EUROPEAN CENTRAL BANK
EUROSYSTEM

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Shorter settlement cycles with DLTs: What consequences for liquidity?

Work in progress – do not quote

15th Payment and Settlement System Simulation Seminar

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Overview

1 The research project
2 Liquidity measures
3 Results from selected days
4 Synthetic indicators for liquidity
5 Concentration indexes
6 Distribution analysis
7 Conclusions and further work

Context and objectives

1. Interaction between financial intermediaries is fragmented
   - DLTs are a possible game-changer
     - Disintermediation (revolution)?
     - Straight-through processing (evolution)?

2. Both scenarios warrant prior analysis to promote:
   - safety and efficiency of FMI (central bank role as an overseer)
   - adoption of innovation cognisant of wider consequences (catalyst role)

3. Market participants trade before posting resources (e.g. T+2)
   - What if straight-through processing via DLTs allowed a shorter cycle?
     - What would be the impact on the safety of market infrastructures?
     - What cost would participants bear in terms of additional liquidity?
     - Could any DLT functionality mitigate such impact?

OBJECTIVE at this stage: Create a framework to analyse impact of intraday cycles on the liquidity available to system and its participants

Data: 10 days of trade/settlement instructions from Italian exchange

The intraday counterparty balance

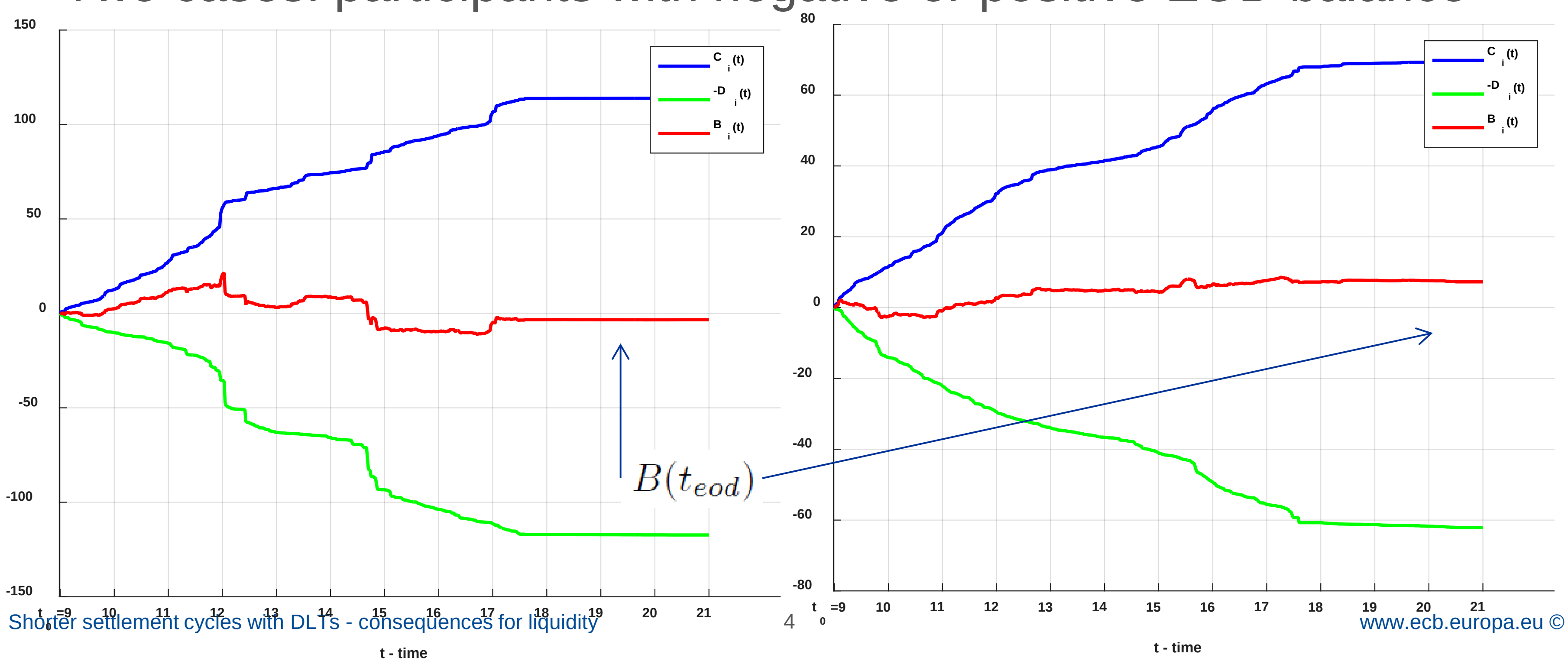
- Assumption (focus on liquidity needs): start of day balance

