Settlement behavior and interbank lending in an agent-based laboratory

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Outline

1. The rational of this work
2. The model
   - agents' micro-behavioural rules on the interbank fund transfer (IFT)
   - probability of acting in the money market (MM)
   - interest rate and quantity proposed on the MM
3. Assessing the quality of the model
4. Stress testing the model
   - Simulating liquidity stress testing
   - Simulating increase in uncertainty
5. Conclusions and the way forward

1. The rational of this work

1) Need for analysis and stress testing on:

- Determinants of money market failure/freeze
- IFT resilience to financial stability shocks

Need for a joint modelling and stress testing tool

2) Structural models or classic simulation tools rely on assumptions of systems' macro properties, do not capture properties emerging from the interplay of several agents

Agent based modelling applied jointy to IFT and MM

3) Higher complexity in micro behavioural rules: more realistic without loss of effectiveness in emerging macro properties and of the stress testing results

2.A The model: agents' behavioural rules to comply with MMR (1/2)

Bank i at the start of the day:

- initial exogenous liquidity amount B_{i0}
- Expected incoming and outgoing payments from time *0* to time *T* (v : uncertainty)

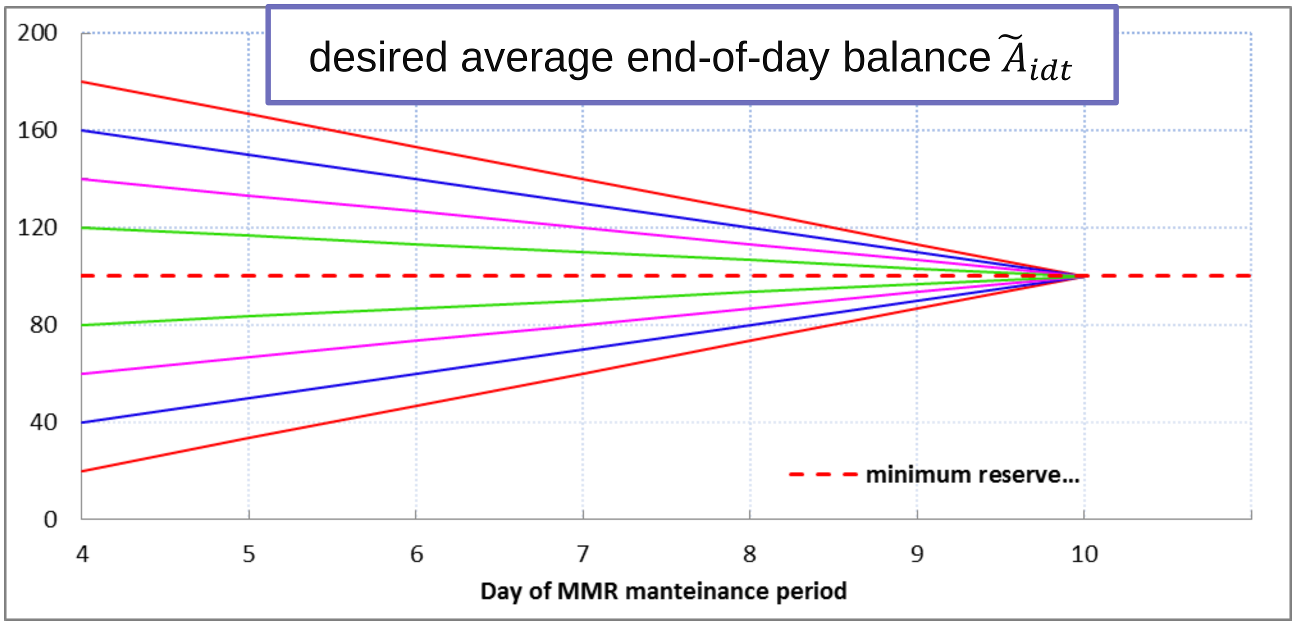
$$v\left[E\left(\sum_{s=t}^{T} O_{ids}\right)+E\left(\sum_{s=t}^{T} I_{ids}\right)\right]$$

- A minimum reserve requirement to comply with over the *D* days of the maintenance period MRR_i
- From a certain moment of the MP (day δ), they will start to be concerned about MRR_i and start targetting a desired average end-of-day balance of next $\mathrm{D}-\delta$ days (equally splitting $\left|MRR_i - A_{i(\delta-1)}\right|$ on the remaining days)

$$\tilde{A}_{id} = A_{i(d-1)} + \frac{1}{(D-d+1)}\left(MRR_i - A_{i(d-1)}\right)$$

