

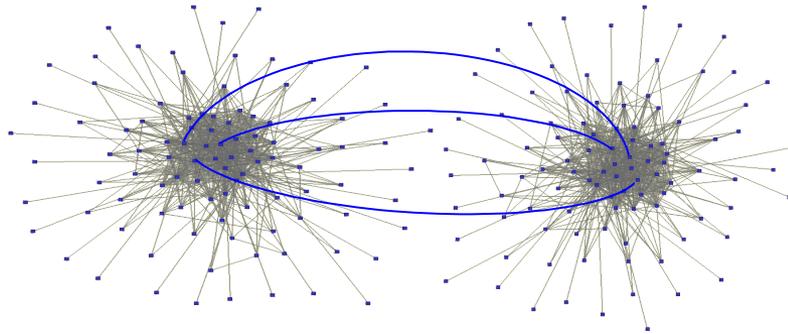


Sandia  
National  
Laboratories



TEKNILLINEN KORKEAKOULU  
TEKNISKA HOGSKOLAN  
HELSINKI UNIVERSITY OF TECHNOLOGY

# Performance and resilience to liquidity disruptions in interdependent RTGS payment systems



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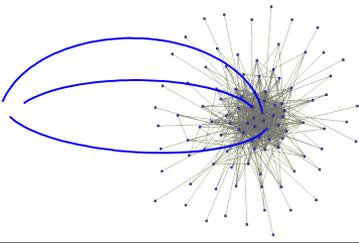
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<sup>3</sup>Sandia National Laboratories

<sup>4</sup>Helsinki University of Technology

Joint Banque de France / European Central Bank conference on  
"Liquidity in interdependent transfer systems"  
Paris, 9 June 2008

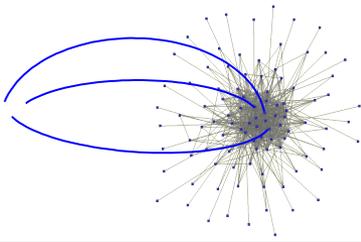
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# Motivation

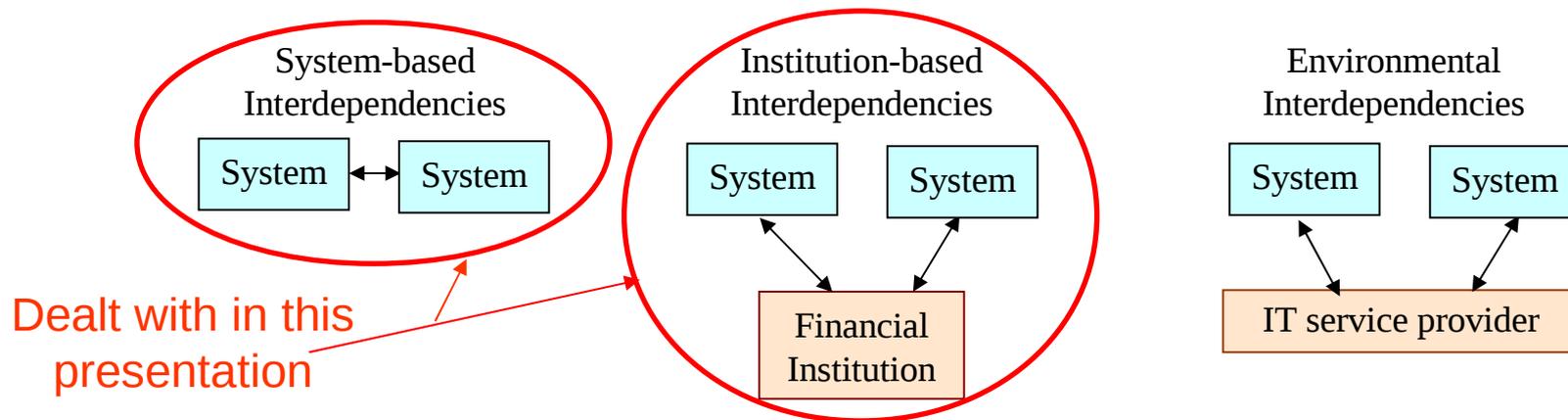
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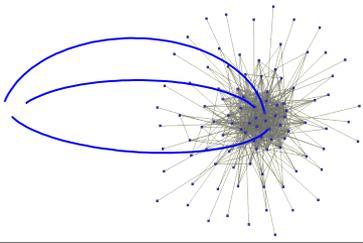
- The 2001 Group of Ten “*Report on Consolidation in the Financial Sector*” (the Ferguson report) noted a possible increased interdependence between the different systems due to:
  - The emergence of global institutions that participate to many systems
  - The emergence of global service providers offering services to many systems
  - The development of DvP procedures linking RTGS and SSS
  - The development of CLS
- The report suggested that these trends might accentuate the role of payment and settlement systems in the transmission of disruptions across the financial system.
- To complement this previous work, the CPSS (Committee on Payment and Settlement Systems) commissioned a working group to:
  - describe the different interdependencies existing among the payment and settlement systems of CPSS countries
  - analyze the risk implications of the different interdependencies



# Motivation

- Could a modeling approach provide any useful additional information to the regulators ?
- So far, payment and settlement system modeling has been mainly limited to a single system, with a few exceptions
- We want to model the interactions between two payment systems and understand how interdependencies arise
- We wish to understand how disruptions in one system manifest in the other

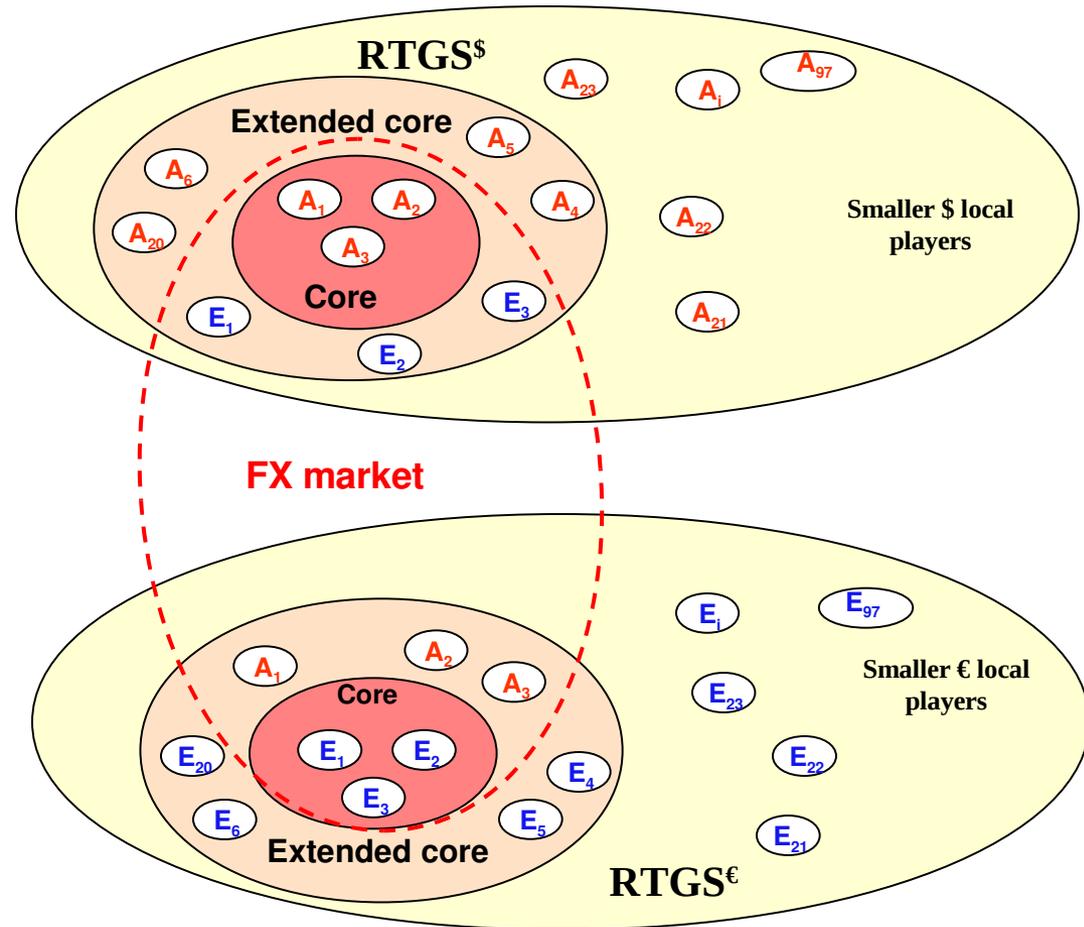


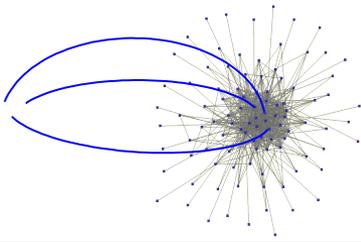


# Coupled RTGS model

## Model description

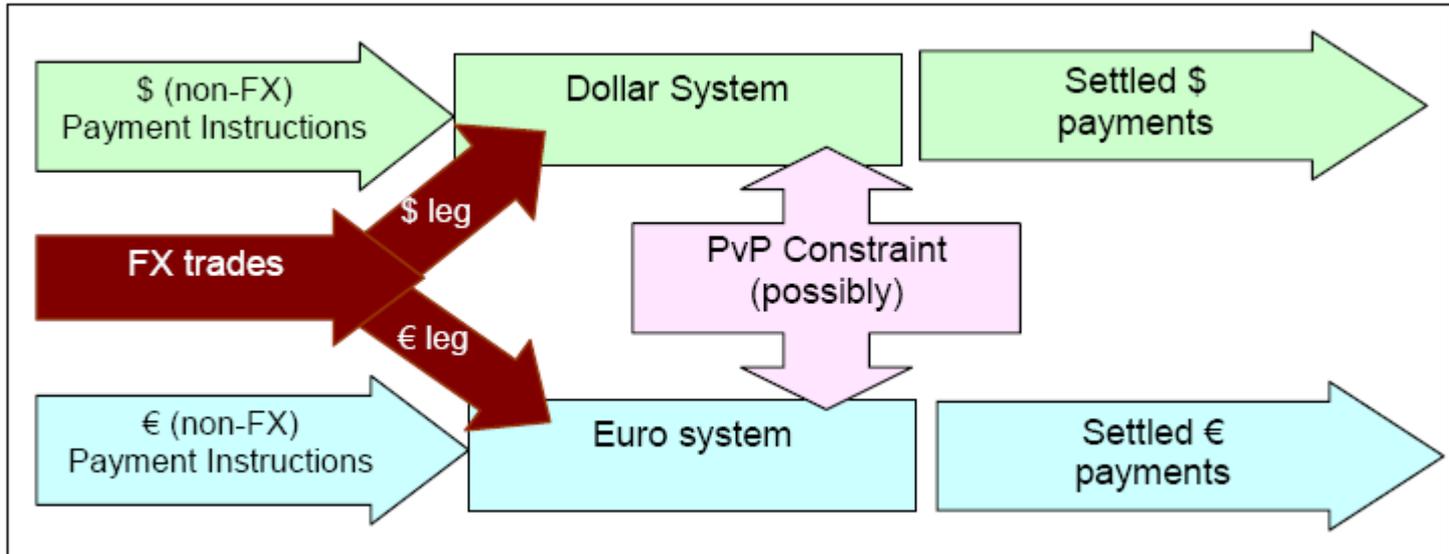
- Two RTGS systems in two different currencies: \$ and €
- Both systems are similar in structure with 100 banks
- Six “global banks”. Top three banks in each system have a presence also in the other system
- The global banks make FX trades (at constant exchange rate) among each other
- All banks make local payments



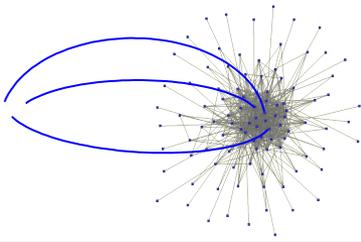


# Coupled RTGS model

## Model description

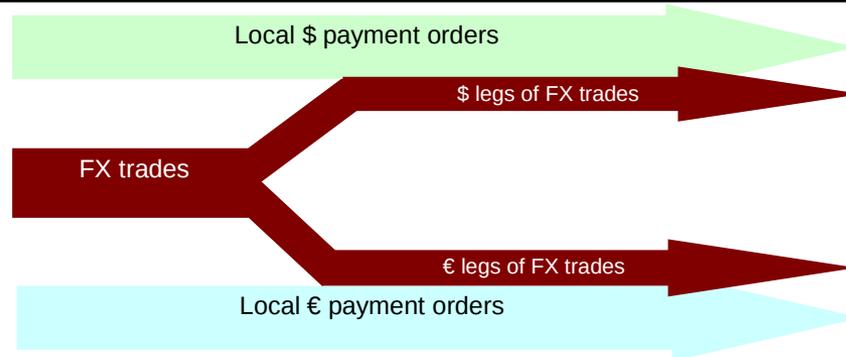


- Payment instructions arrive according to a non-homogenous Poisson process
  - intuition: customers who have received funds issue payments more frequently than bank customers who have already sent many payments
- FX trades arrival is similar as above, now taking into account balances in both currencies
  - E.g. banks with high euro positions are likely to sell euro and vice versa
- Those two systems are linked
  - Via the dual participation of some global banks that can make FX trades (institution-based interdependency)
  - Via a possible PvP (Payment versus Payment) constraint on the FX trades (system-based interdependency), the alternative being a non-PvP settlement



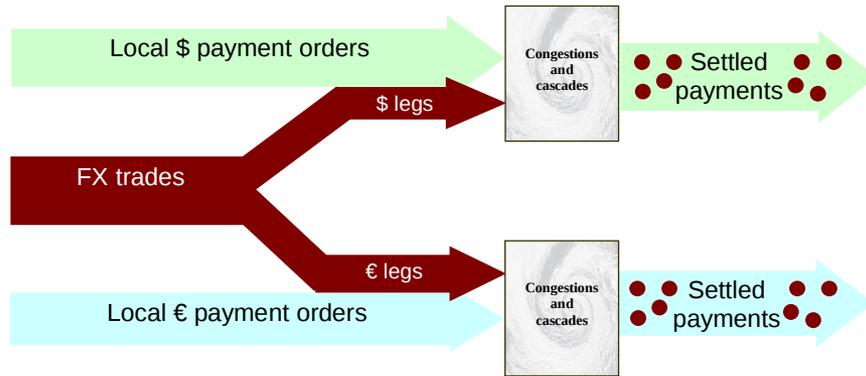
# Correlation dynamics

High liquidity  
PvP or non-PvP



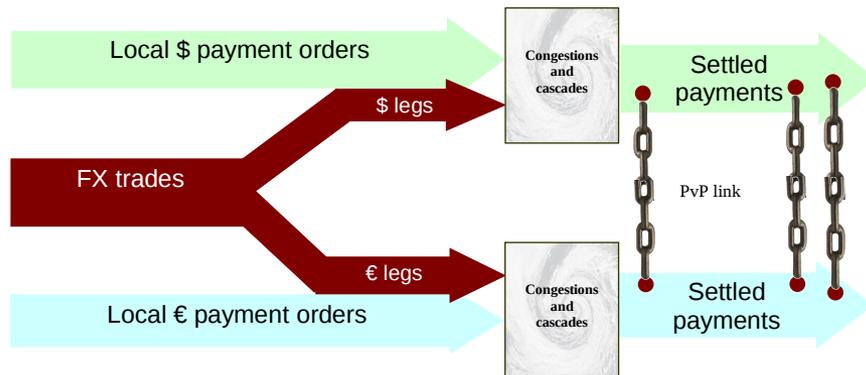
Correlation: **0.22**  
(institution-based interdependency)