$$B_i(t_0) = 0$$

- Cash/security account balance is diff. between credits and debits

$$B_i(t) = C_i(t) - D_i(t)$$

- Two cases: participants with negative or positive EOD balance

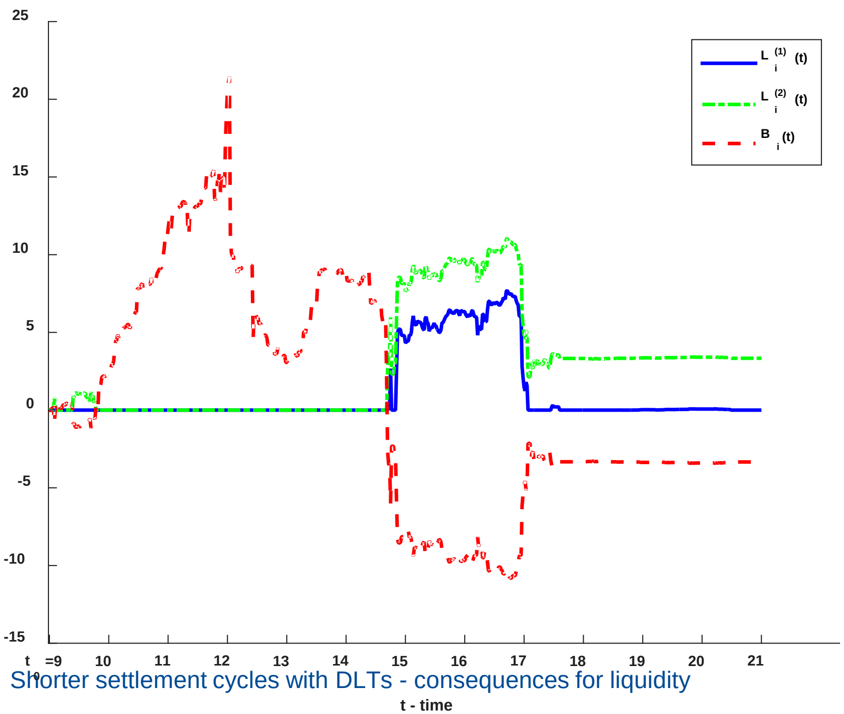


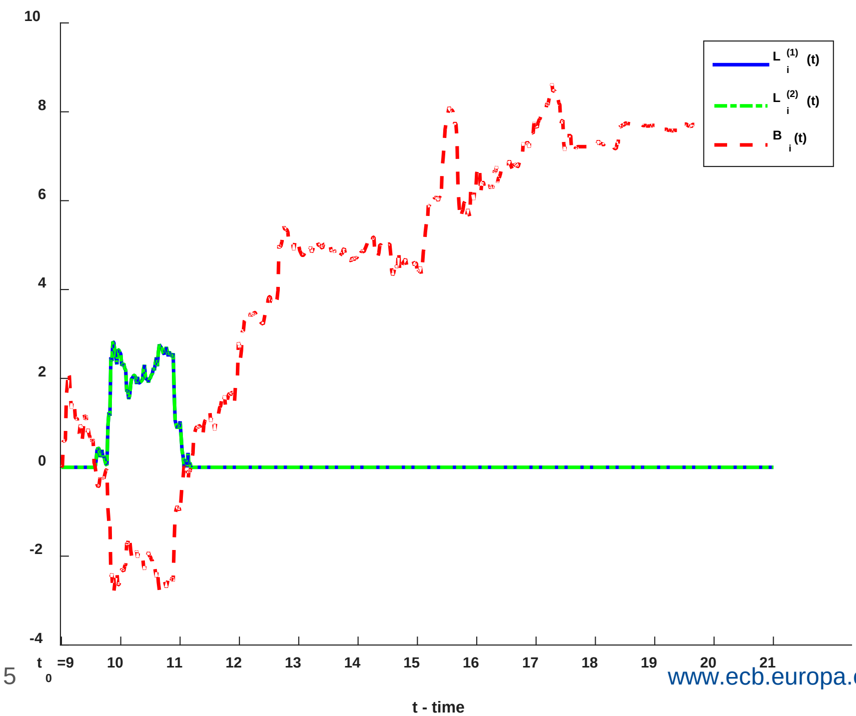
Participant *i*'s intra-day liquidity needs