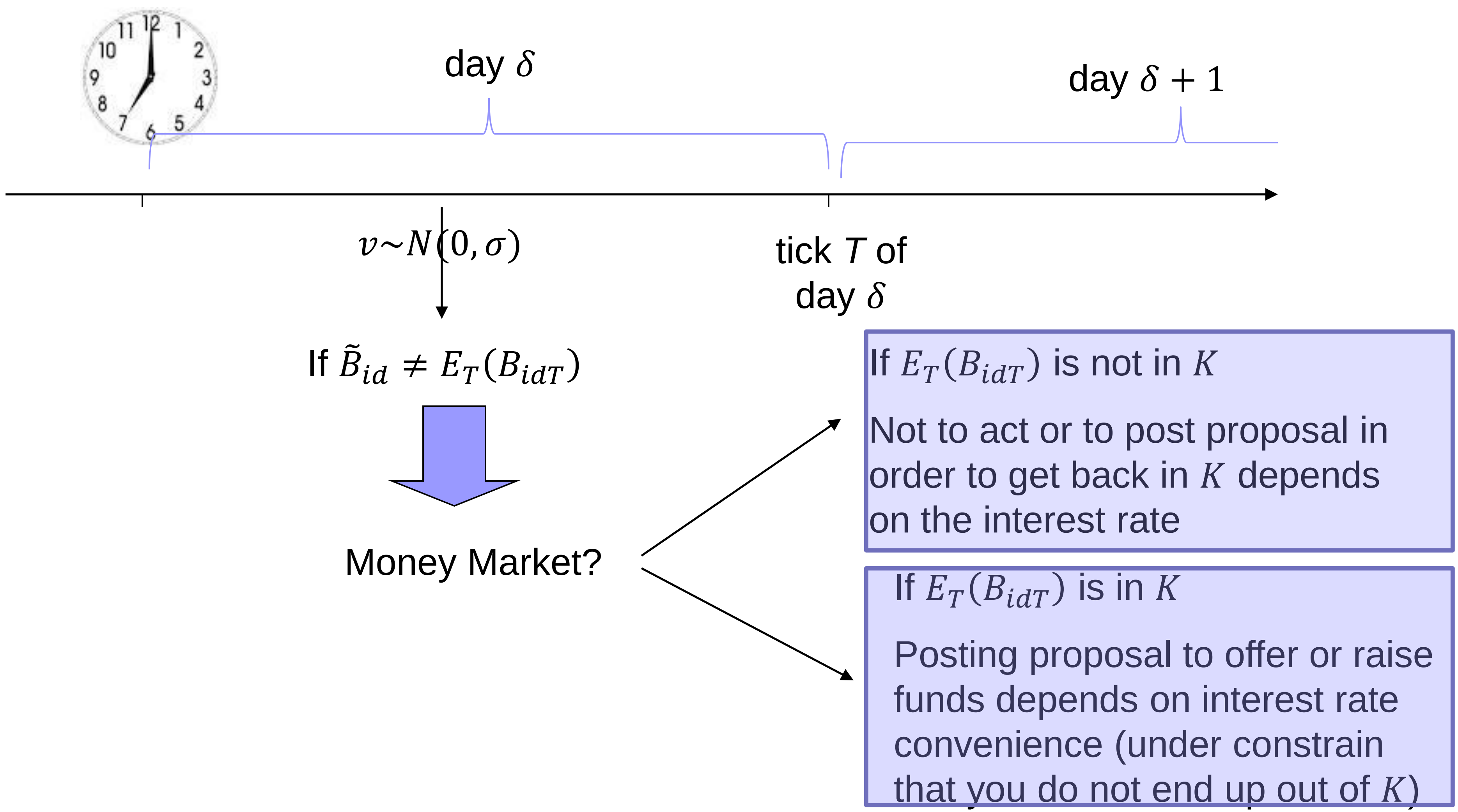
- They are willing to accept some deviation around taget: symmetric corridor around it (dimension shrinkes when approaching *D*)
- Desired end-of-day balance of the next $\mathrm{D}-\delta$ days $\tilde{B}_{id}$ and the specular symmetric corridor round it K_{id}

2.A The model: agents' behavioural rules to comply with MMR (2/2)



- Reserve excesses/deficits are managed in a linear fashion through the MMR period
- Agents are willing to accept symmetric deviations from each end-of-day desired balances (a corridor C around the desired level $\widetilde{A}_{idt}$ is accepted)

2.B The model: probability of acting in the MM when aiming to comply with MRR (day δ to D) (1/6)



2.B The model: probability of acting in the MM when aiming to comply with MRR (day δ to D) (2/6)

If expected end-of-day balances $E_T(B_{idT})$ is outside the corridor K, bank i will consider:

1) How convenient is it to fill the gap now on the basis of the prevailing MM rate?
2) How many days remain until the end of MP?

1) How convenient is it to fill the gap now?

To this end we assume:

I. a policy rate i_p to which, absent monetary policy expectations, the market rate i_m is likely to revert
II. That agents will not expect that market rate i_m will fluctuate too far away from i_p determining de facto an interest rate corridor $[i_{min}; i_{max}]$

Example: If $E_T(B_{idT}) < K$ (deficit) under which conditions will i demand funds (bid)?

- If $i_m > i_{max}$: $p(bid) = 0$ Why? Not at all convenient, rate expected to drop
- If $i_p > i_m$: $p(bid) = 1$ Why? Rate is expected to increase again
- If $i_p < i_m < i_{max}$.....