Low liquidity  
non-PvP

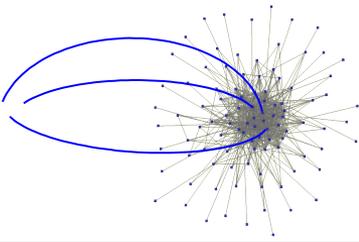


Correlation: **-0.02**  
(none)

Low liquidity  
PvP



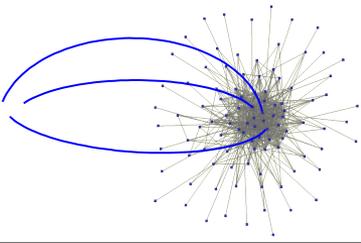
Correlation: **0.83**  
(system-based interdependency)



# Summary of main results

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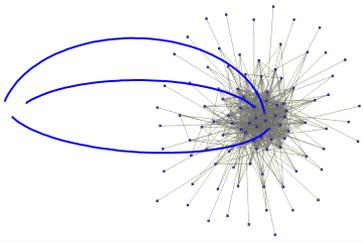
- PvP
  - increases queues
  - eliminates exposures
- Lower liquidity
  - increases queues
  - Increases exposures (in case of non-PvP)
- Liquidity differences in the two systems
  - Reducing liquidity in one system increases queuing in the other (in case of PvP)
  - Banks selling the more liquid currency face higher exposures (in case of non-PvP)
- Higher priority for FX trades
  - Decreases queues in the more liquid system (in case of PvP)
  - Does not affect queues when both systems have same liquidity
  - Substantially reduces exposures (in case of non-PvP)



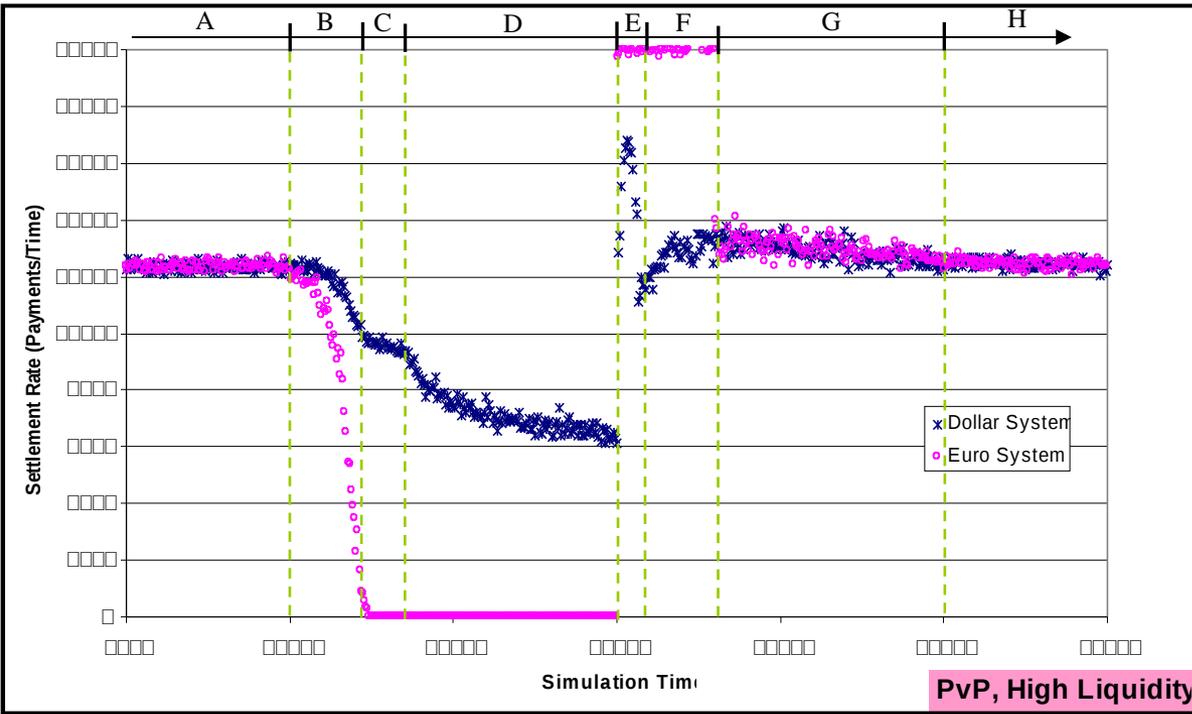
# Operational disruption

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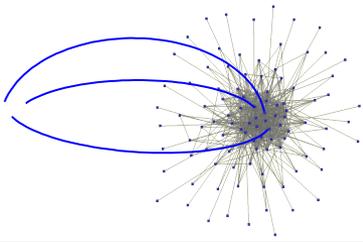
- An operational disruption affects a significant local € bank
  - The affected bank does not participate in RTGS \$, nor engage in FX transactions
  - The affected bank is unable to submit its € local payments for a certain duration
  - The affected bank acts as a liquidity sink for RTGS €
- To which extent will the disruption affect RTGS \$ ?
  - Four different cases:
    - PvP or non-PvP
    - High Liquidity or Low Liquidity (the same in both systems)
- What are the channels of propagation through which the crisis spreads from one RTGS to the other ?



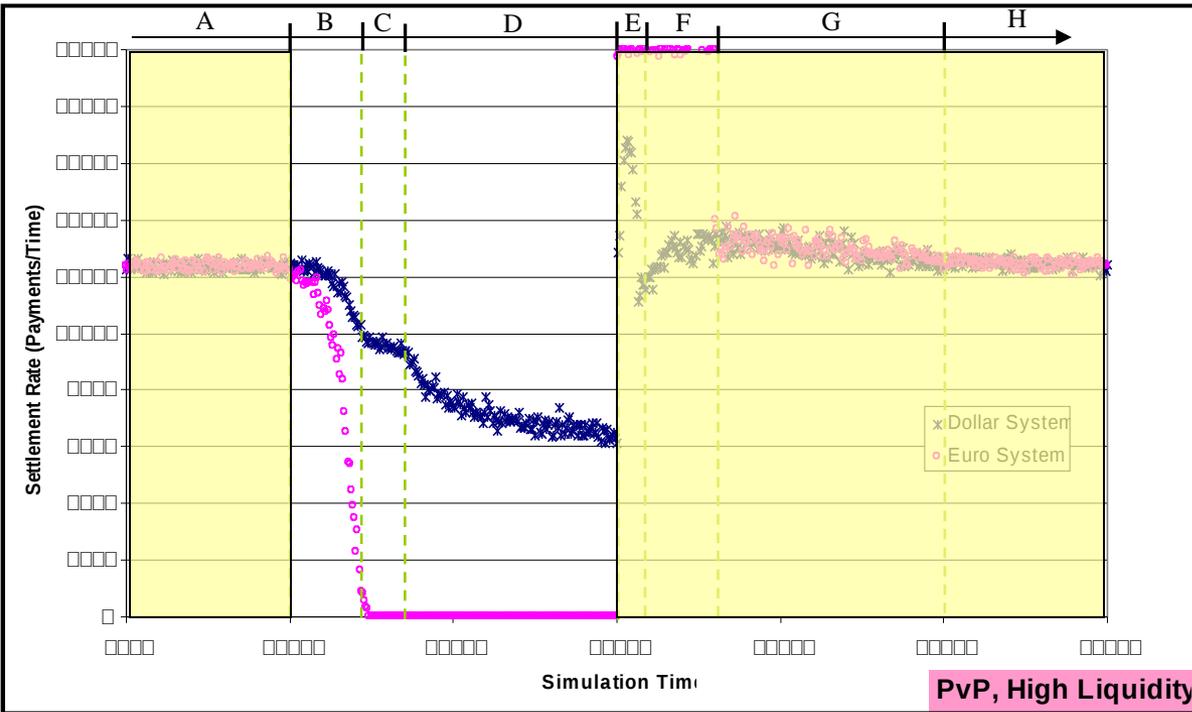
# Operational disruption



**PvP High Liquidity**

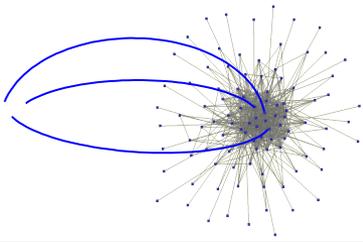


# Operational disruption

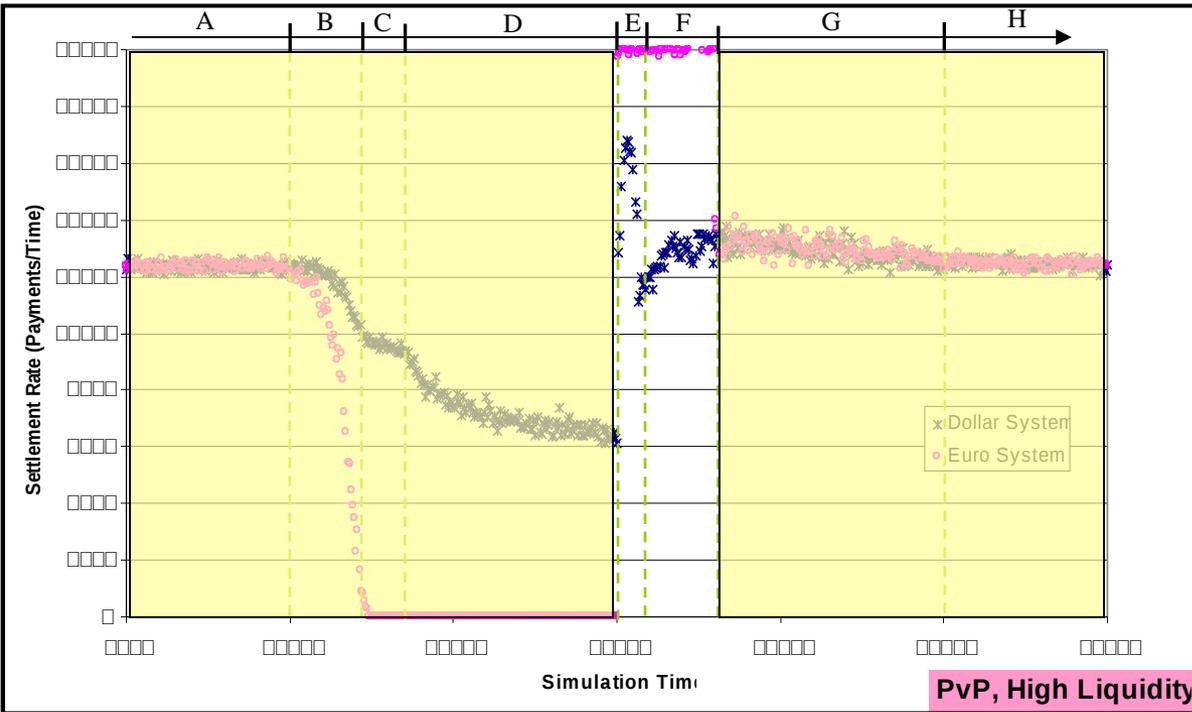


## PvP High Liquidity

- Outage: settlement rate in RTGS \$ decreases (-50 %)

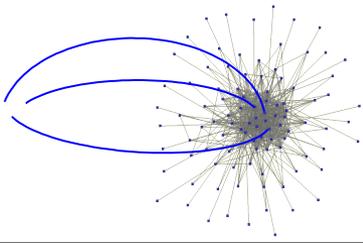


# Operational disruption



## PvP High Liquidity

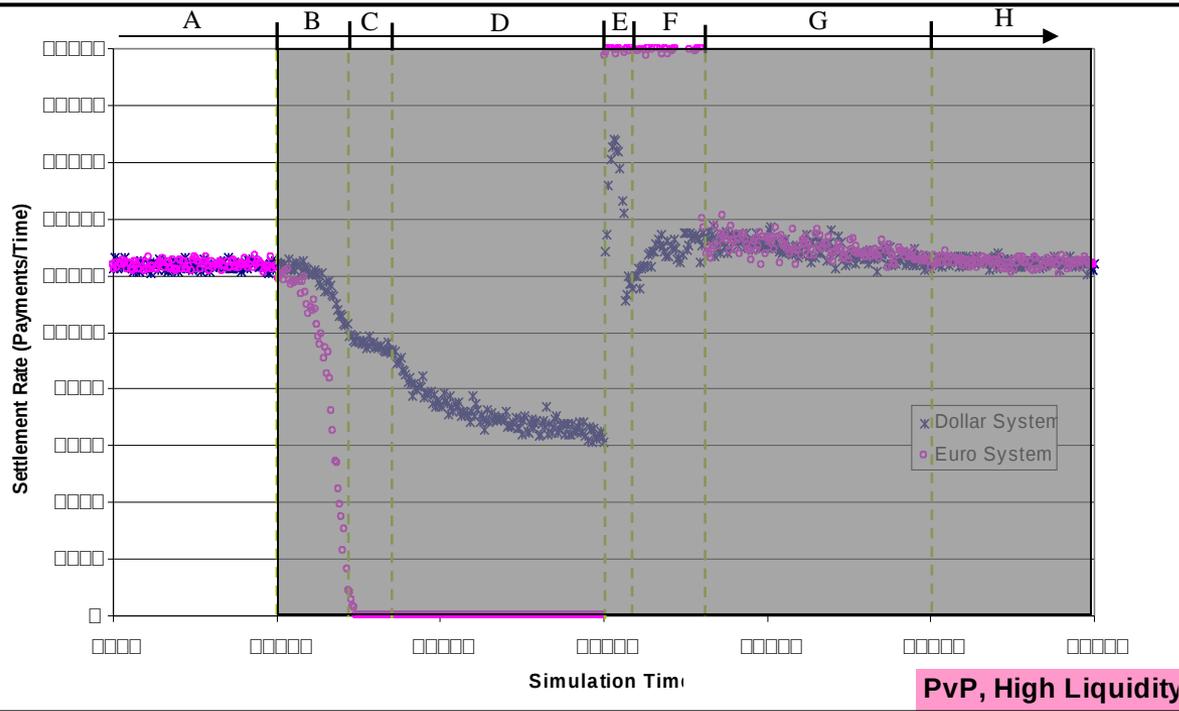
- Outage: settlement rate in RTGS \$ decreases (-50 %)
- Recovery: settlement rate in RTGS \$ overshoots