- $L_i^{(1)}(t)$ measures additional liquidity with respect to end of day need:

$$L_i^{(1)}(t) = \begin{cases} \max(0, B_i(t_{eod}) - B_i(t)) & \text{if } B_i(t_{eod}) < 0 \\ \max(0, -B_i(t)) & \text{if } B_i(t_{eod}) \geq 0 \end{cases}$$

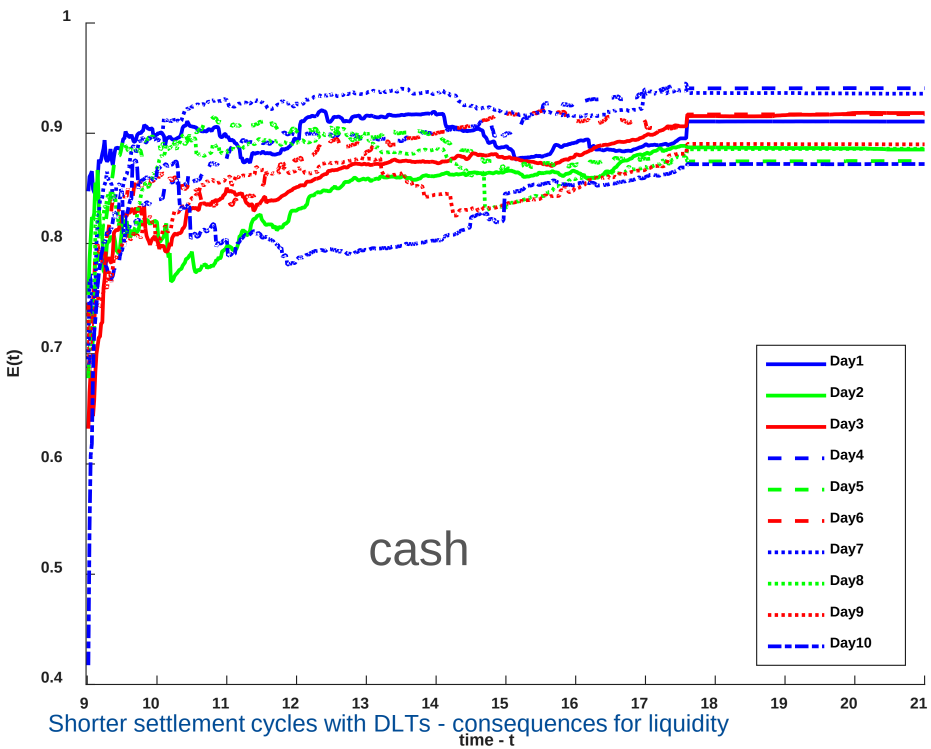
- $L_i^{(2)}(t)$ measures need of liquidity during day: $L_i^{(2)}(t) = \max(0, -B_i(t))$
- Two examples with

