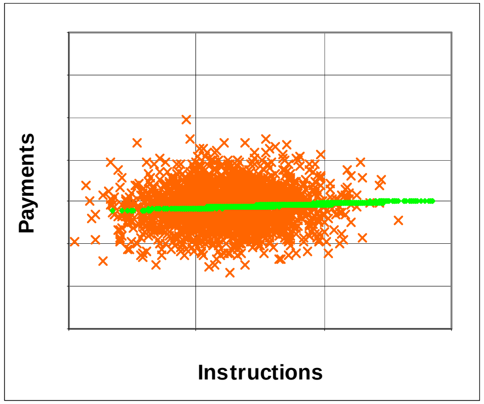


Influence of Liquidity



Reducing liquidity leads to episodes of congestion when queues build, and cascades of settlement activity when incoming payments allow banks to work off queues. Payment processing becomes coupled across the network





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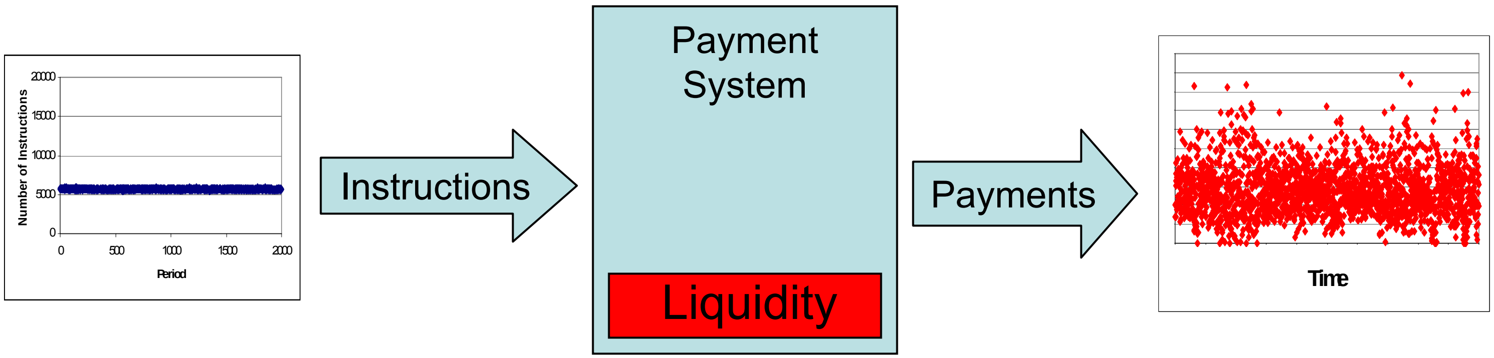
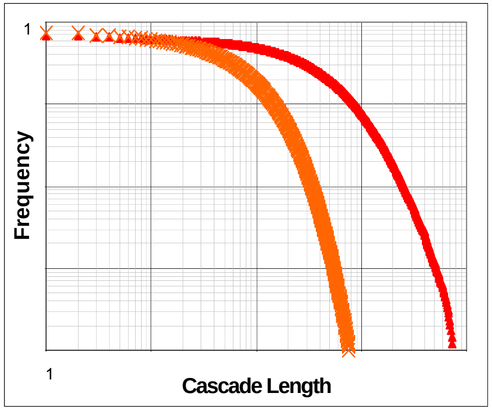
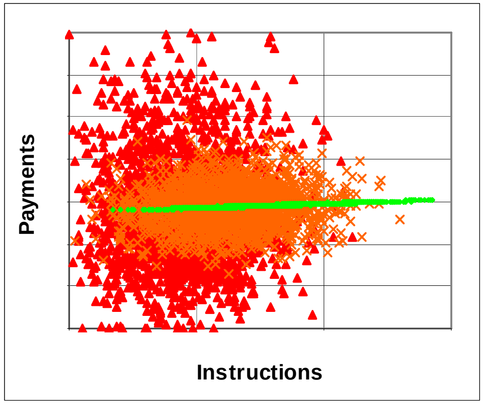
Influence of Liquidity



At very low liquidity payments are controlled by internal dynamics. Settlement cascades are larger and can pass through the same bank numerous times