# Operational disruption

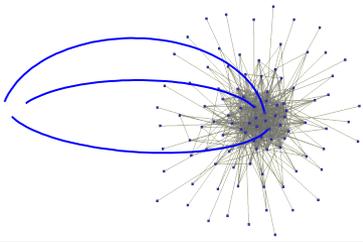
## Period A

- Steady state

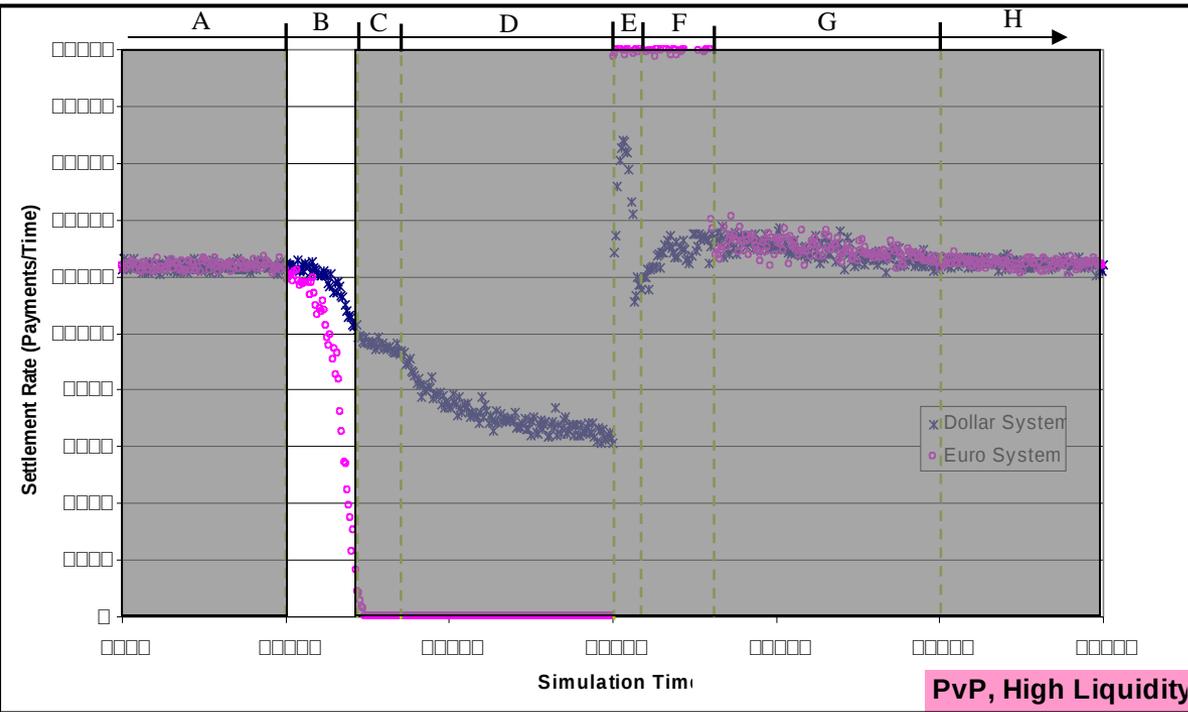


## PvP High Liquidity

- Outage: settlement rate in RTGS \$ decreases (-50 %)
- Recovery: settlement rate in RTGS \$ overshoots



# Operational disruption



## Period A

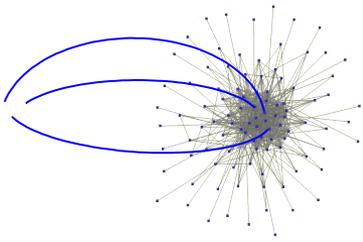
- Steady state

## Period B

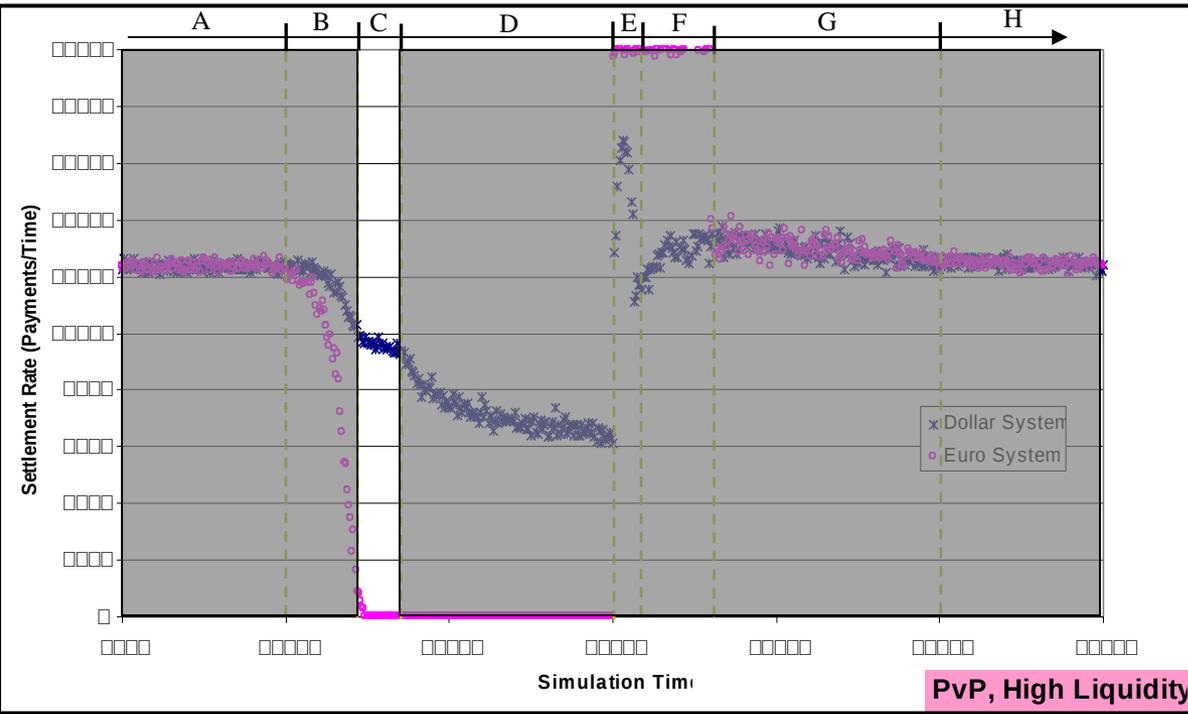
- € balances vanish
- € local payments are queued
- Both legs of FX trades are queued, RTGS \$ deprived of FX activity

## PvP High Liquidity

- Outage: settlement rate in RTGS \$ decreases (-50 %)
- Recovery: settlement rate in RTGS \$ overshoots



# Operational disruption



## Period A

- Steady state

## Period B

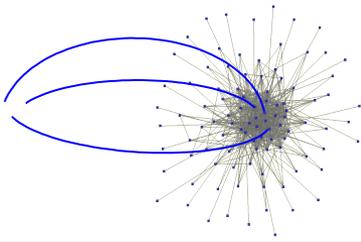
- € balances vanish
- € local payments are queued
- Both legs of FX trades are queued, RTGS \$ deprived of FX activity

## Period C

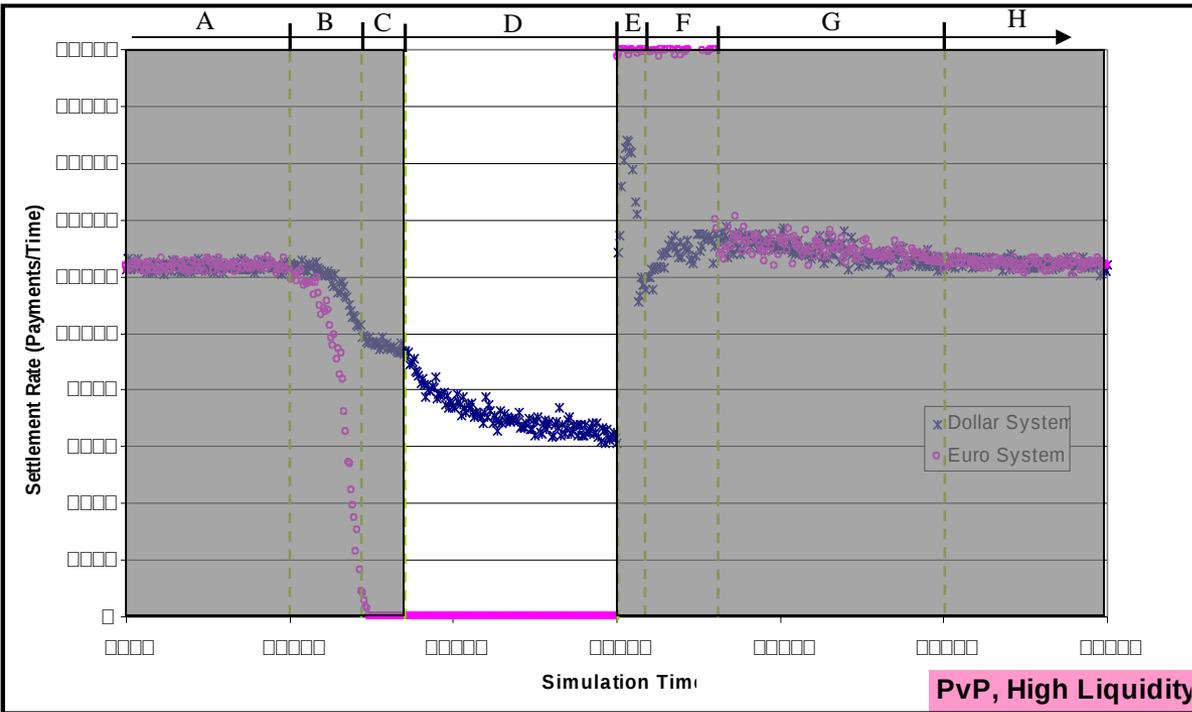
- RTGS \$ down to local activity

## PvP High Liquidity

- Outage: settlement rate in RTGS \$ decreases (-50 %)
- Recovery: settlement rate in RTGS \$ overshoots



# Operational disruption



## Period A

- Steady state

## Period B

- € balances vanish
- € local payments are queued
- Both legs of FX trades are queued, RTGS \$ deprived of FX activity

## Period C

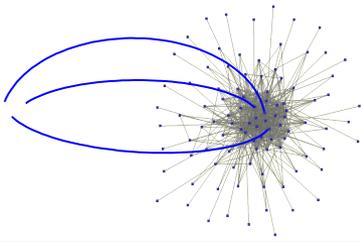
- RTGS \$ down to local activity

## Period D

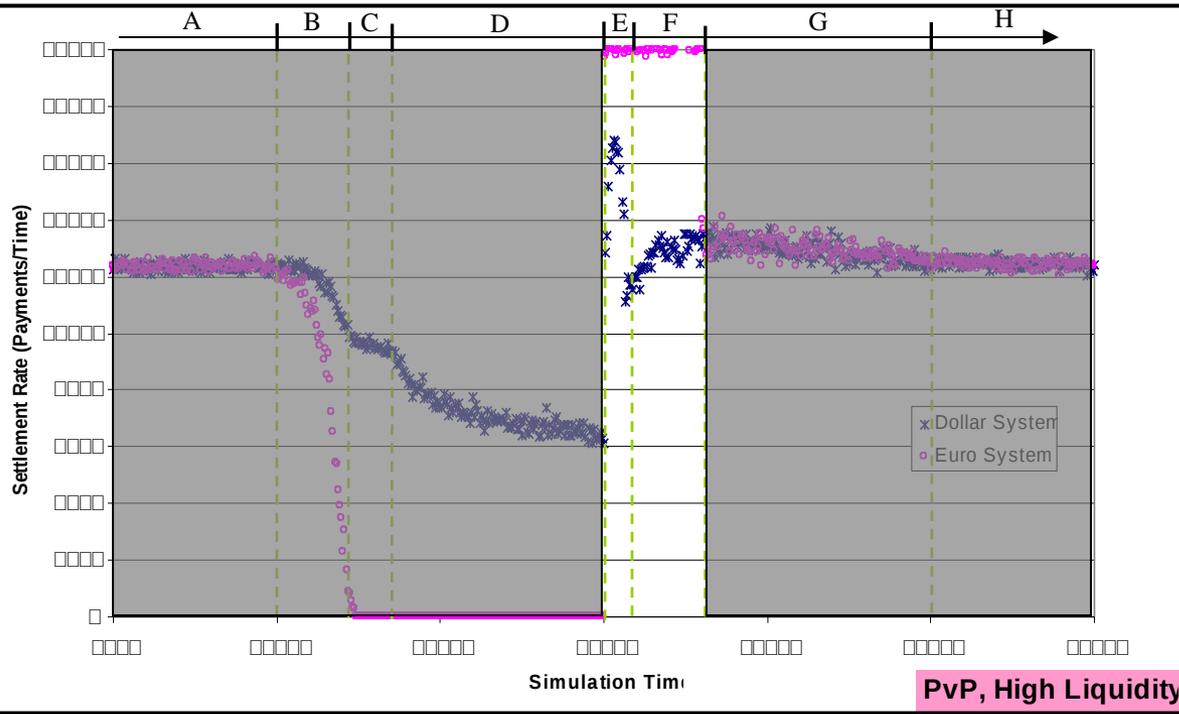
- Because of the queuing of FX trades (PvP), customers have lower \$ funds and make fewer \$ local payments

## PvP High Liquidity

- Outage: settlement rate in RTGS \$ decreases (-50 %)
- Recovery: settlement rate in RTGS \$ overshoots



# Operational disruption



## PvP High Liquidity

- Outage: settlement rate in RTGS \$ decreases (-50 %)
- Recovery: settlement rate in RTGS \$ overshoots

### Period A

- Steady state

### Period B

- € balances vanish
- € local payments are queued
- Both legs of FX trades are queued, RTGS \$ deprived of FX activity

### Period C

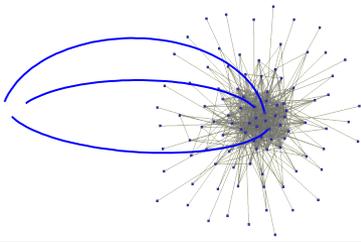
- RTGS \$ down to local activity

### Period D

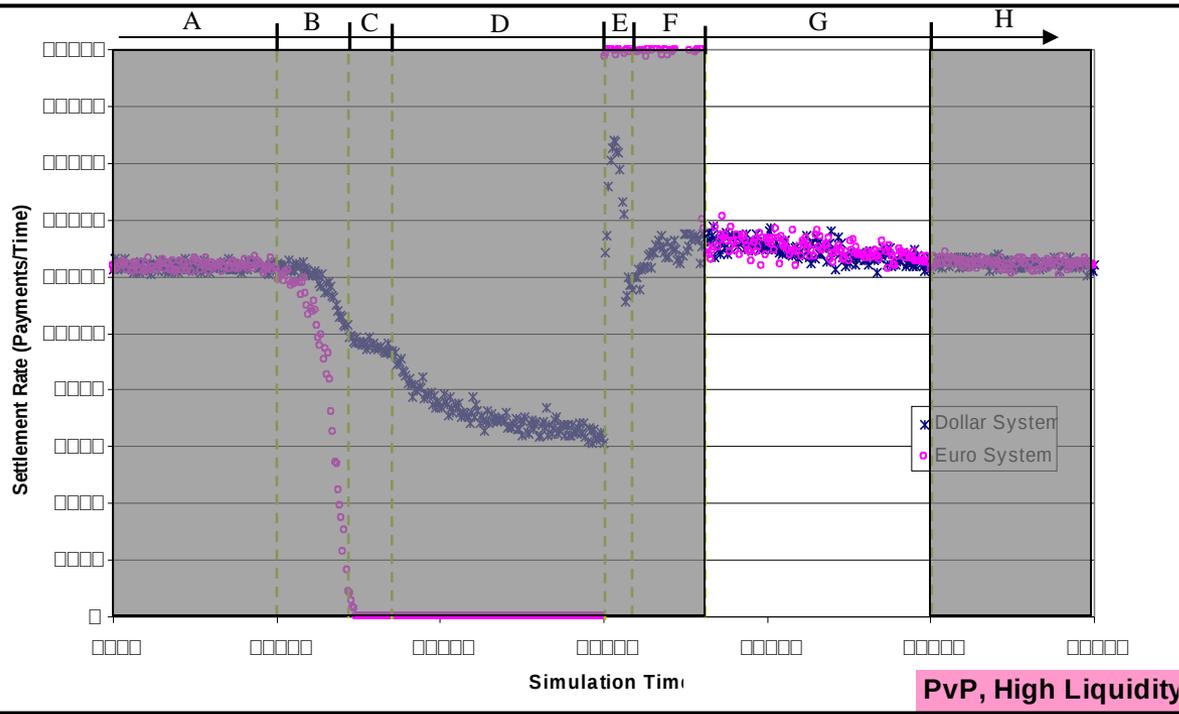
- Because of the queuing of FX trades (PvP), customers have lower \$ funds and make fewer \$ local payments