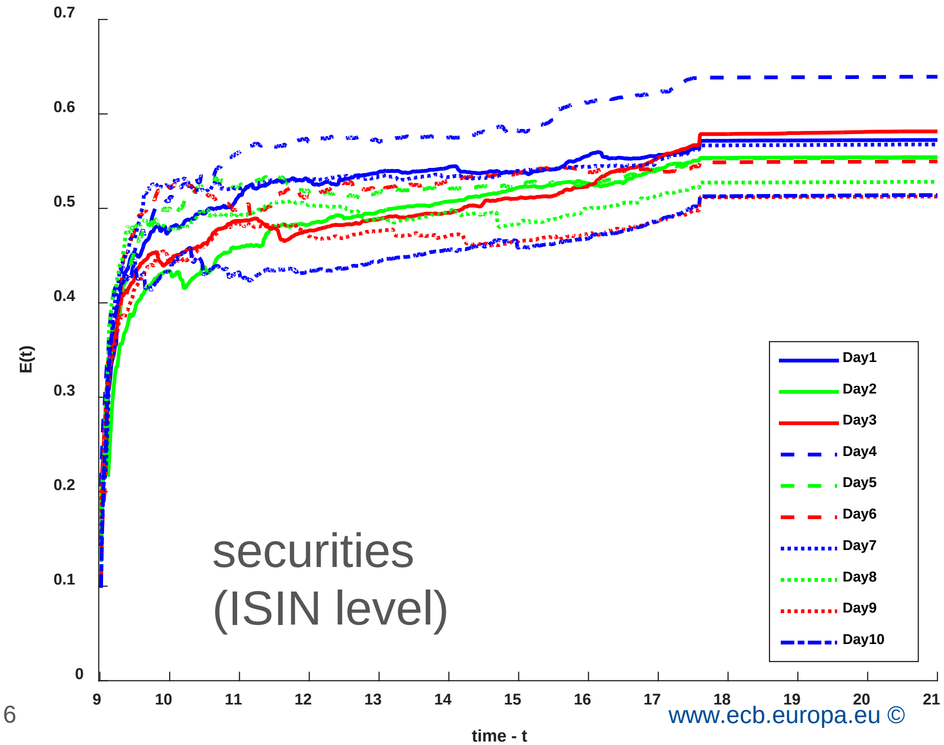




Netting efficiency of the system

- Efficiency of liquidity use is measured as: $E(t) = 1 - \frac{\sum_{i=1}^{N_{ctp}} L_i^{(2)}(t)}{\sum_{i=1}^{N_{ctp}} D_i(t)}$
- E(t)=1 means perfect netting
- E(t)=0 means liquidity needed equals the sum of all transactions