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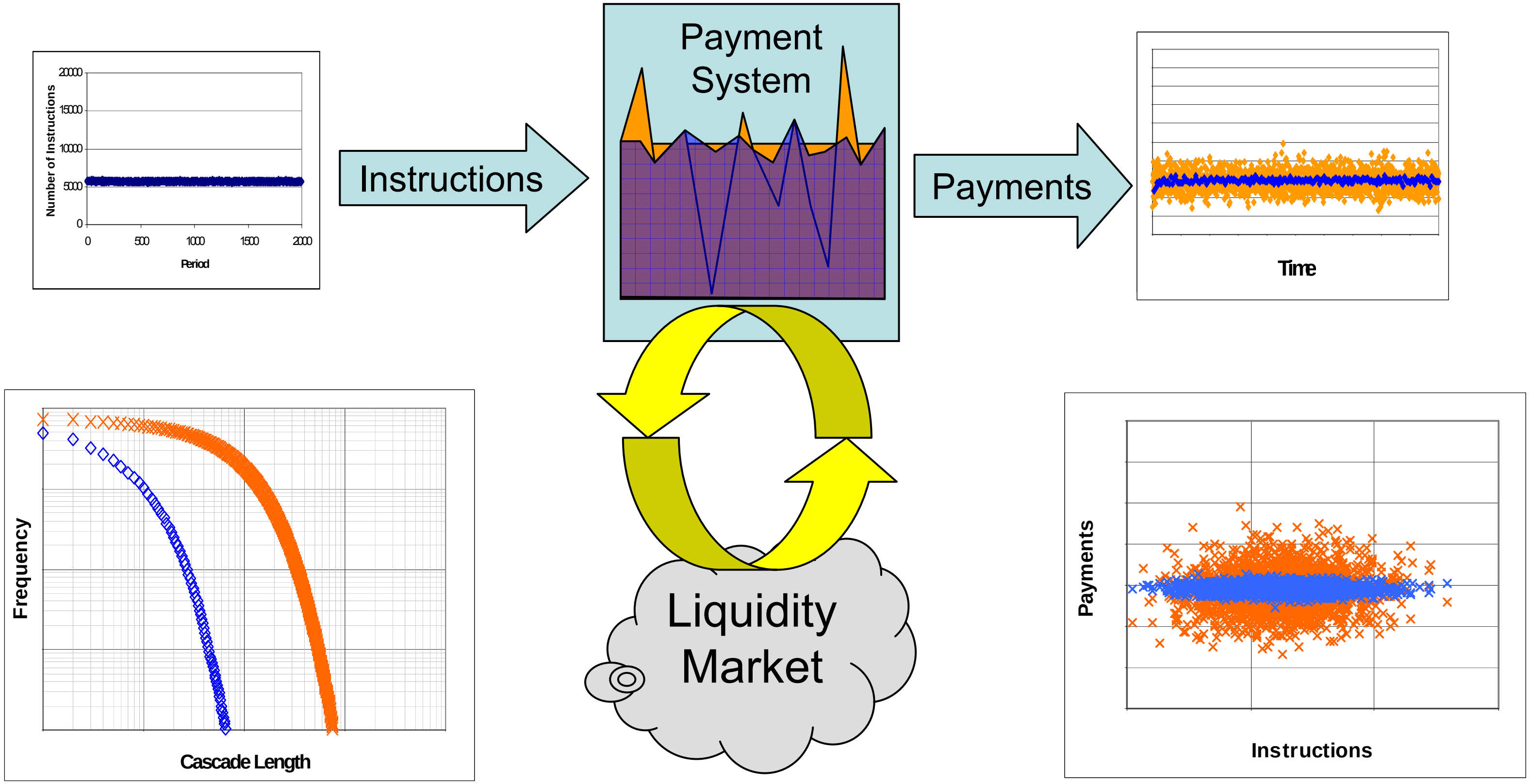
Influence of Market



A liquidity market substantially reduces congestion using only a small fraction (e.g. 2%) of payment-driven flow