### Period E-F

- Queued € local payments settle
- Queued FX trades settle



# Operational disruption



## PvP High Liquidity

- Outage: settlement rate in RTGS \$ decreases (-50 %)
- Recovery: settlement rate in RTGS \$ overshoots

## Period A

- Steady state

## Period B

- € balances vanish
- € local payments are queued
- Both legs of FX trades are queued, RTGS \$ deprived of FX activity

## Period C

- RTGS \$ down to local activity

## Period D

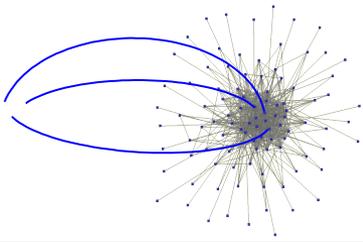
- Because of the queuing of FX trades (PvP), customers have lower \$ funds and make fewer \$ local payments

## Period E-F

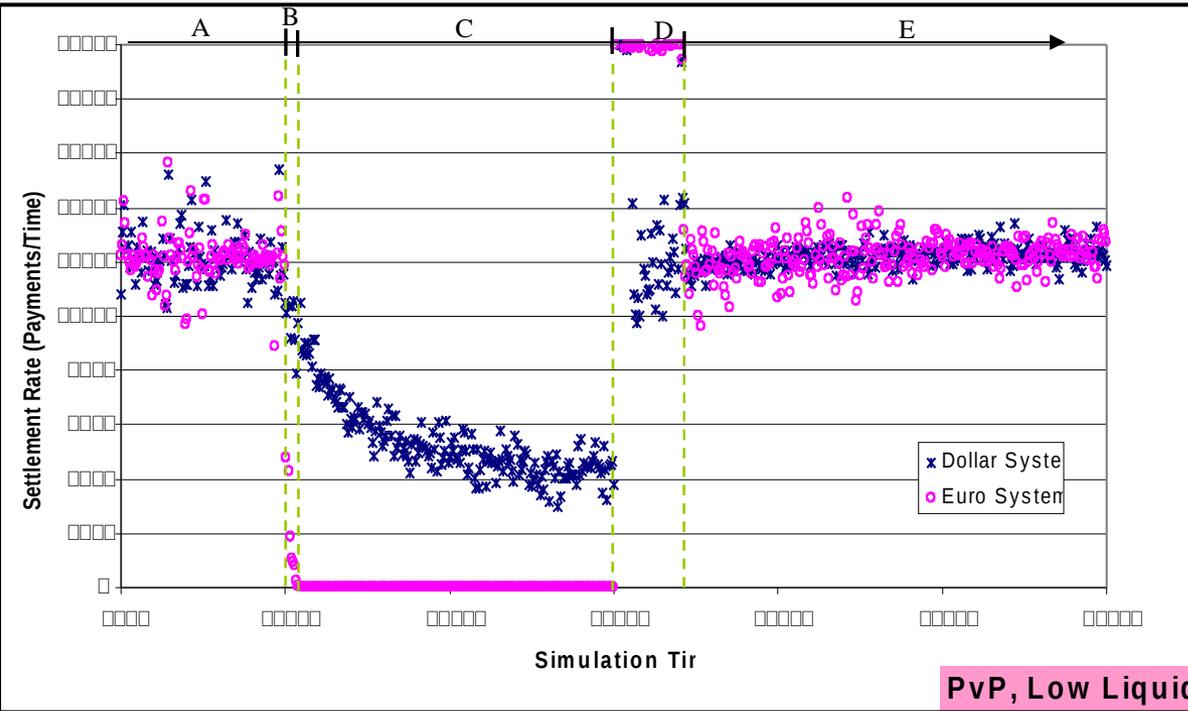
- Queued € local payments settle
- Queued FX trades settle

## Period G

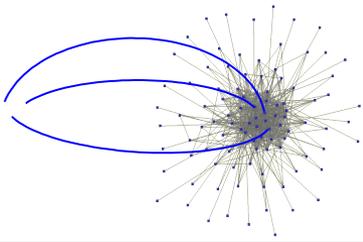
- Return to equilibrium generates extra trades



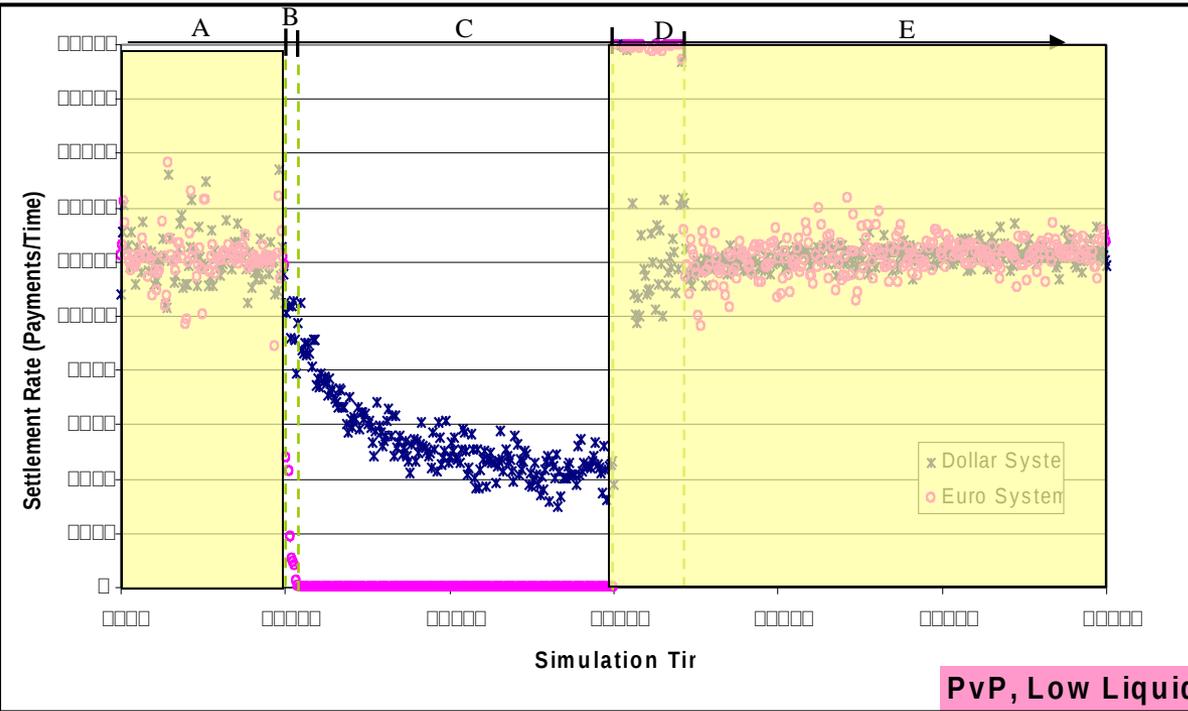
# Operational disruption



**PvP Low Liquidity**

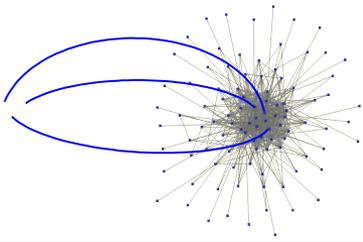


# Operational disruption

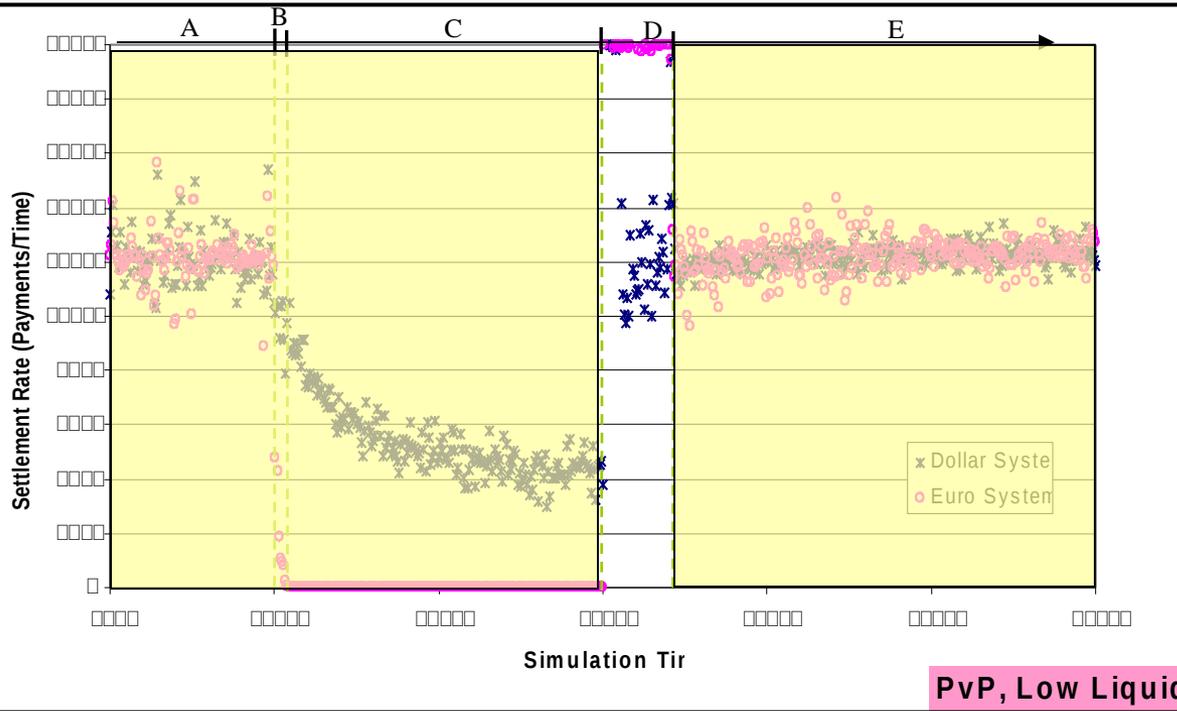


## PvP Low Liquidity

- Outage: settlement rate in RTGS \$ decreases (-65 %)

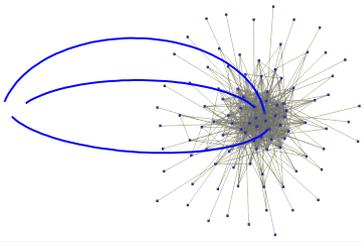


# Operational disruption

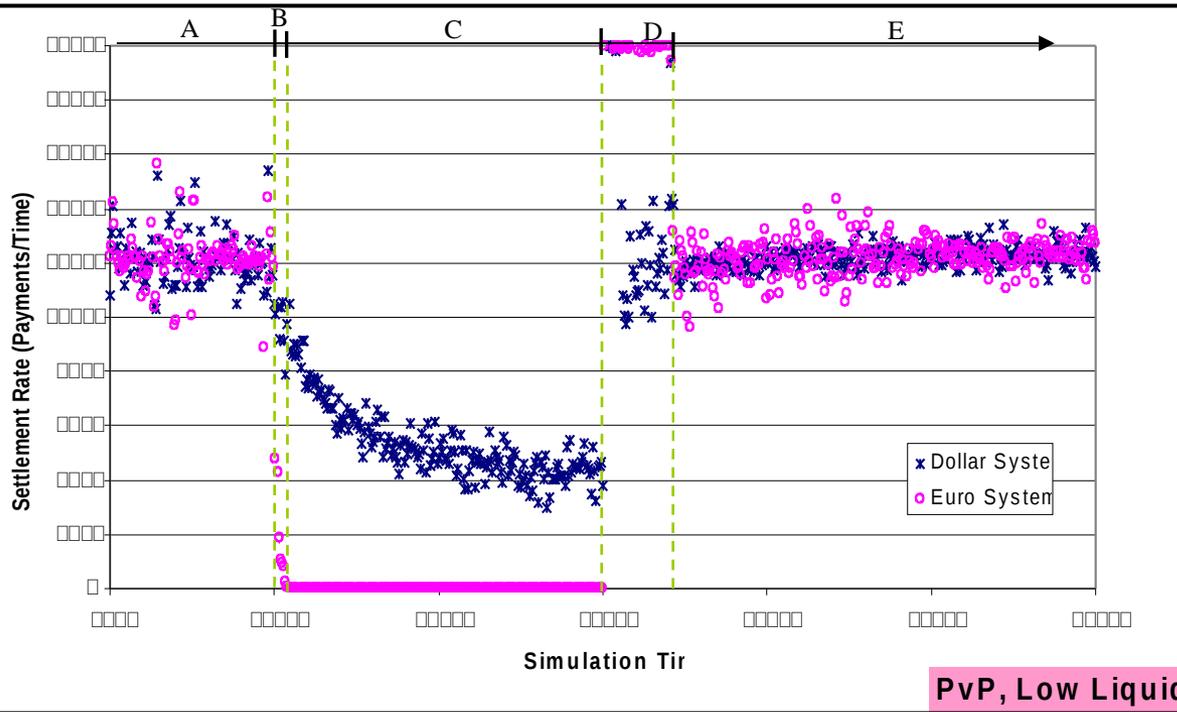


## PvP Low Liquidity

- Outage: settlement rate in RTGS \$ decreases (-65 %)
- Recovery: settlement rate in RTGS \$ overshoots (reaches maximum rate)



# Operational disruption



## Period B

- € balances vanish
- € local payments are queued
- Both legs of FX trades are queued, RTGS \$ deprived of FX activity

## Period C

- The queuing of FX trades decreases \$ deposits. Agents are uncertain about their \$ position, fewer \$ local payments emitted
- The distribution of \$ deposits is brought out of equilibrium because of the disruption. In this low liquidity context, this causes \$ local payments to be queued

## Period D

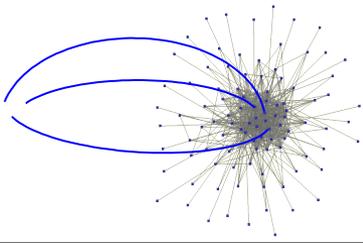
- Queued € local payments settle
- Queued FX trades settle
- Queued \$ local payments settle