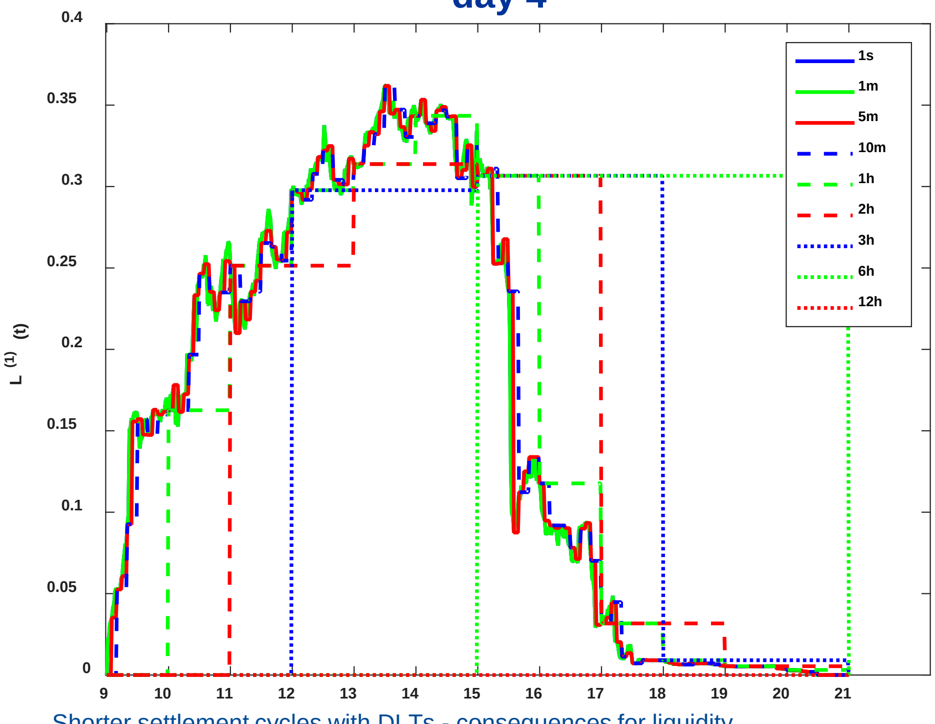
System intraday liquidity needs 1/2

- Additional liquidity need with respect to EOD settlement is

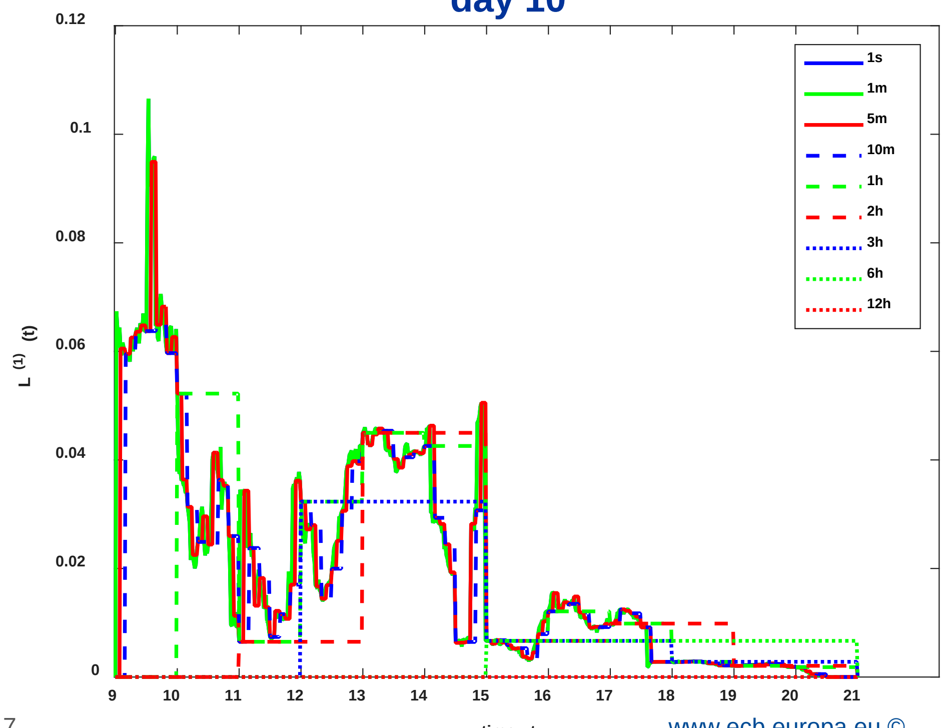
$$L^{(1)}(t) = \frac{\sum_{i=1}^{N_{ctp}} L_i^{(1)}(t)}{L_{tot}} \quad \text{where} \quad L_{tot} = \sum_{i=1}^{N_{ctp}} L_i^{(2)}(t_{eod})$$

The graphs below plot $L^{(1)}(t)$ for cash accounts with different intraday cycles:

day 4



day 10

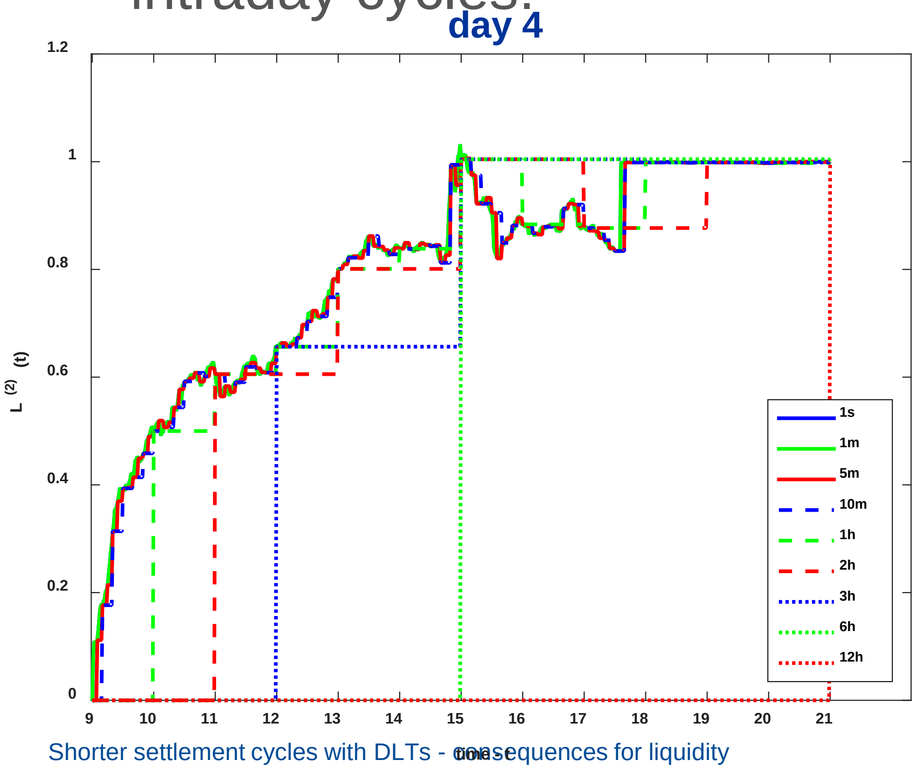


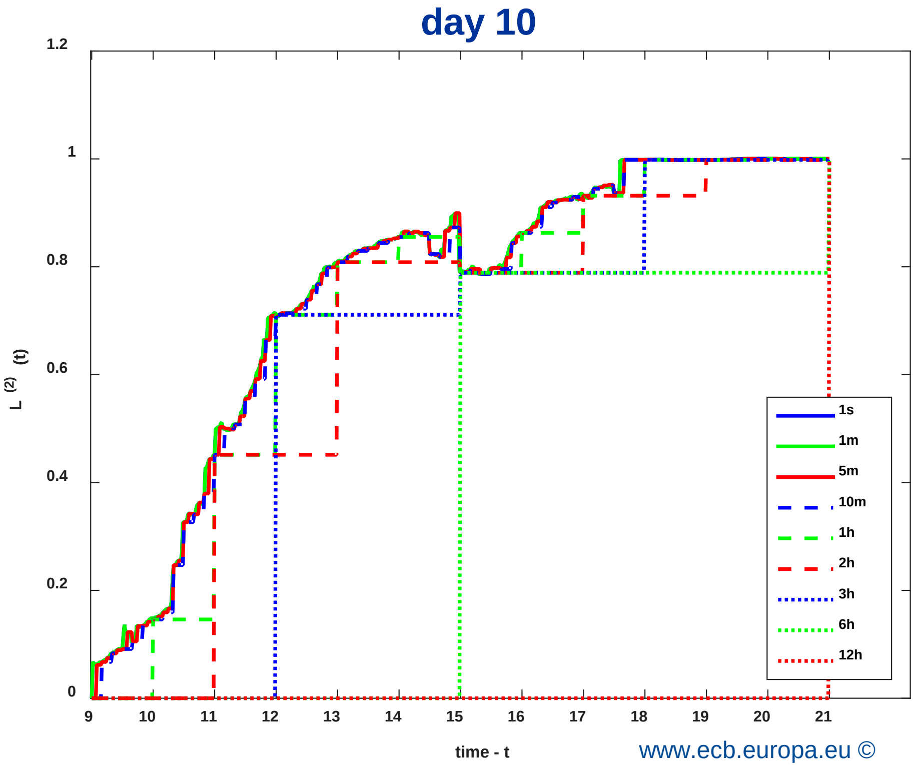
System intraday liquidity needs 2/2

- Portion of EOD liquidity need required over time