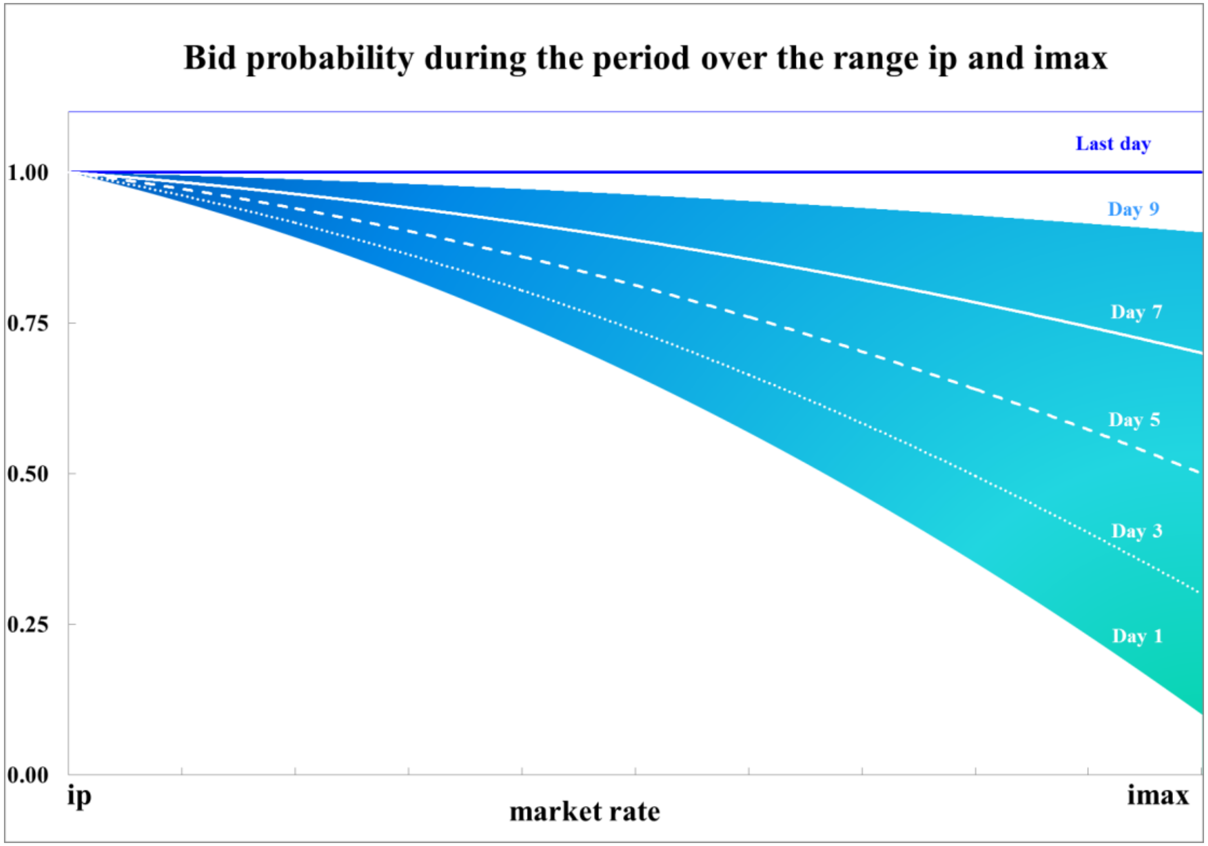
2.B The model: probability of acting in the MM when aiming to comply with MRR (day δ to D) (3/6)

…. if $i_p < i_m < i_{max}$: $p(bid) = F(d, i_{mt}|\theta)$ where θ is a sensitivity parameter

2.B The model: probability of acting in the MM when aiming to comply with MRR (day δ to D) (4/6)

2) How many days remain until the end of MMR period?

The probability $p(bid)$ over the range $[i_p; i_{max}]$ will increase as the end of MMR period approaches (urgency to fill the gap)



Algebra

2.B The model: probability of acting in the MM when aiming to comply with MRR (day δ to D) (5/6)

If expected end-of-day balances $E_T(B_{idT})$ is inside the corridor K:
the bank would not be compelled to get active on the money market to fullfill its minimum reserve requirements but it could act as the money market rates are profitable.

Example: If $E_T(B_{idT}) \epsilon K$ under which conditions will bank i offer funds (ask)?

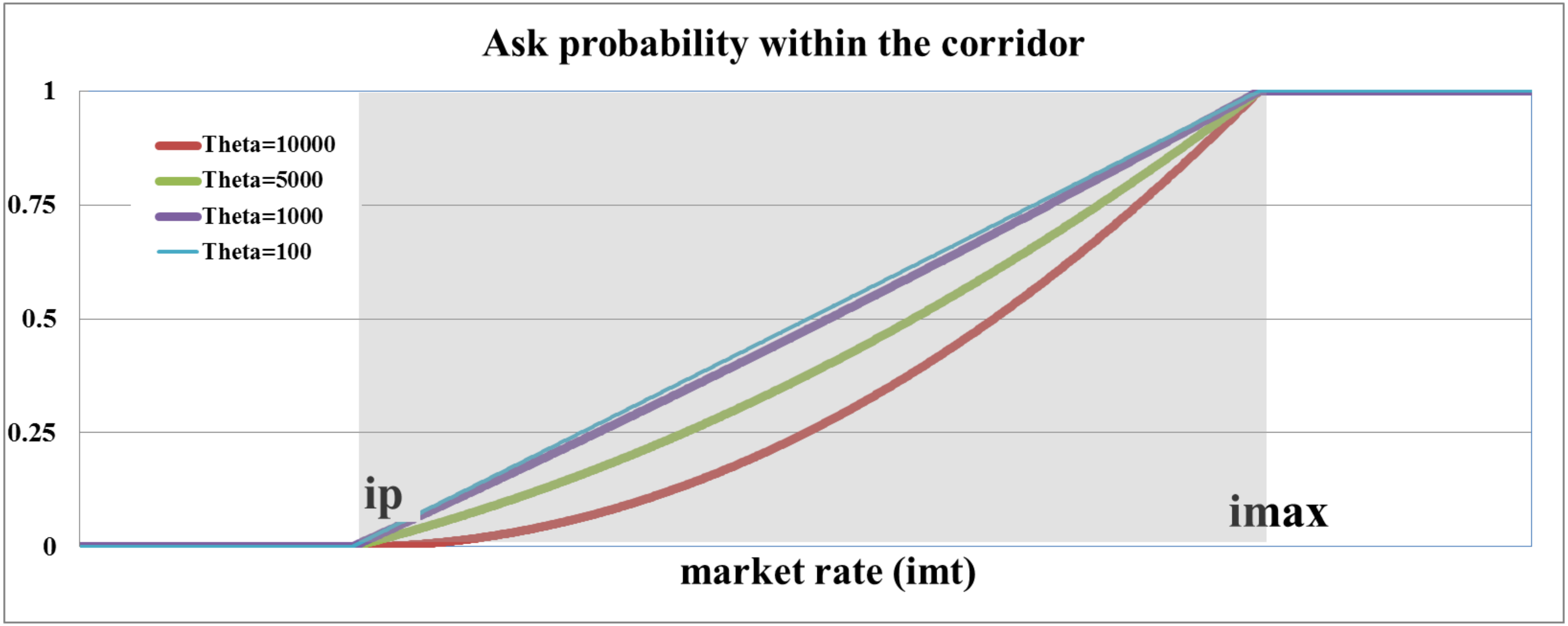
a) strong incentive to offer fund if the market rate lies over the maximum expected rate i_{max} (which is also the expected highest funding cost) $(i_m > i_{max} : p(ask) = 1)$