## Period E

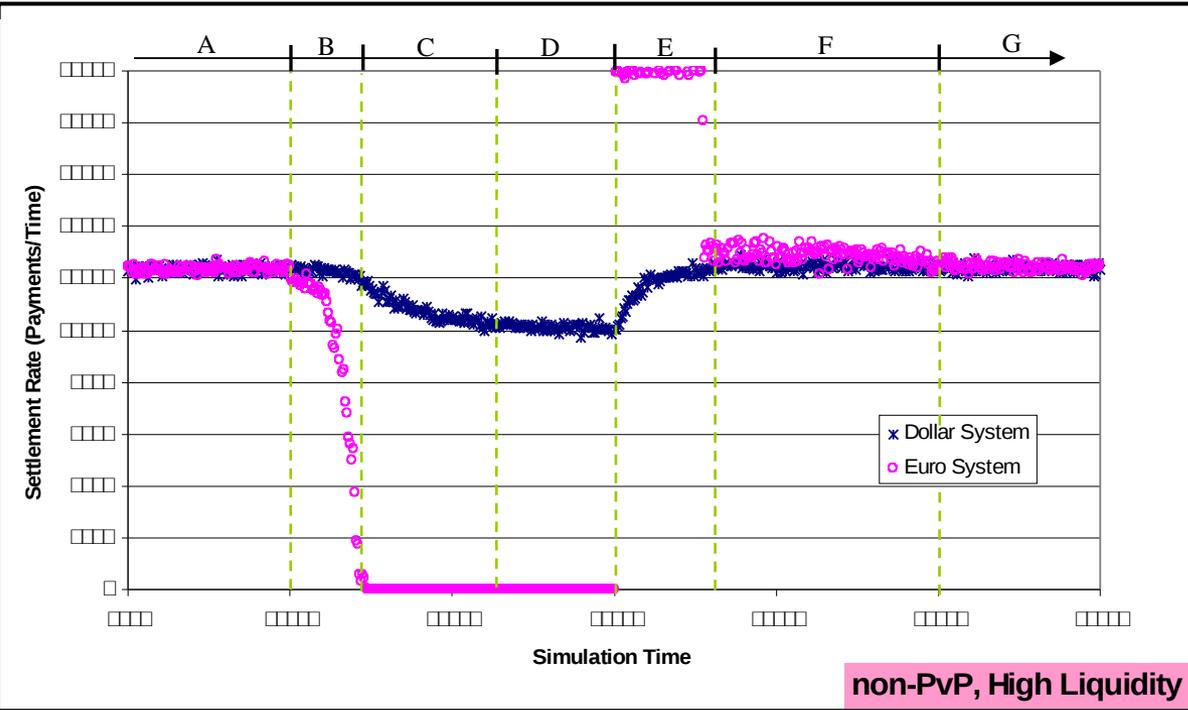
- Return to equilibrium marginally affects settlement rate

## PvP Low Liquidity

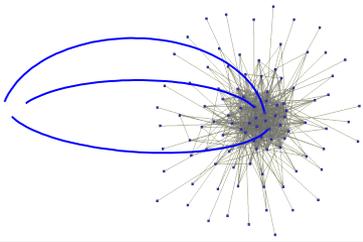
- Outage: settlement rate in RTGS \$ decreases (-65 %)
- Recovery: settlement rate in RTGS \$ overshoots (reaches maximum rate)



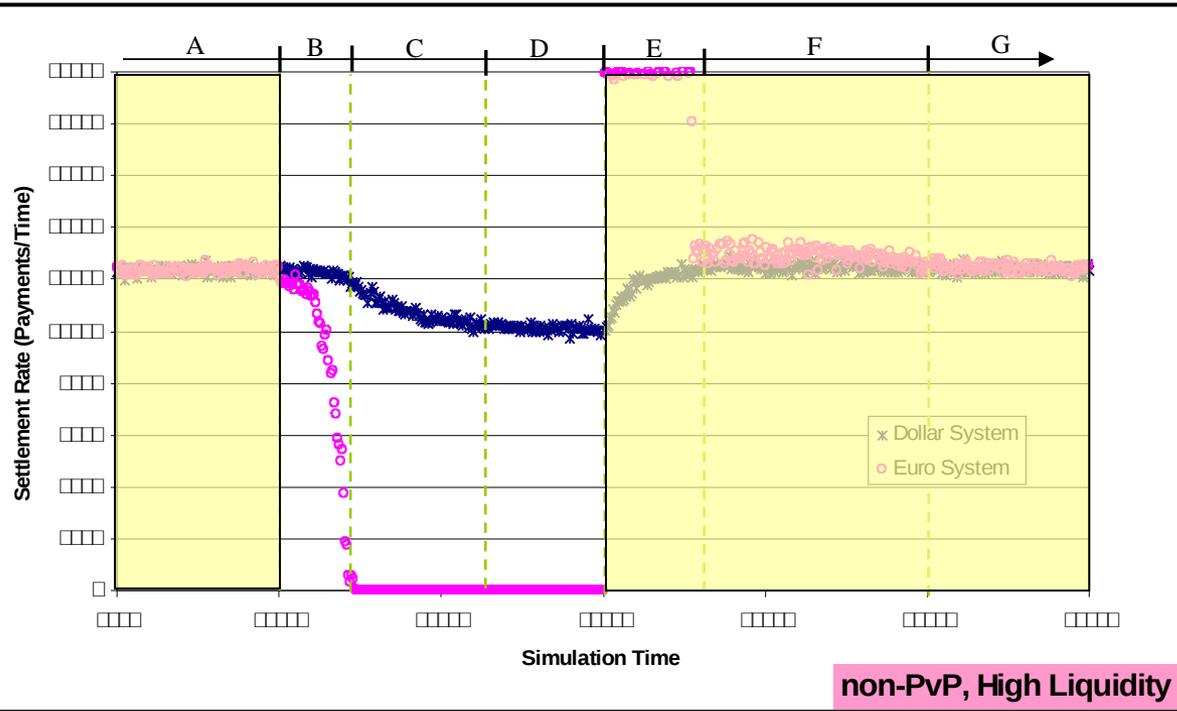
# Operational disruption



**Non-PvP High Liquidity**

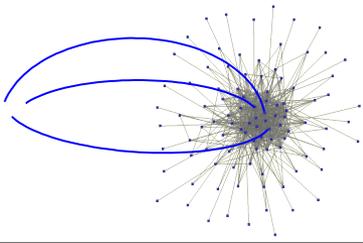


# Operational disruption

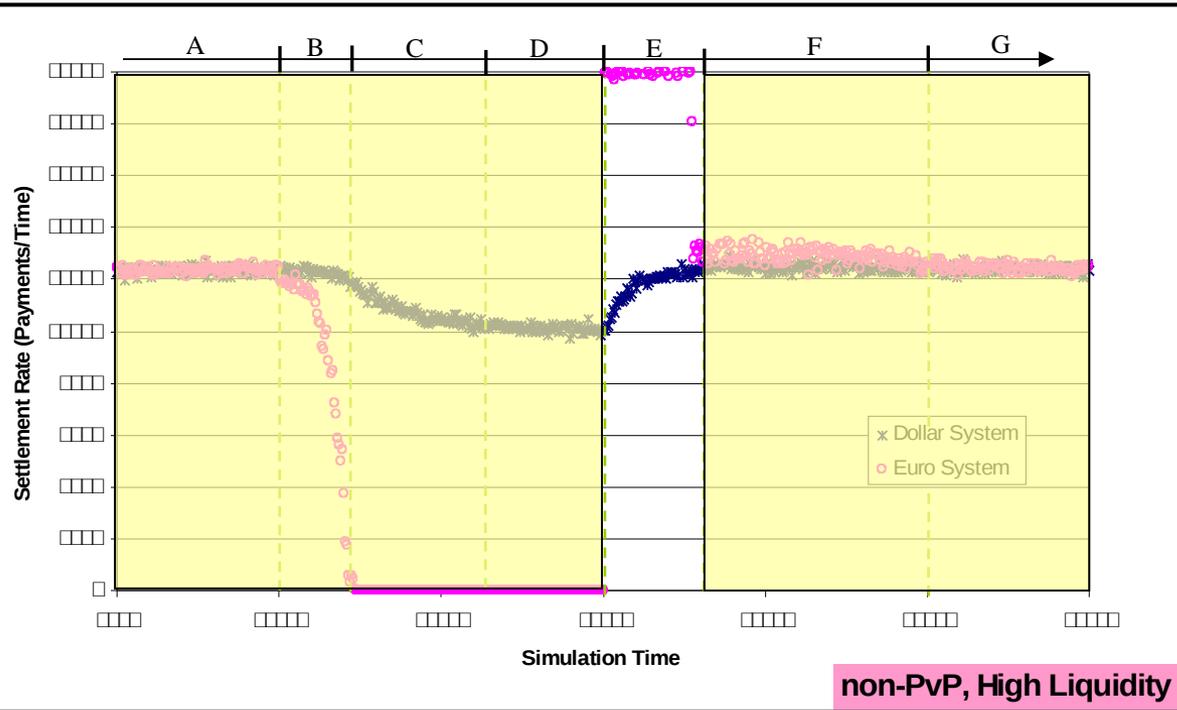


## Non-PvP High Liquidity

- **Outage:** settlement rate in RTGS \$ decreases (-17 %)
- **Recovery:** no overshoot in RTGS \$

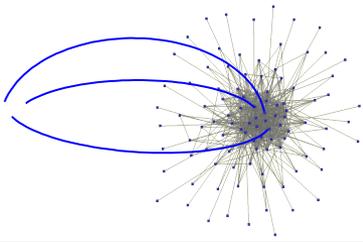


# Operational disruption

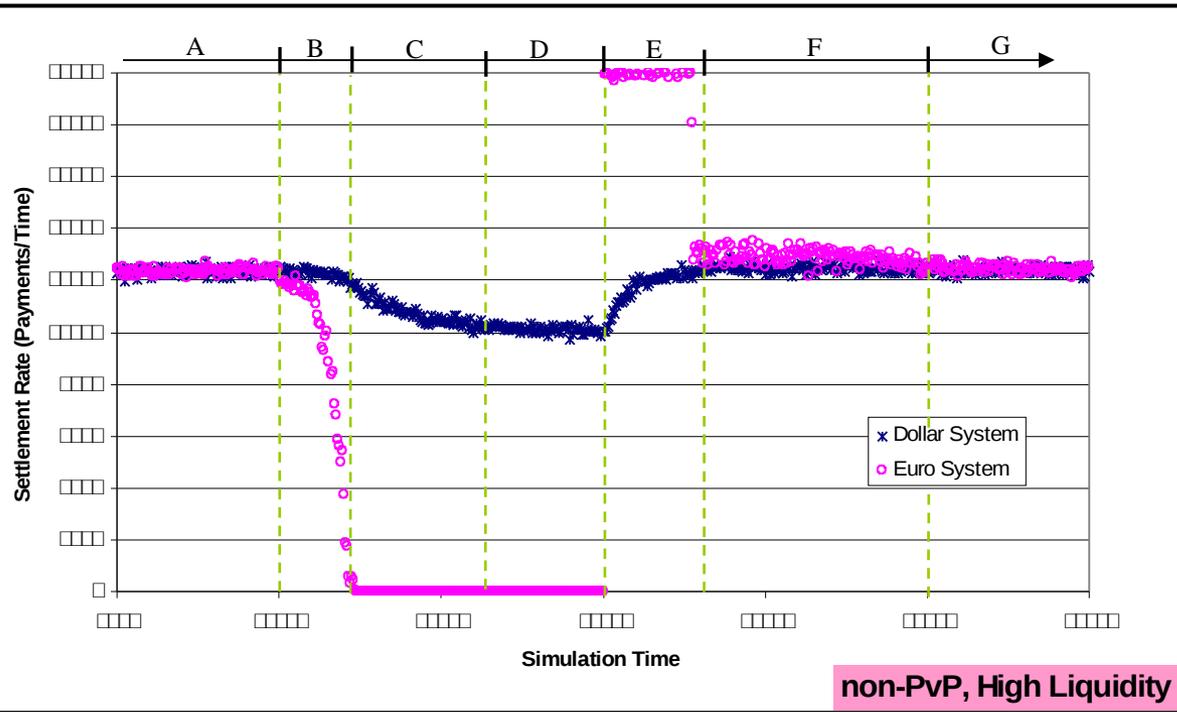


## Non-PvP High Liquidity

- Outage: settlement rate in RTGS \$ decreases (-17 %)
- Recovery: no overshoot in RTGS \$



# Operational disruption



## Non-PvP High Liquidity

- Outage: settlement rate in RTGS \$ decreases (-17 %)
- Recovery: no overshoot in RTGS \$

### Period B

- € balances vanish
- € local payments are queued
- € leg of FX trades are queued
- \$ leg of FX trades still settle

### Period C

- The queuing of € local payments decreases € deposits. Agents are uncertain about their € position, fewer FX trades emitted. RTGS \$ is deprived from FX activity

### Period D

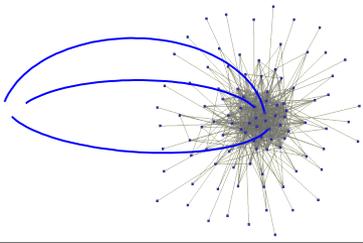
- Only local activity in RTGS \$

### Period E

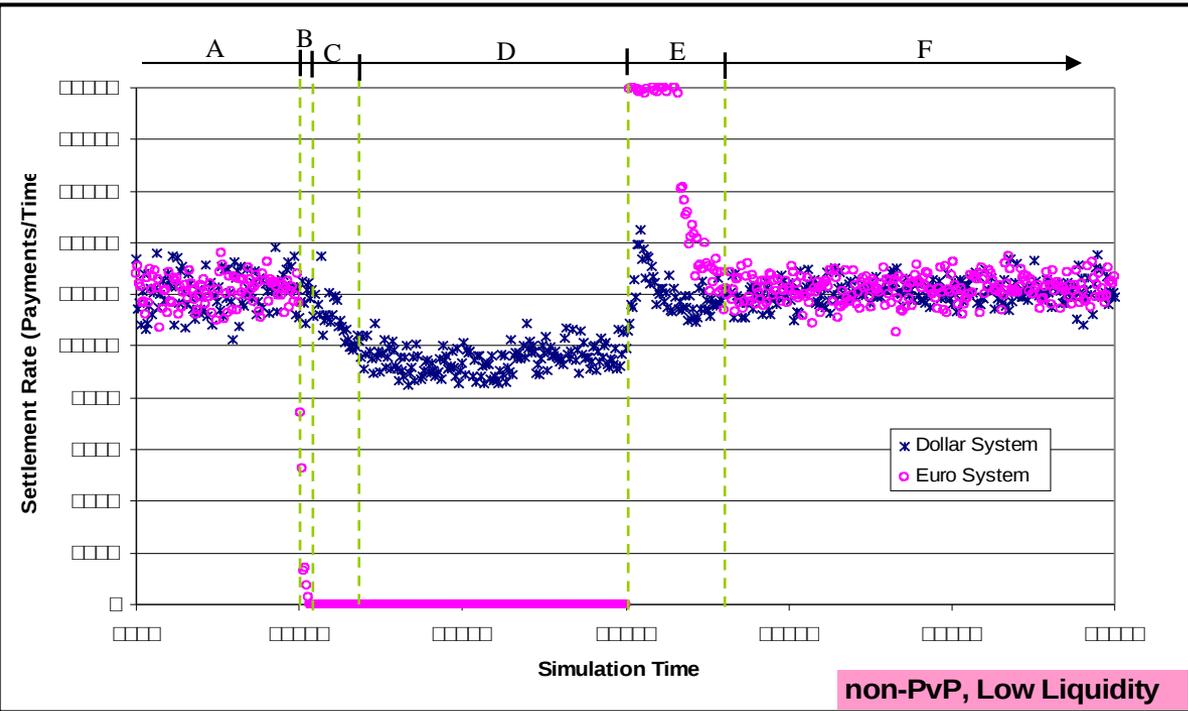
- Queued € local payments settle
- Queued € leg of FX trades settle