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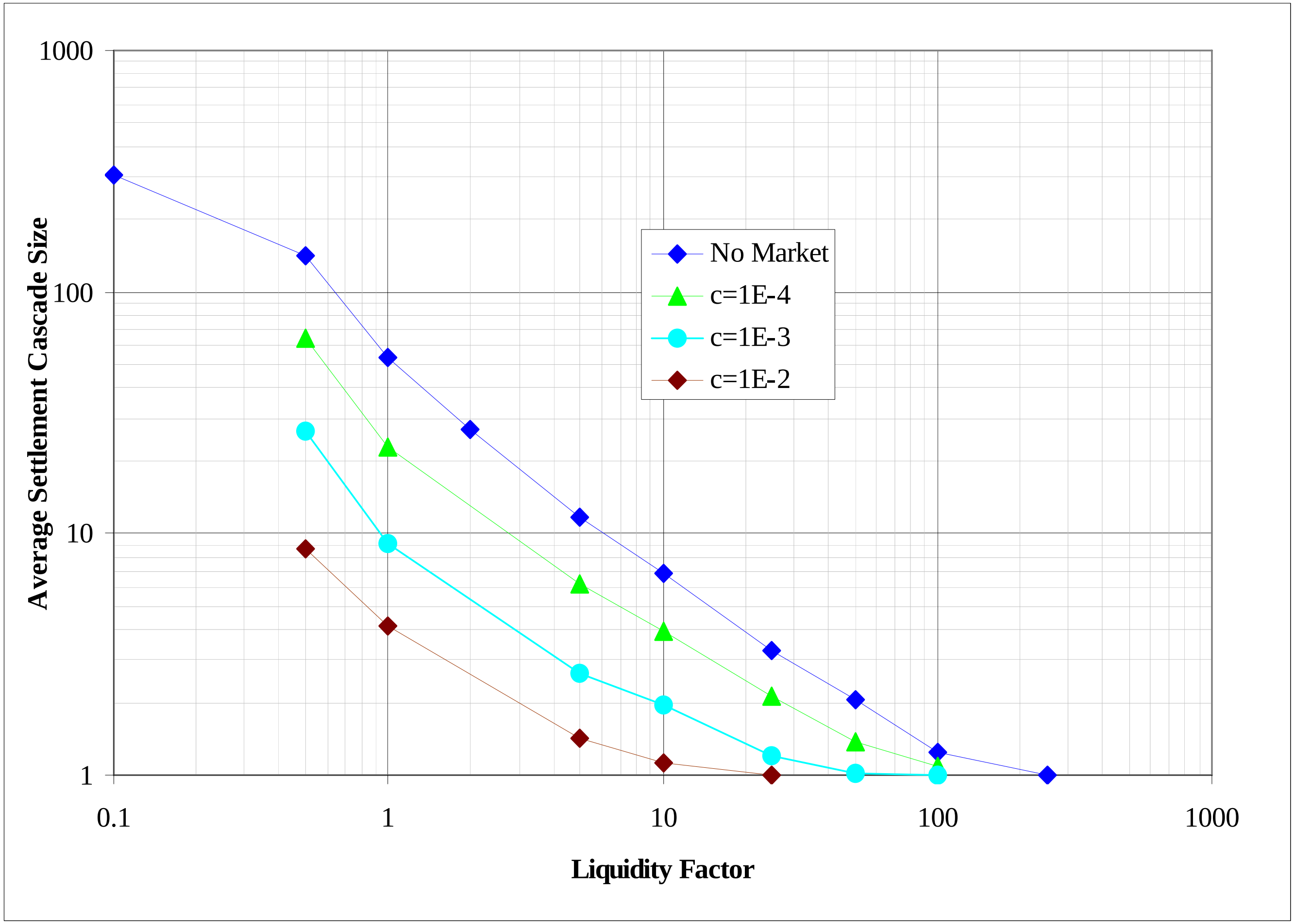
Liquidity and Markets Influence Congestion



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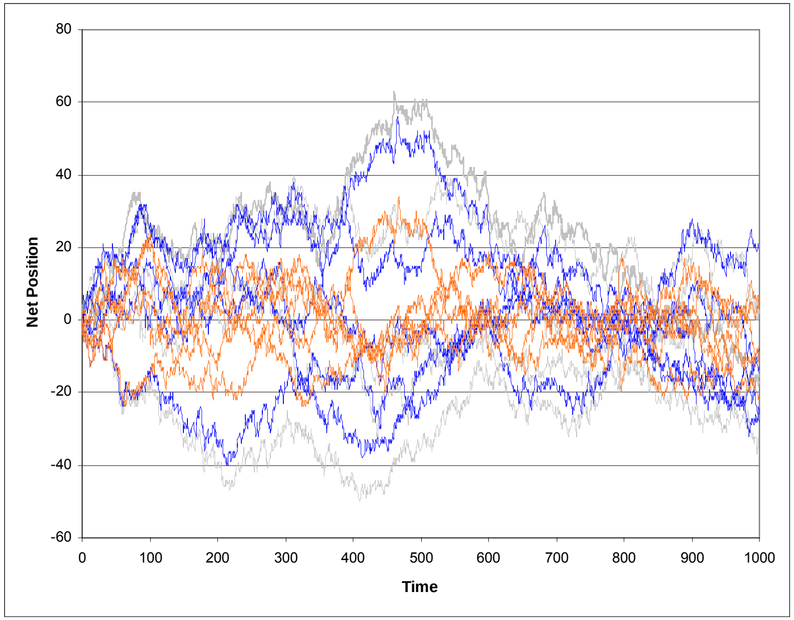
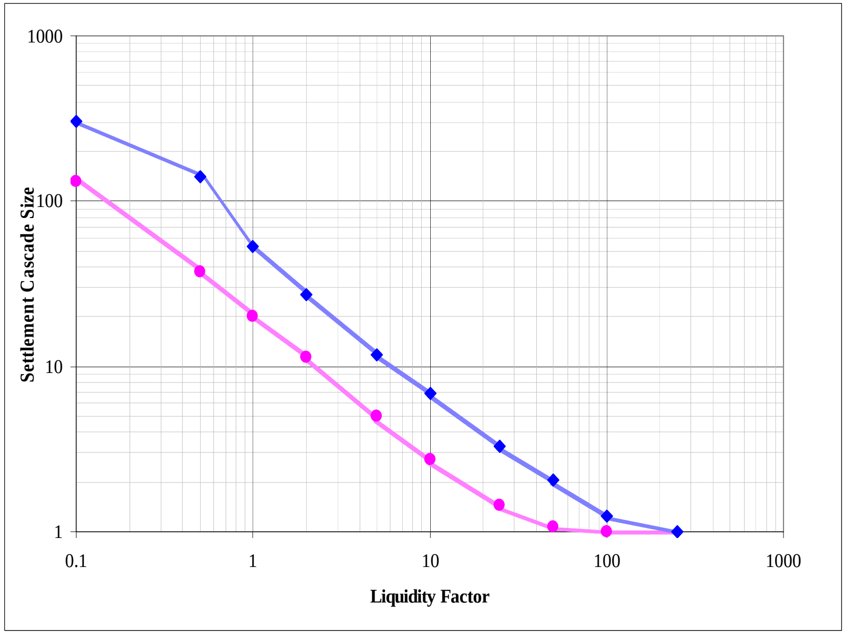
Influence of Return Time on Congestion