a) no incentive to lend money if the market rate lies under the policy rate i_p because it will likely gain more in the future $(i_p > i_m : p(ask) = 0)$

c) In between, If $i_p < i_m < i_{max}$.....

2.B The model: probability of acting in the MM when aiming to comply with MRR (day δ to D) (6/6)

…. if $i_p < i_m < i_{max}$: $p(ask) = F(d, i_{mt}|\theta)$ where θ is a sensitivity parameter



[Algebra]

2.C The model: interest rate and quantity proposed on the MM

Setting

a) Interest rate of the proposal: $i_{idt} = i_{mt} + \alpha_1 \varphi^{MRR\_imbalance} + \alpha_2 \varphi^{BOOK\_strength}$

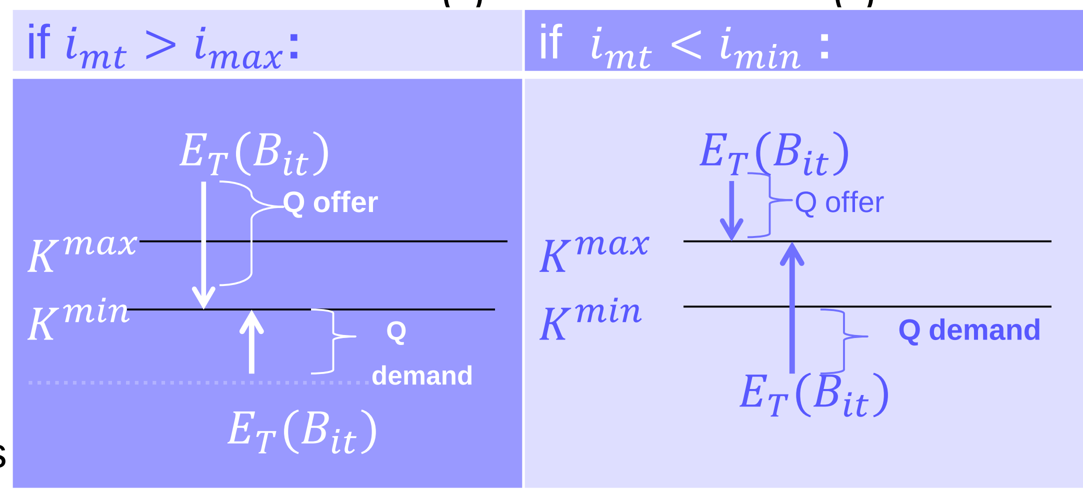
for the ones demanding funds: (+) (+)

for the ones offering funds: (-) (-)

b) Quantity of the proposal:

for the ones offering funds:

for the ones demanding funds



c) Revising the interest rate of the proposal if the proposal is not hit

for the ones demanding funds: (+)

for the ones offering funds: (-)

3. Assessing the quality of the model

Emerging macro-level dynamics:

- MM interest rate dynamic:
  1) Positively related to liquidity at agents' disposal
  2) Mean- reverting
  3) Volatility peak on the last day of MP

- The majority of our artificial banks are able to comply with their average minimum reserve requirements over a multiday horizon.

4. Stress testing the model (1/6)

Simulating liquidity stress testing

1) High liquidity scenario:

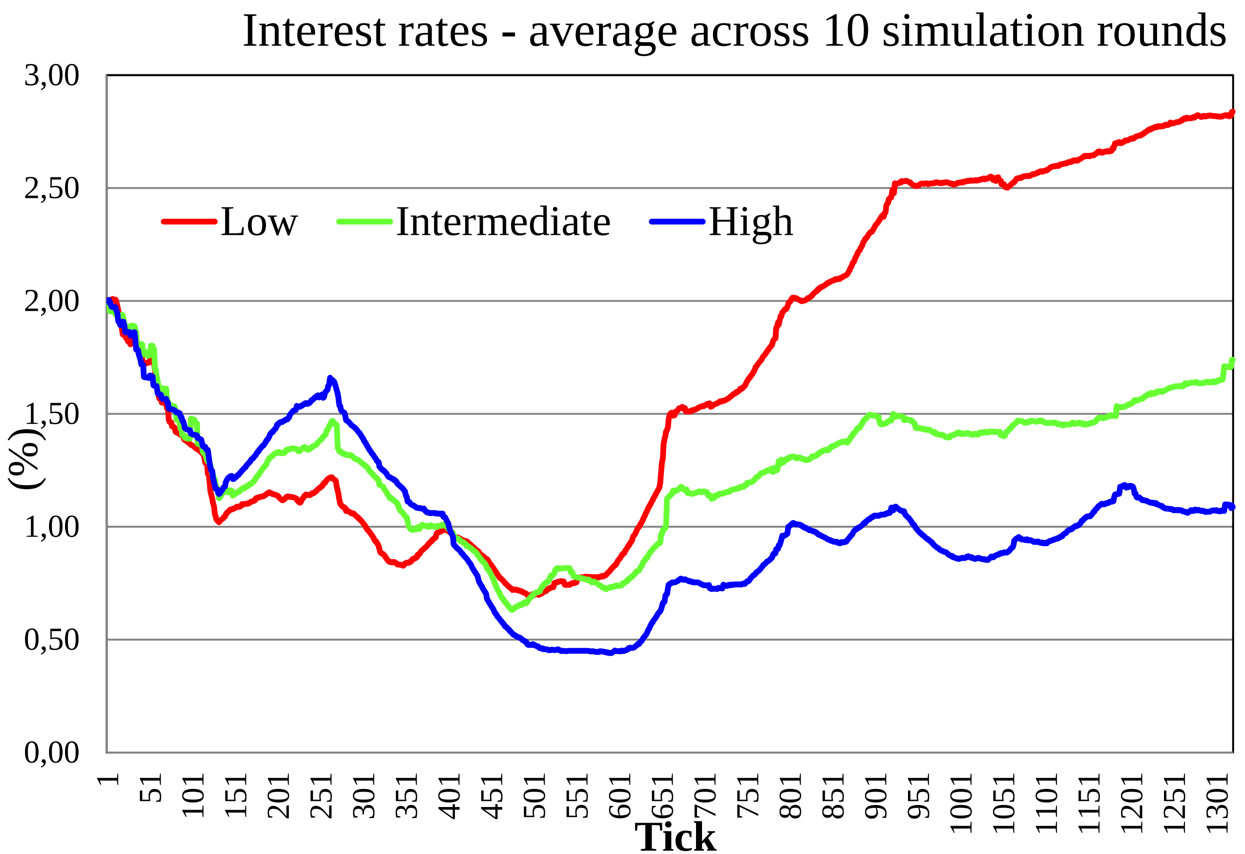
$$B_{id0} = 35\%\ K_{id}^{max}$$

2) Intermediate liquidity scenario:

$$B_{id0} = 25\%\ K_{id}^{max}$$

3) Low liquidity scenario:

$$B_{id0} = 15\%\ K_{id}^{max}$$



1. MACRO-DYNAMIC: interest rate's aggregate pattern

….. *i* inversely correlated to participants' liquidity….

4. Stress testing the model (2/6)

Simulating liquidity stress testing (continues)

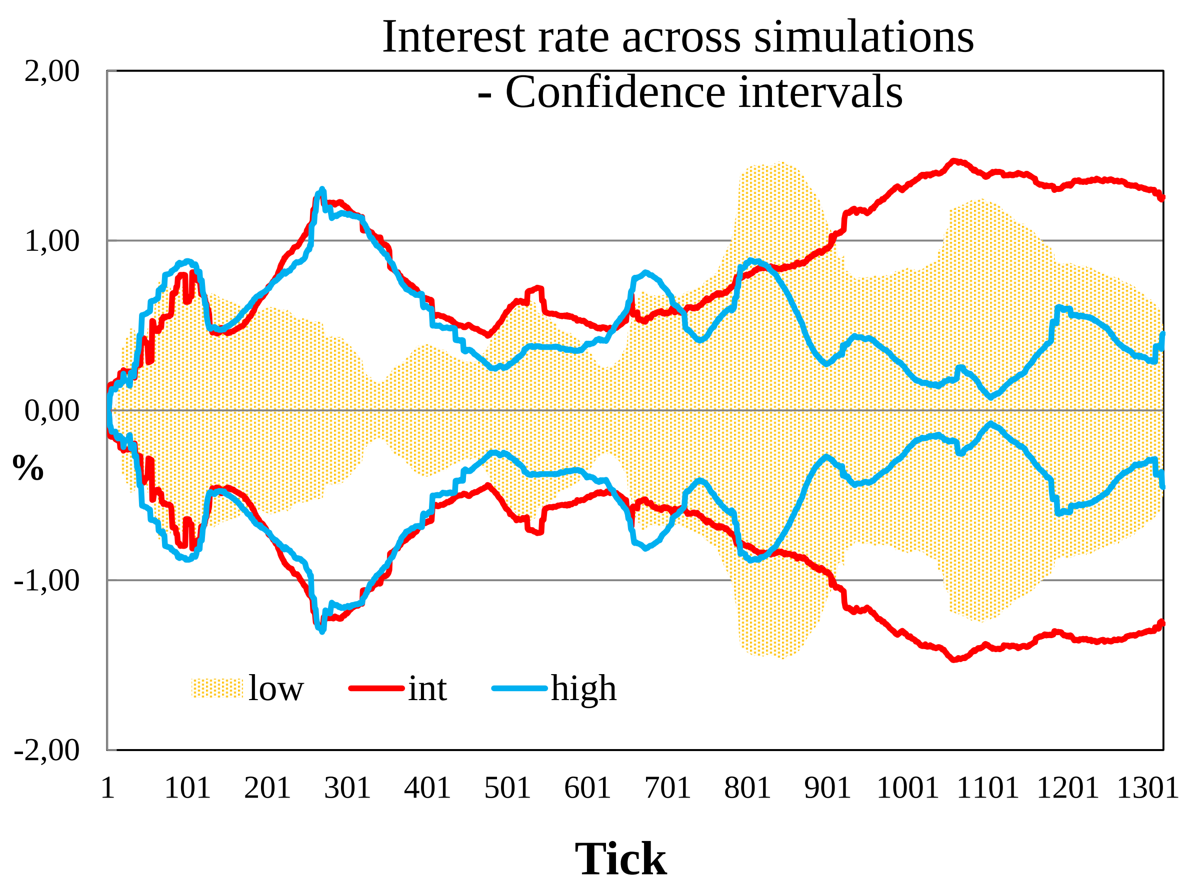
... but tricky results for
the interest rate volatility:

a) Volatility within a scenario:

Scenario	Intraday volatility
Low	20 b.p.
Interm.	7 b.p.
High	30 b.p

…both extreme scenarios seem undesirable

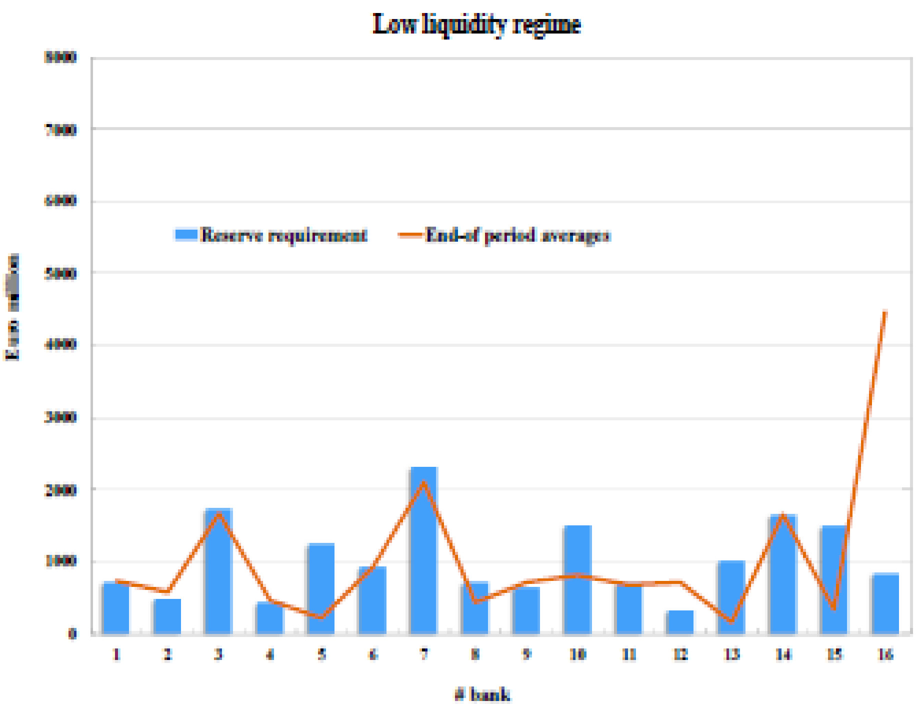
b) variability of *i* across scenarios:



4. Stress testing the model (3/6)

Simulating liquidity stress testing (continues)

2. MACRO-DYNAMIC: MRR fulfillment



3. MACRO-DYNAMIC: PS performance

Liquidity scenario	Unsettled exogenous payments (% of tot value)	Unsettled endogenous MM repayments (% tot repayment value)
Low	5.8%	15.8%
Interm	5.8%	16.8%
High	2.3%	3.46%