### Period F

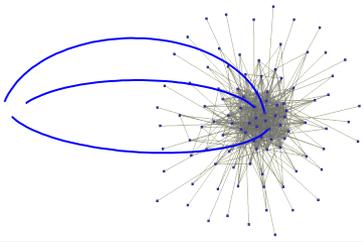
- Return to equilibrium generates extra trades



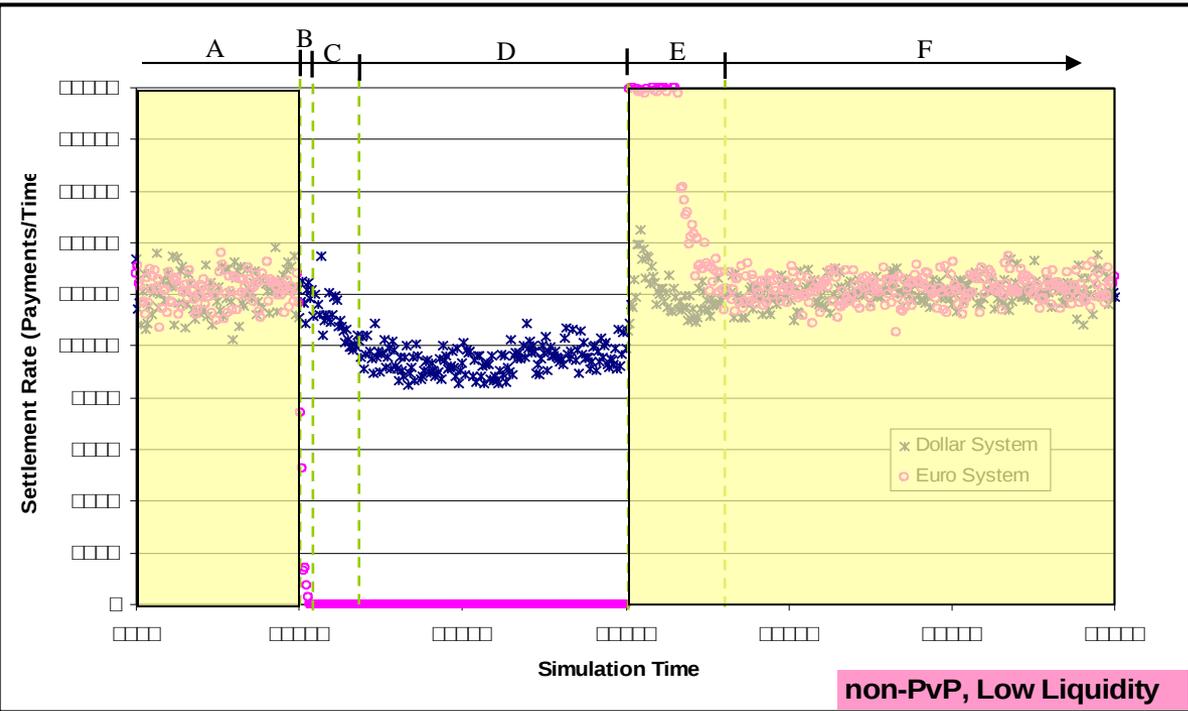
# Operational disruption



**Non-PvP Low Liquidity**

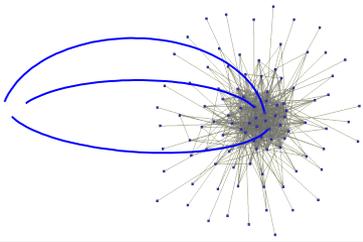


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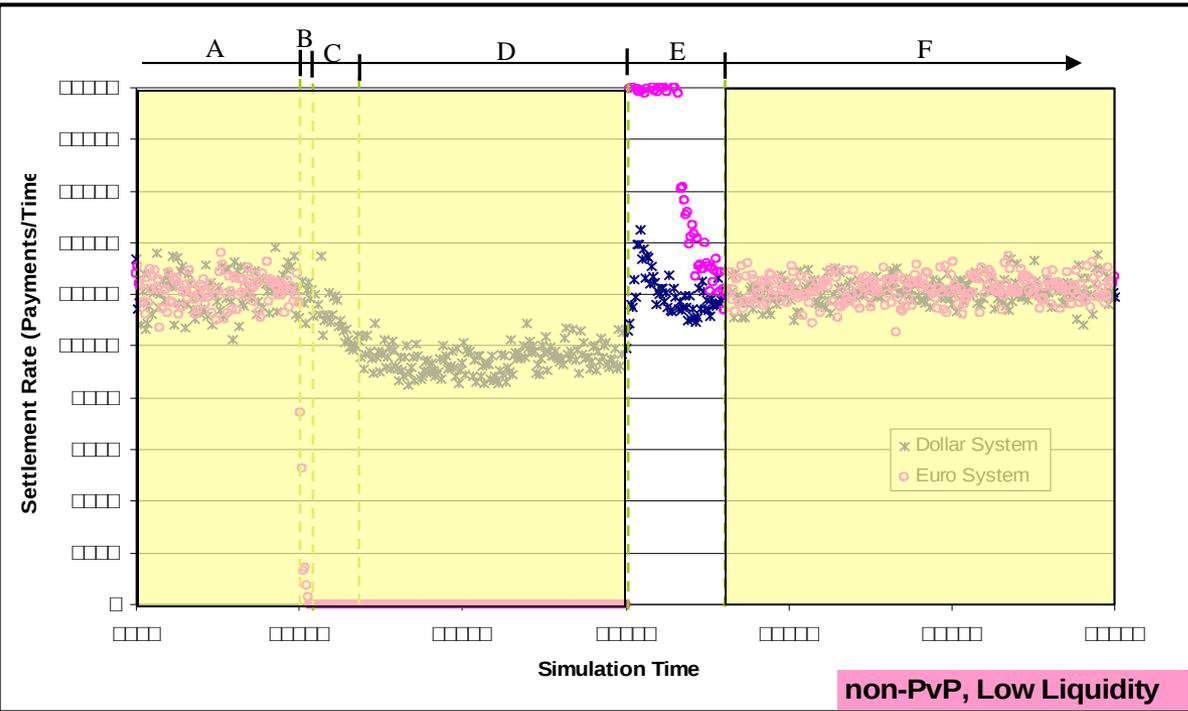


## Non-PvP Low Liquidity

- Outage: settlement rate in RTGS \$ decreases (-25 %)

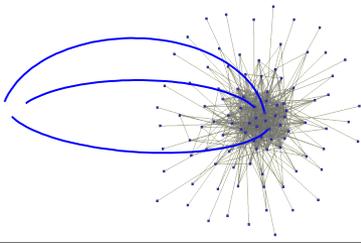


# Operational disruption

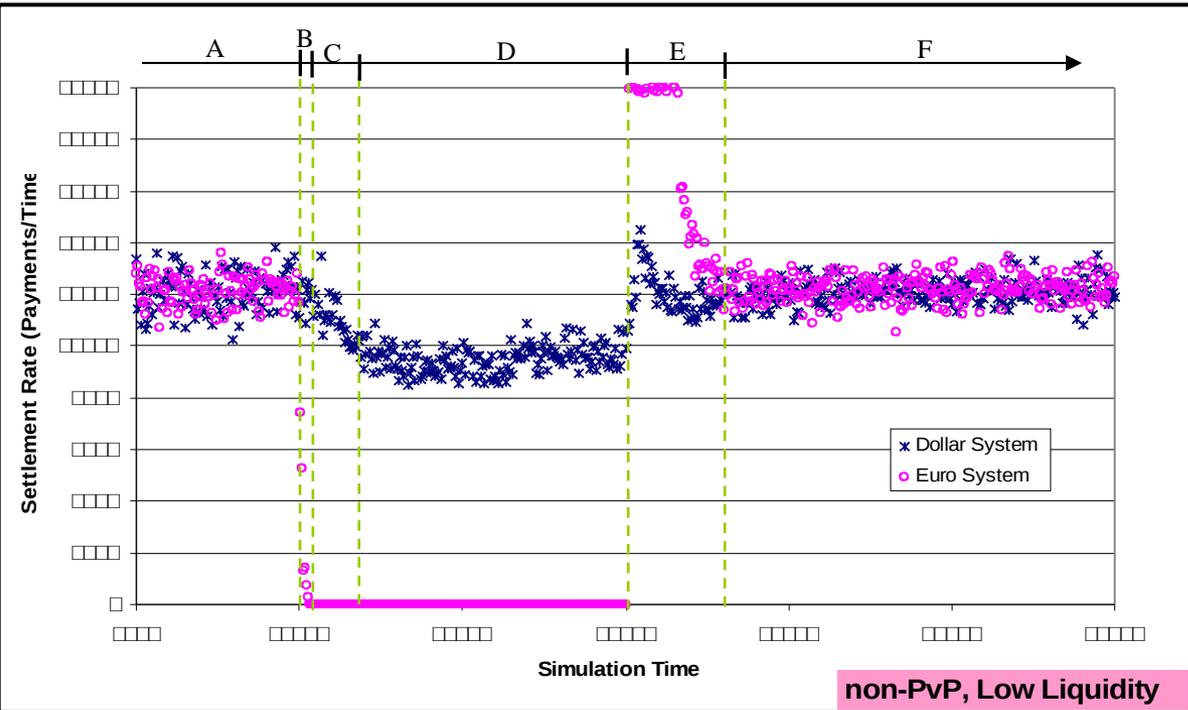


## Non-PvP Low Liquidity

- Outage: settlement rate in RTGS \$ decreases (-25 %)
- Recovery: settlement rate in RTGS \$ overshoots



# Operational disruption



## Non-PvP Low Liquidity

- Outage: settlement rate in RTGS \$ decreases (-25 %)
- Recovery: settlement rate in RTGS \$ overshoots

### Period B

- € balances vanish
- € local payments are queued
- € leg of FX trades are queued  
\$ leg of FX trades still settle

### Period C

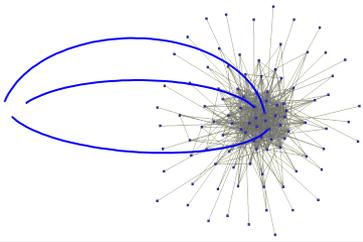
- The queuing of € local payments decreases € deposits. Agents are uncertain about their € position, fewer FX trades emitted. RTGS \$ is deprived from FX activity

### Period D

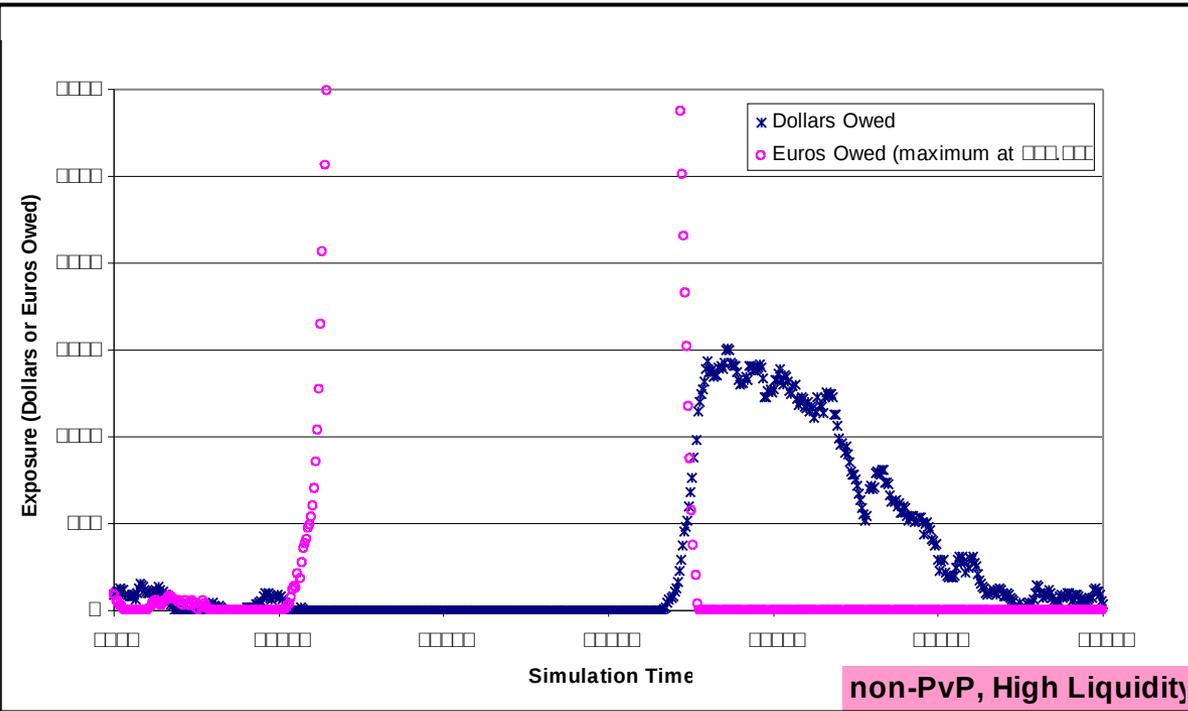
- Only local activity in RTGS \$
- The distribution of \$ deposits is brought out of equilibrium because of the disruption. In this low liquidity context, this causes \$ local payments to be queued

### Period E

- Queued € local payments settle
- Queued FX trades settle
- Queued \$ local payments settle

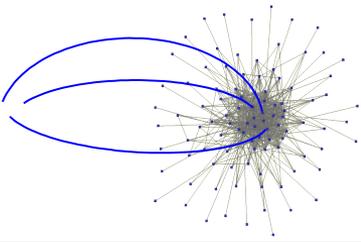


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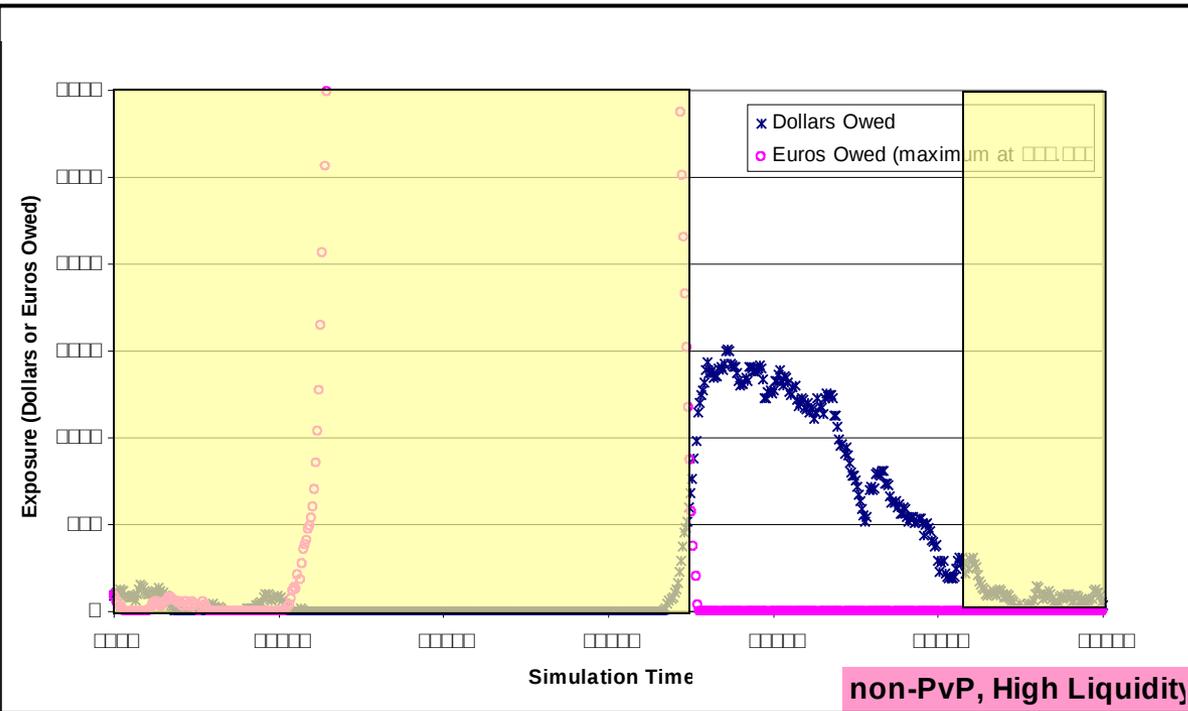