Amount of deposits determines the variability of a bank's net position

Less variability leads to less congestion

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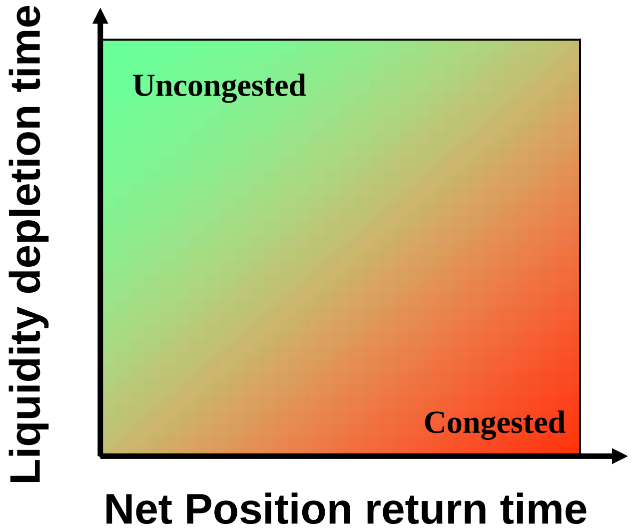
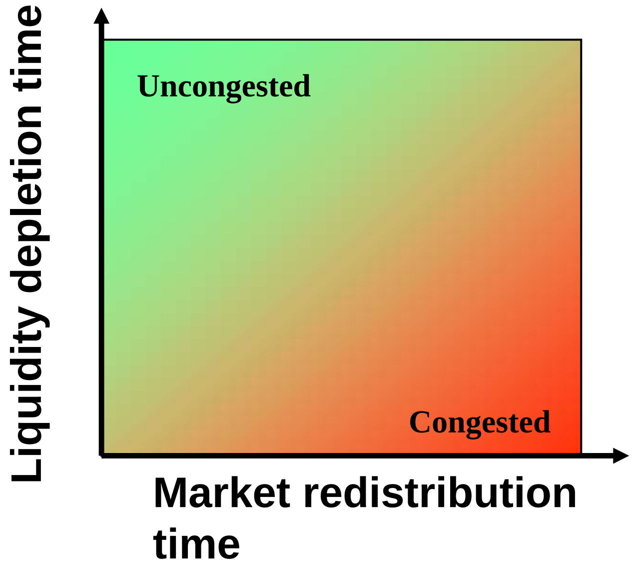
What determines transition?

- Three key time constants
  - Time over which a bank is in surplus or deficit (d_0)
  - Time to deplete initial liquidity (L)
  - Time for the market to redistribute liquidity (1/c)





What we've learned

- System performance can be greatly improved by moving small amounts of liquidity to the places where it's needed
- System congestion seems to be determined by the relative values of three time constants
  - Liquidity depletion time
  - Net position return time
  - Liquidity redistribution time through the market

- *What about disruptions?* …

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