4. Stress testing the model (4/6)

Simulating an increase in payments' uncertainty

1) <u>No uncertainty scenario:</u>

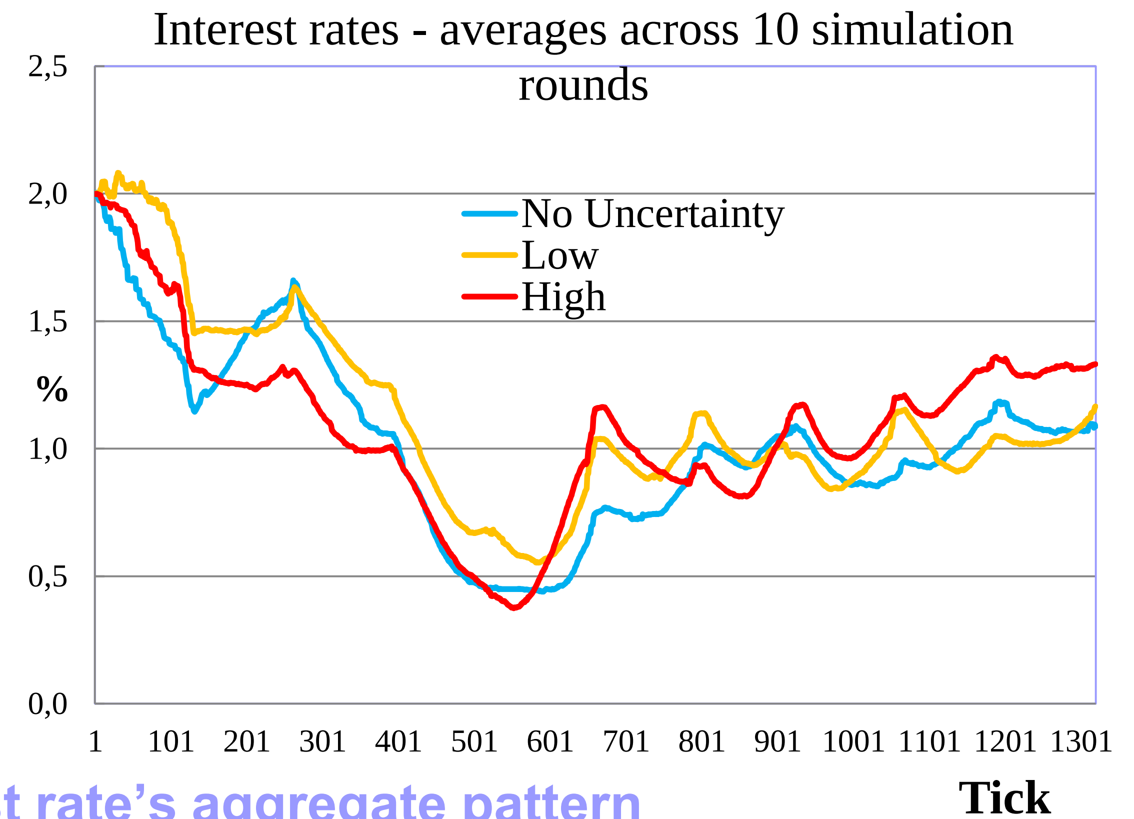
$$v \sim N(0,0)$$

2) <u>Intermediate uncertainty scenario:</u>

$$v \sim N(0,0.2)$$

3) <u>High uncertainty scenario:</u>

$$v \sim N(0,0.5)$$



1. MACRO-DYNAMIC: interest rate's aggregate pattern

….. Uncertainty in payments does not affect interest rate pattern….

(is this reasonable?)

4. Stress testing the model (5/6)

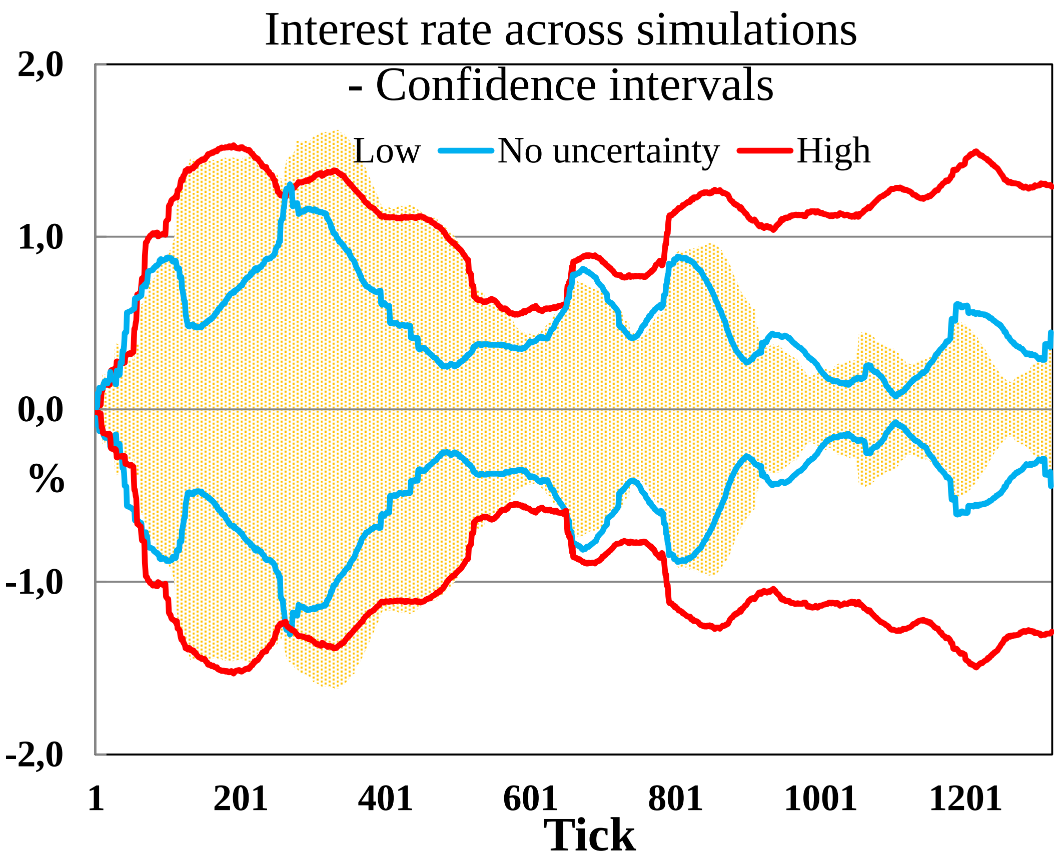
Simulating an increase in payments' uncertainty

... but for sure reasonable results for interest rate volatility:

a) Volatility within a scenario:

Scenario	Intraday volatility
No	7 b.p.
Low.	12 b.p.
High	17 b.p

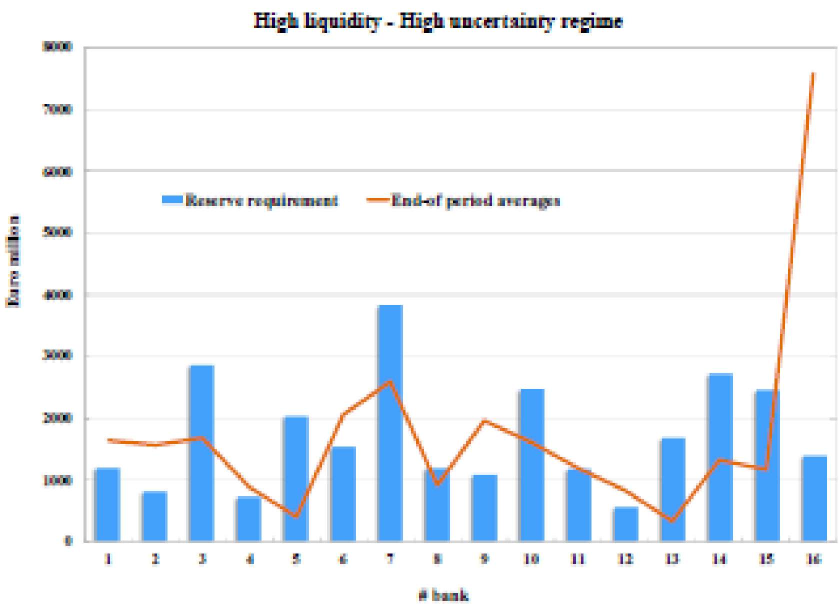
b) variability of *i* across scenarios:



4. Stress testing the model (6/6)

Simulating an increase in payments' uncertainty

2. MACRO-DYNAMIC: MRR fulfillment



Ability to fulfill MRR severely hampered

3. MACRO-DYNAMIC: PS performance

Uncertainty scenario	Unsettled exogenous payments (% of tot value)	Unsettled endogenous MM repayments (% tot repayment value)
No	2.3%	3.46%
Low	3.8%	4.58%
High	4.6%	3.95%

5. Conclusions and next steps (1/3)

- **Model that allows**
  - simulating jointly IFTsystem and the MM
  - Capturing their decentralized nature of MM and IFT system
  - As a result of interaction of several agents' choices from the model emerge realistic macro-dynamics

- **Model allows stress test jointly the IFT and the MM:**
  - Liquidity stress testing: when liquidity drops interest rate increases, but its volatilty is lower in a scenario with intermediate liquidity amounts at micro level. Banks fulfill MRR also in the low liquidity scenario.
  - Uncertainty on IFT payments: higher uncertainty does not increase interest rates (the amount of liquidity is more important than uncertainty for the interest rate level), but the volatility of the interest rate remains high until the very last moment of the period . Uncertainty hampers ability of banks to fulfill MRR.

5. Conclusions and next steps (2/3)

Next steps:

- Improving the model:
  - Avoiding the "postpone payments if you lack liquidity" strategy (introducing urgent payments, delay costs);
  - acting on the money market also to avoid payments delay (introducing an intraday horizon)

- Expand the range of stress testing:
  - stressing the impatience of agents to offer / demand funds (sensitivity parameter θ);
  - simulating the default of a bank partecipating both in the IFT and in the MM

5. Conclusions and next steps (3/3)

- **Questions from the audience?**
- **…and a question *to* the audience…**

Which level of complexity should micro behavioral rules of an ABM have to ensure high quality stress testing?

Thank you!

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Appendix: Bid and Ask probability: the algebra

1. If $i_{mt} < i_p$, it is expected to increase:

a) If $\mathbb{E}_t(B_{id}) < K_{id}^{min}$

$$P(Ask_{idt}) = 0$$

$$P(Bid_{idt}) = \begin{cases} 1 & \text{if } \Delta \leq 0 \\ 1 - \frac{D-d}{D}\left[\frac{1-\theta_{out}(i_{max}-i_p)^2}{(i_{max}-i_p)} \cdot \Delta + \theta_{out}\Delta^2\right] & \text{if } \Delta > 0 \\ 0 & \text{if } i_{mt} \geq i_{max} \end{cases}$$

$$P(N_{idt}) = 1 - P(Bid_{idt})$$

b) If $\mathbb{E}_t(B_{id}) \in [K_{id}^{min}; d \cdot \tilde{A}_{id} - A(d-1)]$ and $\Delta < 0$

$$P^*(Ask_{idt}) = 0$$

$$P^*(Bid_{idt}) = \left[\frac{1 - \theta_{in}(i_{min} - i_p)^2}{(1_{min} - i_p)}\right] \cdot \Delta + \theta_{in}\Delta^2$$

$$P^*(N_{idt}) = 1 - P^*(Bid_{idt})$$

2. If $i_{mt} > i_p$, it is expected to decrease:

a) If $\mathbb{E}_t(B_{id}) > K_{id}^{max}$

$$P(Ask_{idt}) = \begin{cases} 1 & \text{if } \Delta \geq 0 \\ 1 - \frac{D-d}{D}\left[\frac{1-\theta_{out}(i_{min}-i_p)^2}{(i_{min}-i_p)} \cdot \Delta + \theta_{out}\Delta^2\right] & \text{if } \Delta < 0 \\ 0 & \text{if } i_{mt} \leq i_{min} \end{cases}$$

$$P(Bid_{idt}) = 0$$

$$P(N_{idt}) = 1 - P(Ask_{idt}).$$

b) If $\mathbb{E}_t(B_{id}) \in [d \cdot \tilde{A}_{id} - A(d-1); K_{id}^{max}]$ and $\Delta > 0$

$$P^*(Ask_{idt}) = \left[\frac{1 - \theta_{in}(i_{max} - i_p)^2}{(1_{max} - i_p)}\right] \cdot \Delta + \theta_{in}\Delta^2$$

$$P^*(Bid_{idt}) = 0$$

$$P^*(N_{idt}) = 1 - P^*(Ask_{idt})$$

Back to the presentation – Back again