**Non-PvP High Liquidity, FX exposures**



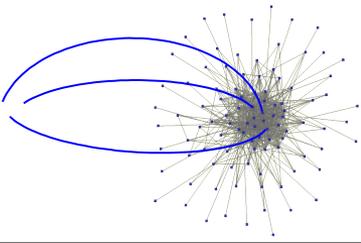


# Operational disruption

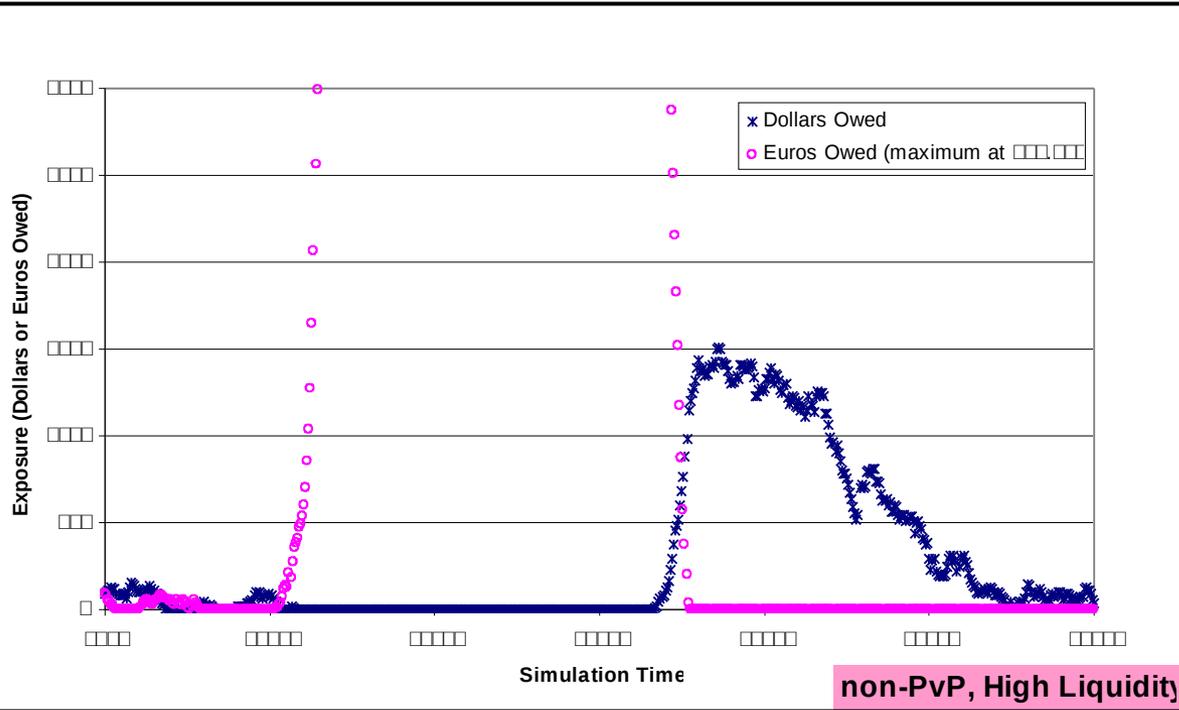


## Non-PvP High Liquidity, FX exposures

- Outage: huge increase in € owed (1 000 times normal exposures)
- Recovery: large increase in \$ owed (15 time normal exposure)

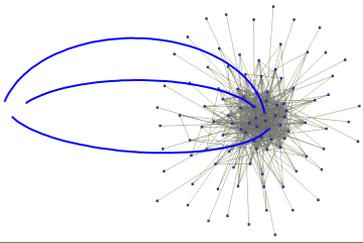


# Operational disruption



## Non-PvP High Liquidity, FX exposures

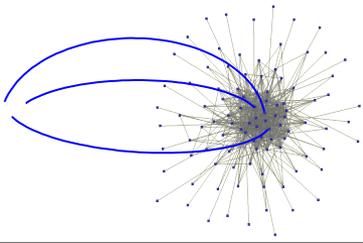
- Outage: huge increase in € owed (1 000 times normal exposures)
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# Cross-currency channels of disruption propagation

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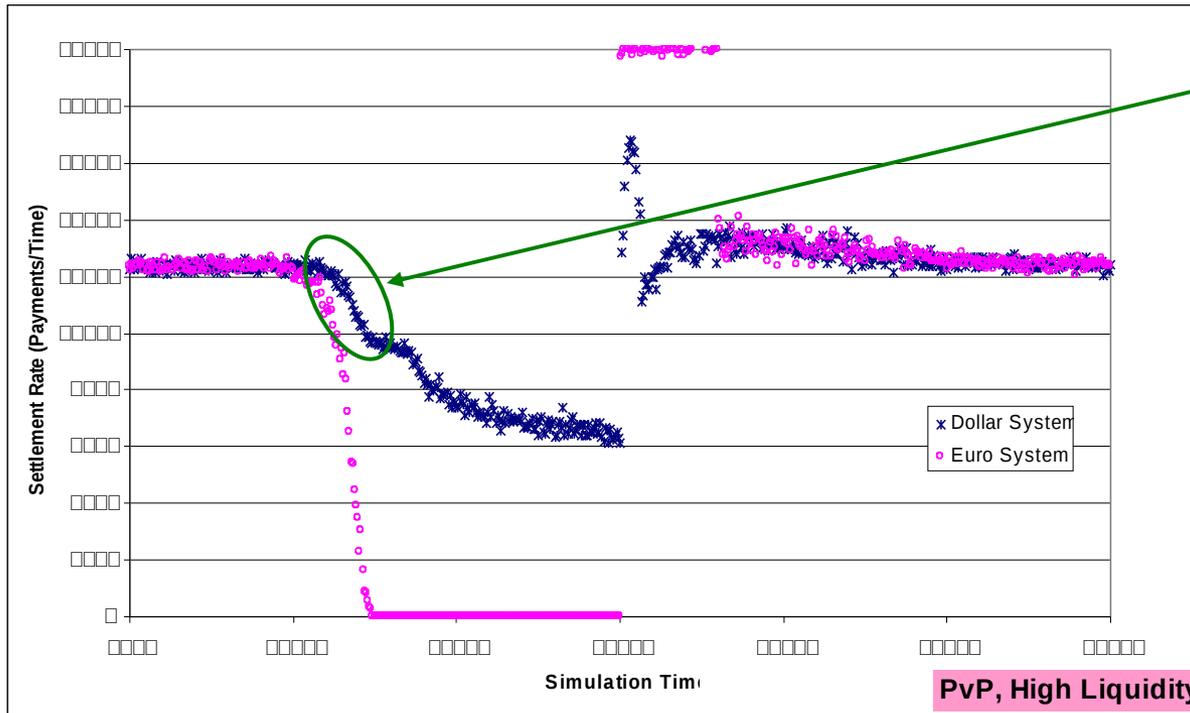
- **Channel 1: Low € balances at the CB prevent settlement of € leg of FX transactions (PvP) or create FX exposures (non-PVP)**

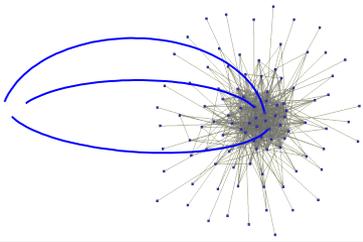


# Cross-currency channels of disruption propagation

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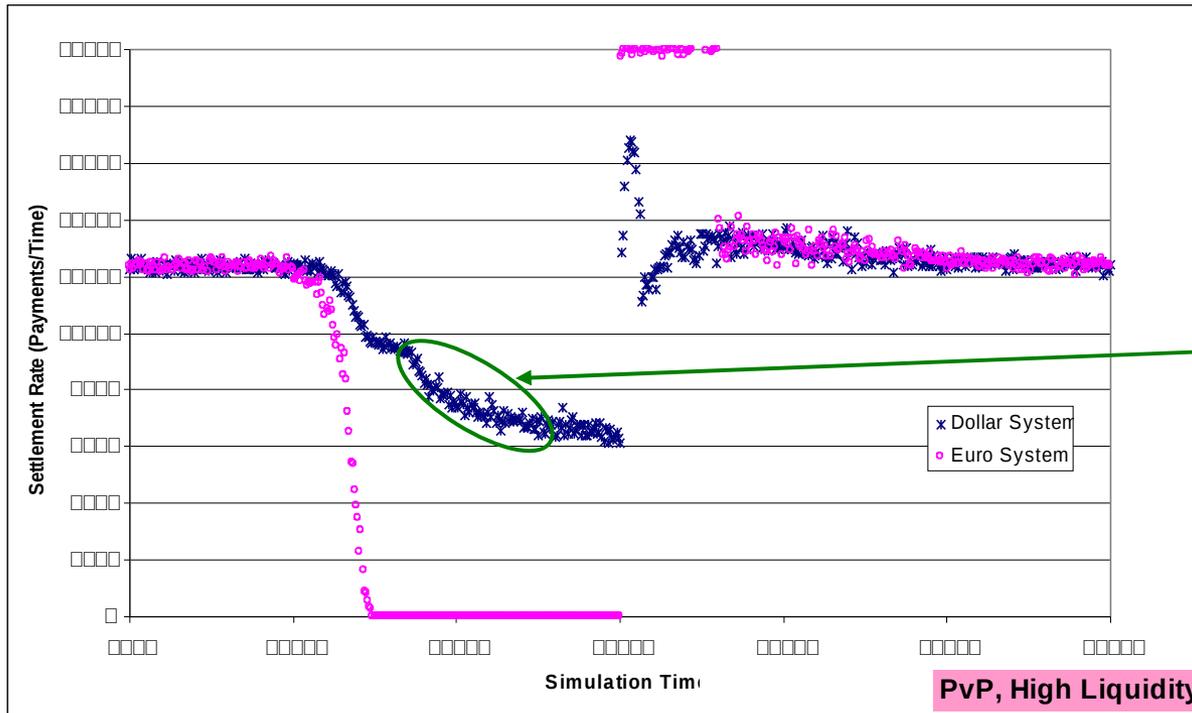
- PvP:
  - All FX settlement activity stops, RTGS \$ is deprived from FX settlement activity



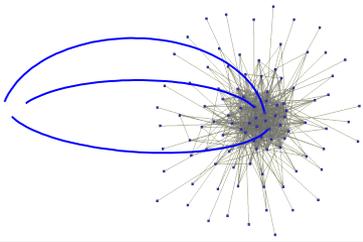


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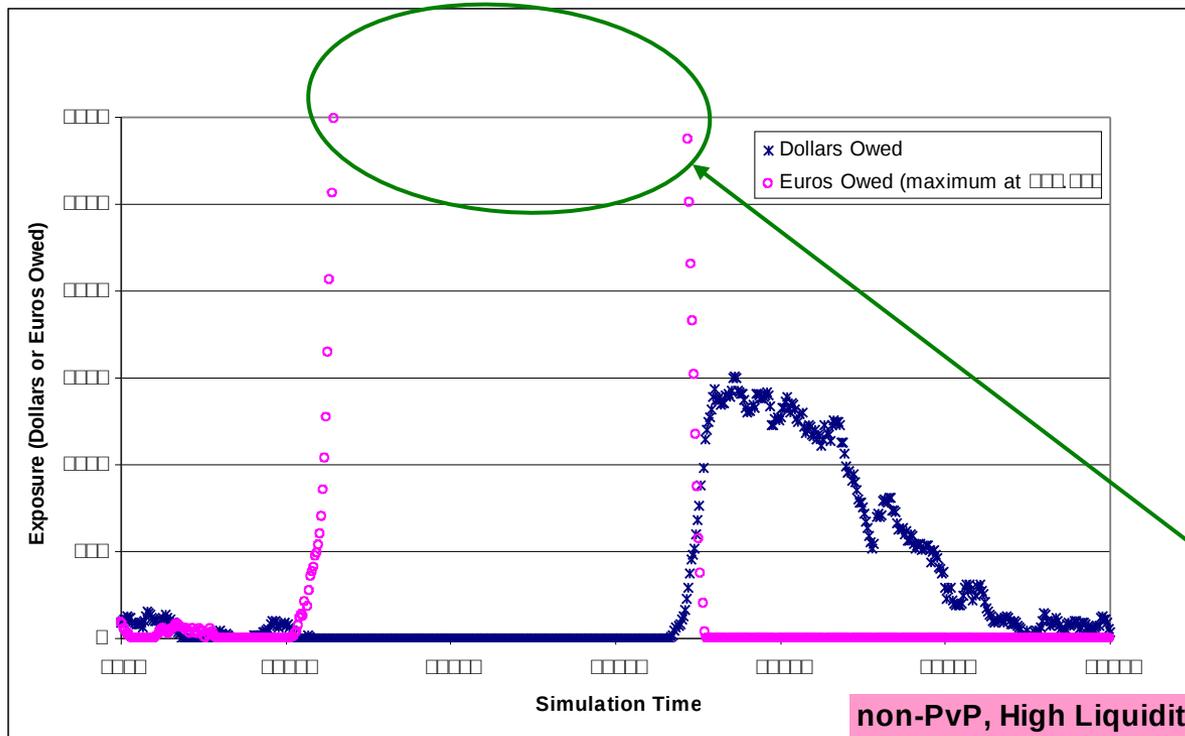


- **PvP:**
  - All FX settlement activity stops, RTGS \$ is deprived from FX settlement activity
  - Because of the queuing of FX trades (PvP), customers have lower \$ funds and make fewer \$ local payments

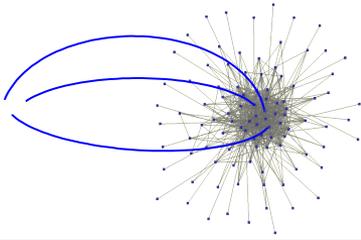


# Cross-currency channels of disruption propagation

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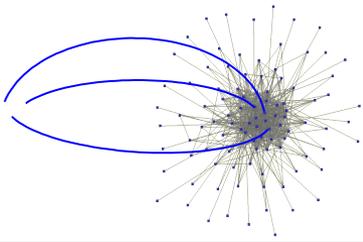
- **PvP:**
  - All FX settlement activity stops, RTGS \$ is deprived from FX settlement activity
  - Because of the queuing of FX trades (PvP), customers have lower \$ funds and make fewer \$ local payments
- **Non-PvP:**
  - Very high exposures (unsettled € legs) during crisis



# Cross-currency channels of disruption propagation

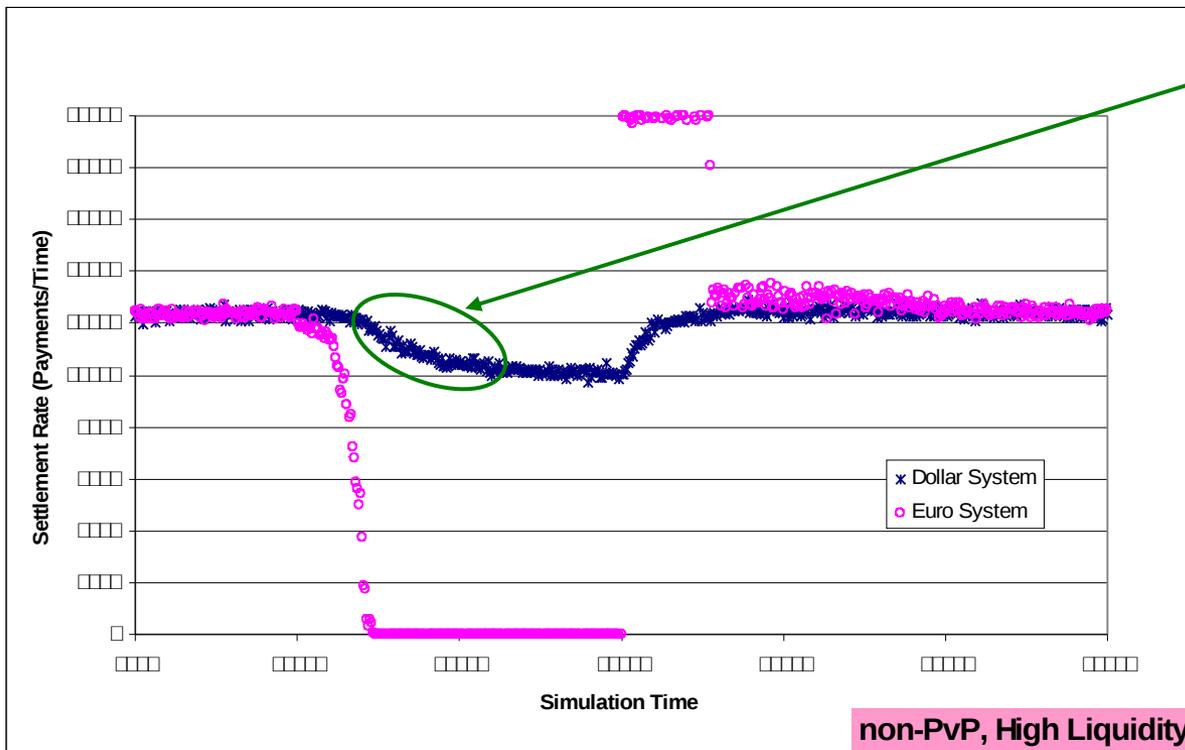
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- **Channel 2: Low € customer funds lead to fewer emitted FX trades**
  - Banks customers' € liquidity is trapped within queued payments. Therefore, customers emit fewer FX trades

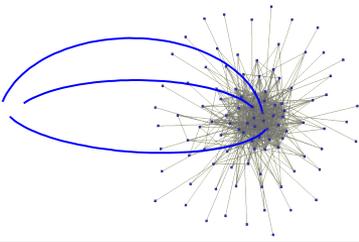


# Cross-currency channels of disruption propagation

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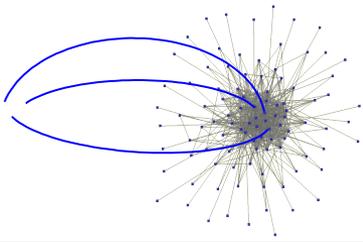
This leads to RTGS \$ being eventually deprived of FX activity, even in the non-PvP case



# Cross-currency channels of disruption propagation

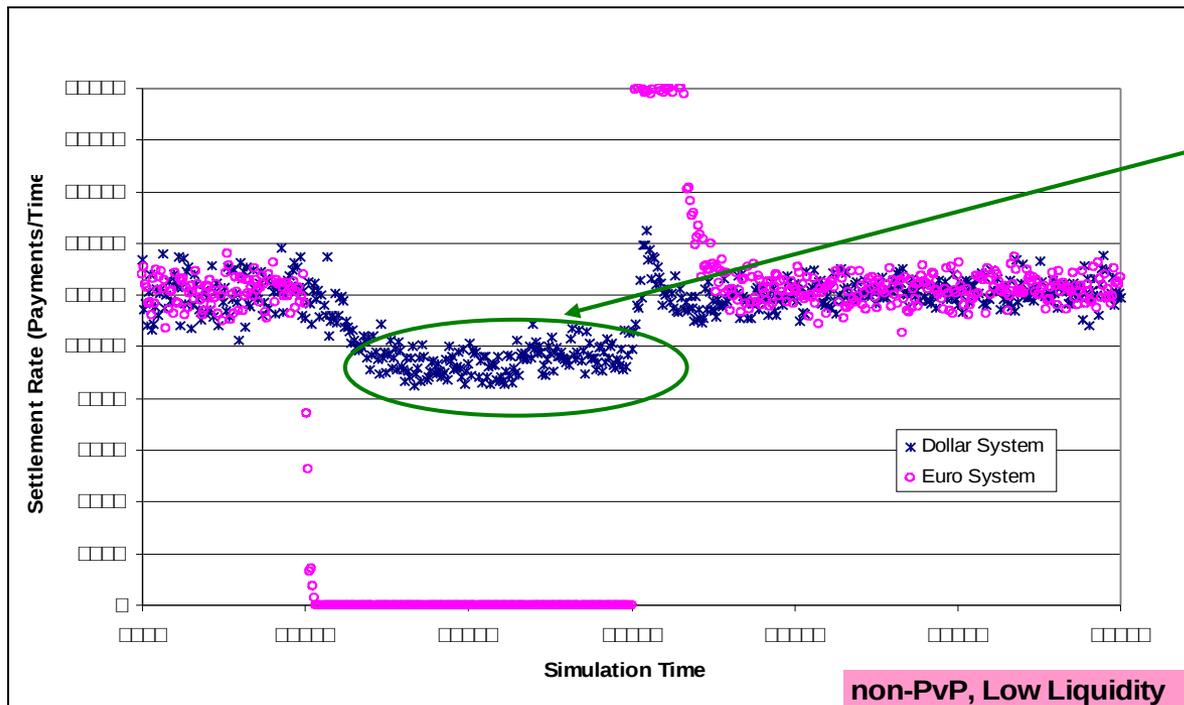
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- **Channel 3: As not all banks are similarly affected, the system becomes unbalanced**
  - The FX banks for which the disrupted bank is an important counterparty see their level of € customer funds decrease more rapidly.
  - These banks become net € buyers (\$ sellers) on the FX market. RTGS \$ becomes unbalanced.

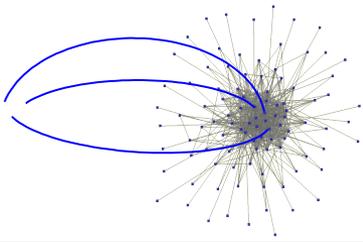


# Cross-currency channels of disruption propagation

- **Channel 3: As not all banks are similarly affected, the system becomes unbalanced**
  - The FX banks for which the disrupted bank is an important counterparty see their level of € deposits decrease more rapidly.
  - These banks become net € buyers (\$ sellers) on the FX market. RTGS \$ becomes unbalanced.

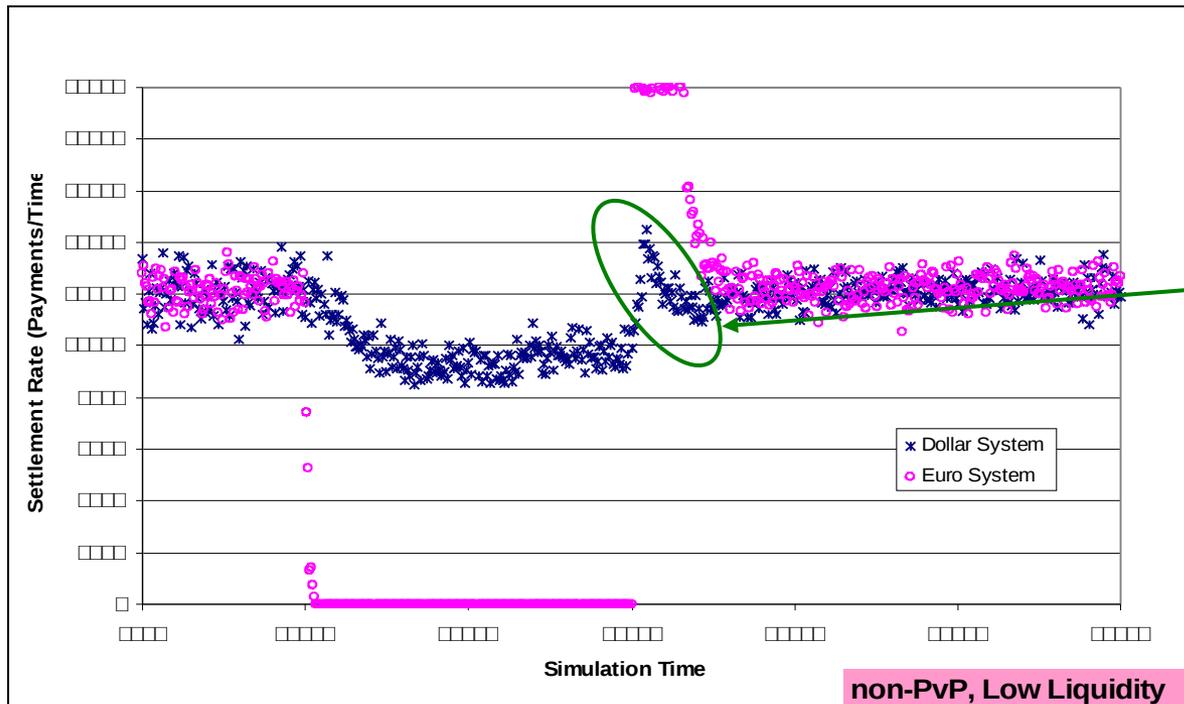


- Low Liquidity:
  - this leads to the queuing of several \$ local payments, even in the non-PvP case...

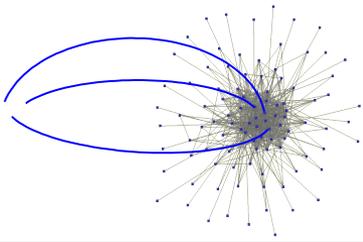


# Cross-currency channels of disruption propagation

- **Channel 3: As not all banks are similarly affected, the system becomes unbalanced**
  - The FX banks for which the disrupted bank is an important counterparty see their level of € deposits decrease more rapidly.
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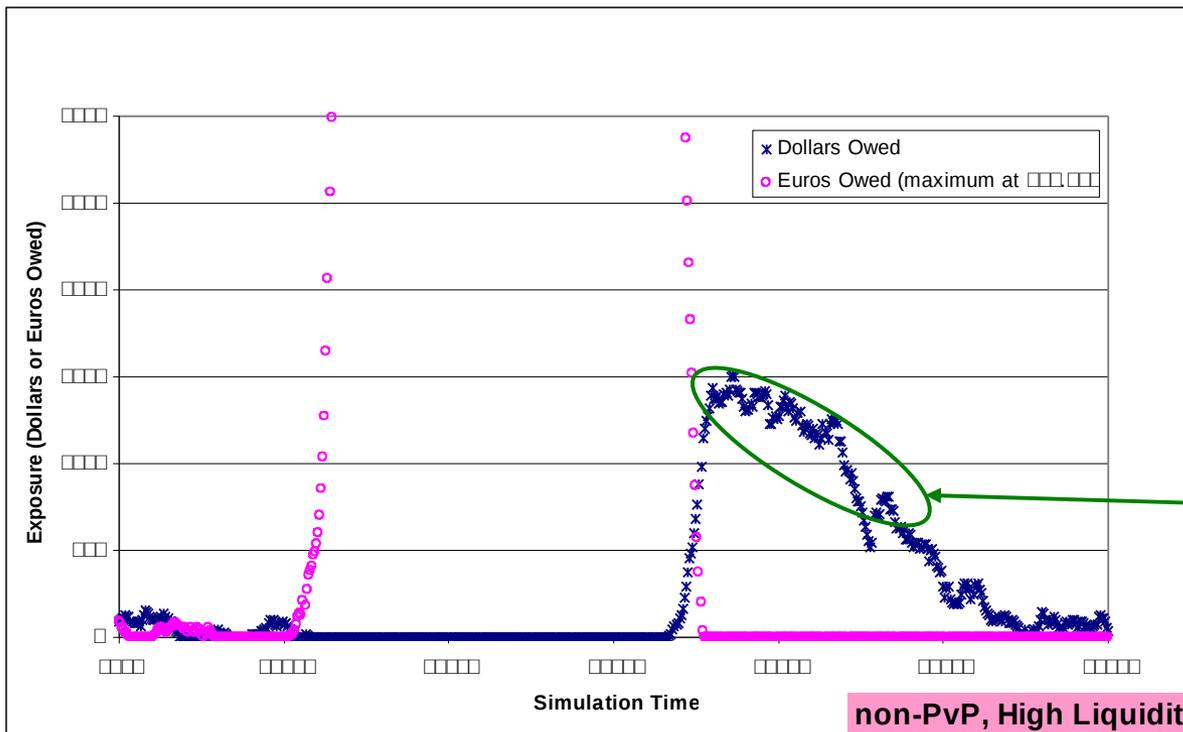


- **Low Liquidity:**
  - this leads to the queuing of several \$ local payments, even in the non-PvP case...
  - And to an overshoot at recovery, even in non-PvP case

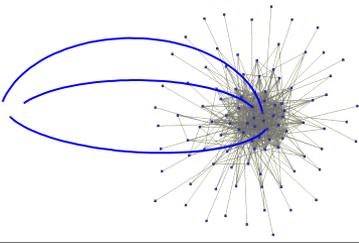


# Cross-currency channels of disruption propagation

- **Channel 3: As not all banks are similarly affected, the system becomes unbalanced**
  - The FX banks for which the operationally disrupted bank is an important counterparty see their level of € deposits decrease more rapidly.
  - These banks become net € buyers (\$ sellers) on the FX market. RTGS \$ becomes unbalanced.



- Low Liquidity:
  - this leads to the queuing of several \$ local payments...
  - And to an overshoot at recovery, even in non-PvP case
- Non-PvP:
  - This creates a peak in \$ owed exposures at recovery, event at high liquidity



# Conclusions

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- A simple model of interconnected RTGS was developed
- During normal operation, the two RTGS are shown to be interdependent
- When a liquidity crisis affects one RTGS, the crisis propagates to second RTGS in all considered cases
  - PvP:
    - sharp decrease in activity (local and FX) in second RTGS
  - Non-PvP:
    - Decrease in activity in second RTGS due to fewer FX trades emitted
    - At low liquidity, local payments in second RTGS are also affected
    - Large increase of FX exposures during crisis and recovery