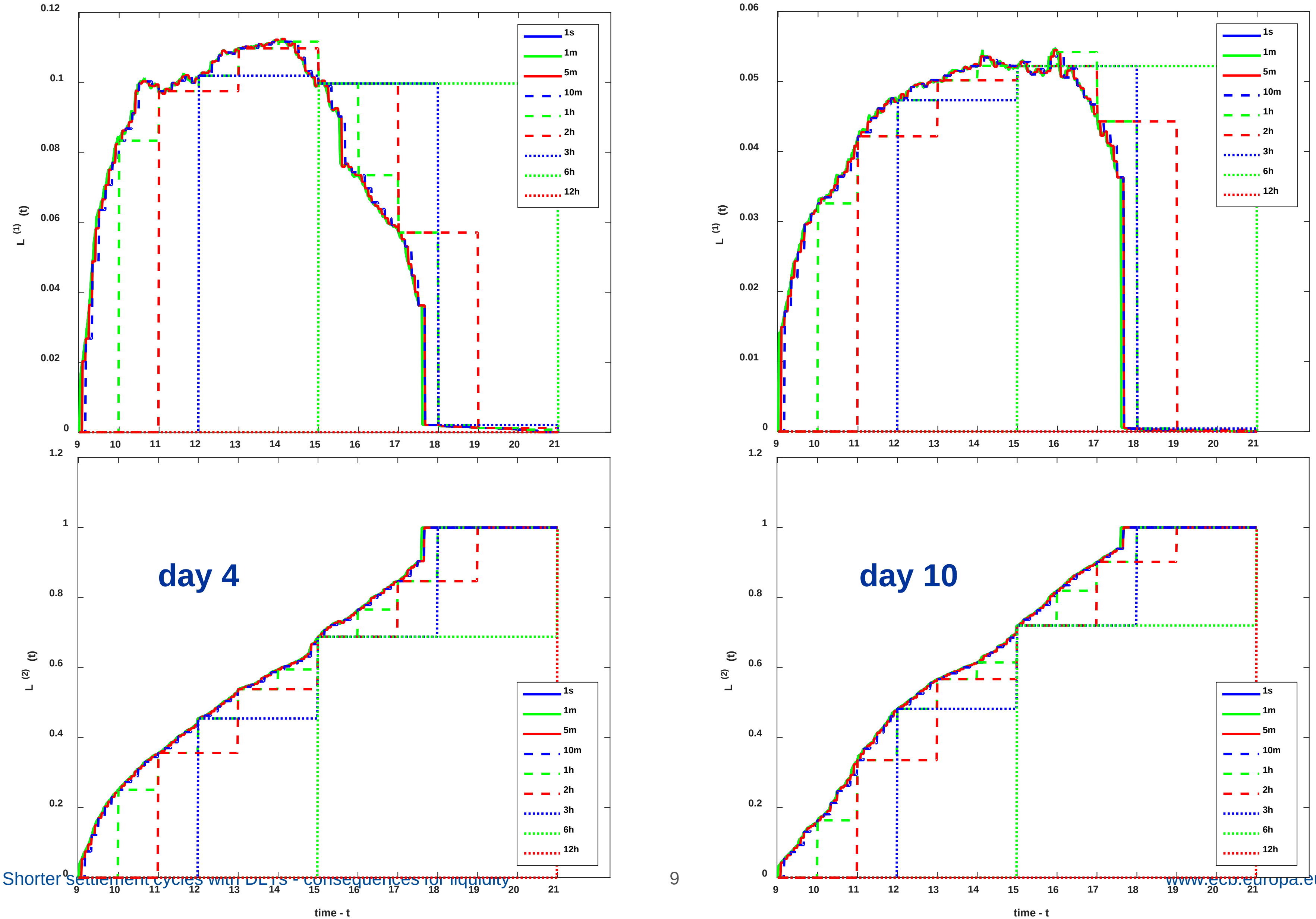
$$L^{(2)}(t) = \frac{\sum_{i=1}^{N_{ctp}} L_i^{(2)}(t)}{L_{tot}}$$

- The graphs below plot $L^{(2)}(t)$ for cash accounts with different intraday cycles:





For securities accounts



Definitions

System level

$$\tilde{L}^{(1)}_{max} = \max_t [L^{(1)}(t)]$$

$$\tilde{L}^{(2)}_{max} = \max_t [L^{(2)}(t)]$$

Participant level

$$L^{(1)}_{i,max} = \max_t [L^{(1)}_i(t)]$$

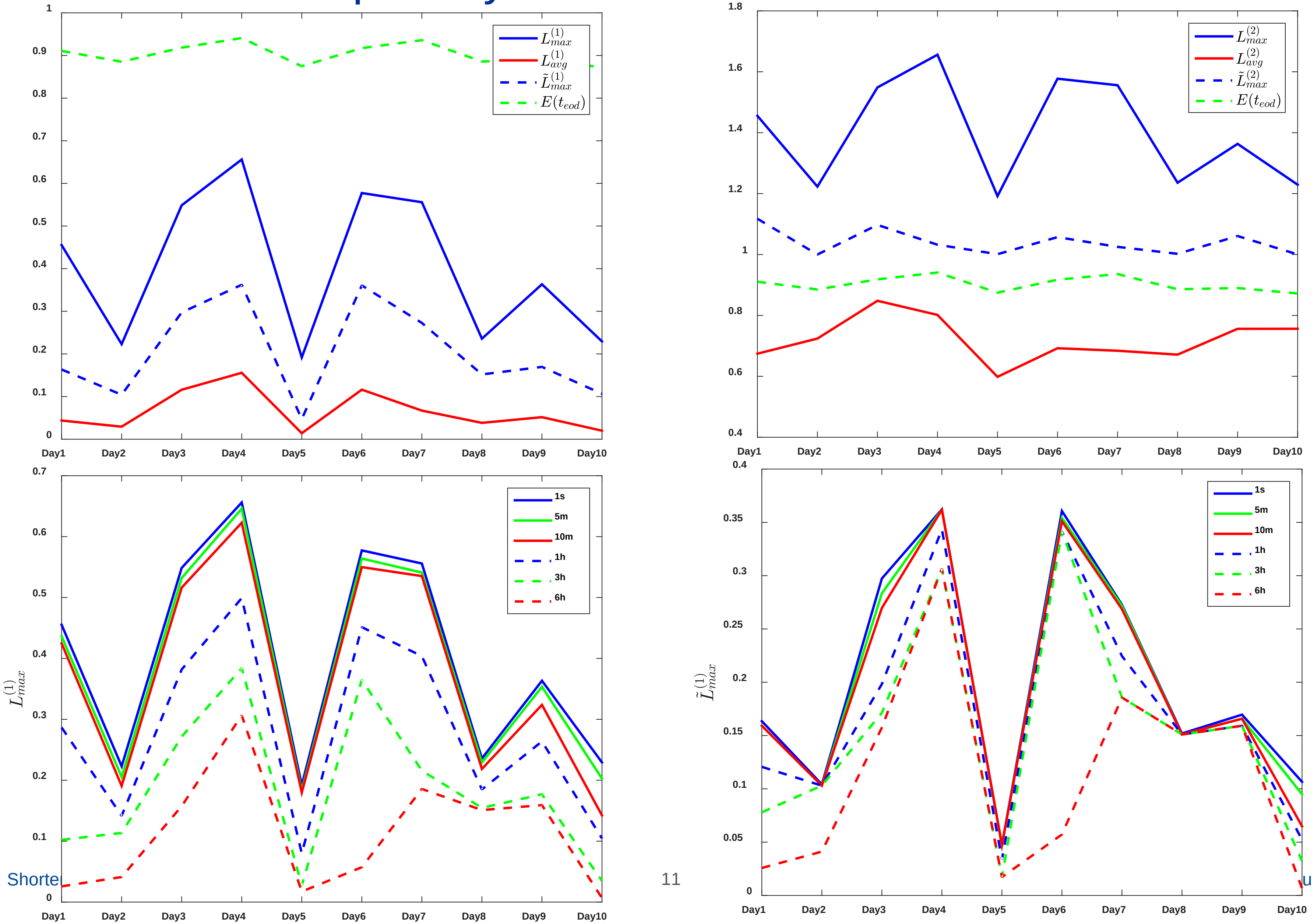
$$L^{(2)}_{i,max} = \max_t [L^{(2)}_i(t)]$$

$$L^{(1)}_{max} = \frac{\sum_{i=1}^{N_{ctp}} L^{(1)}_{i,max}}{L_{tot}}$$

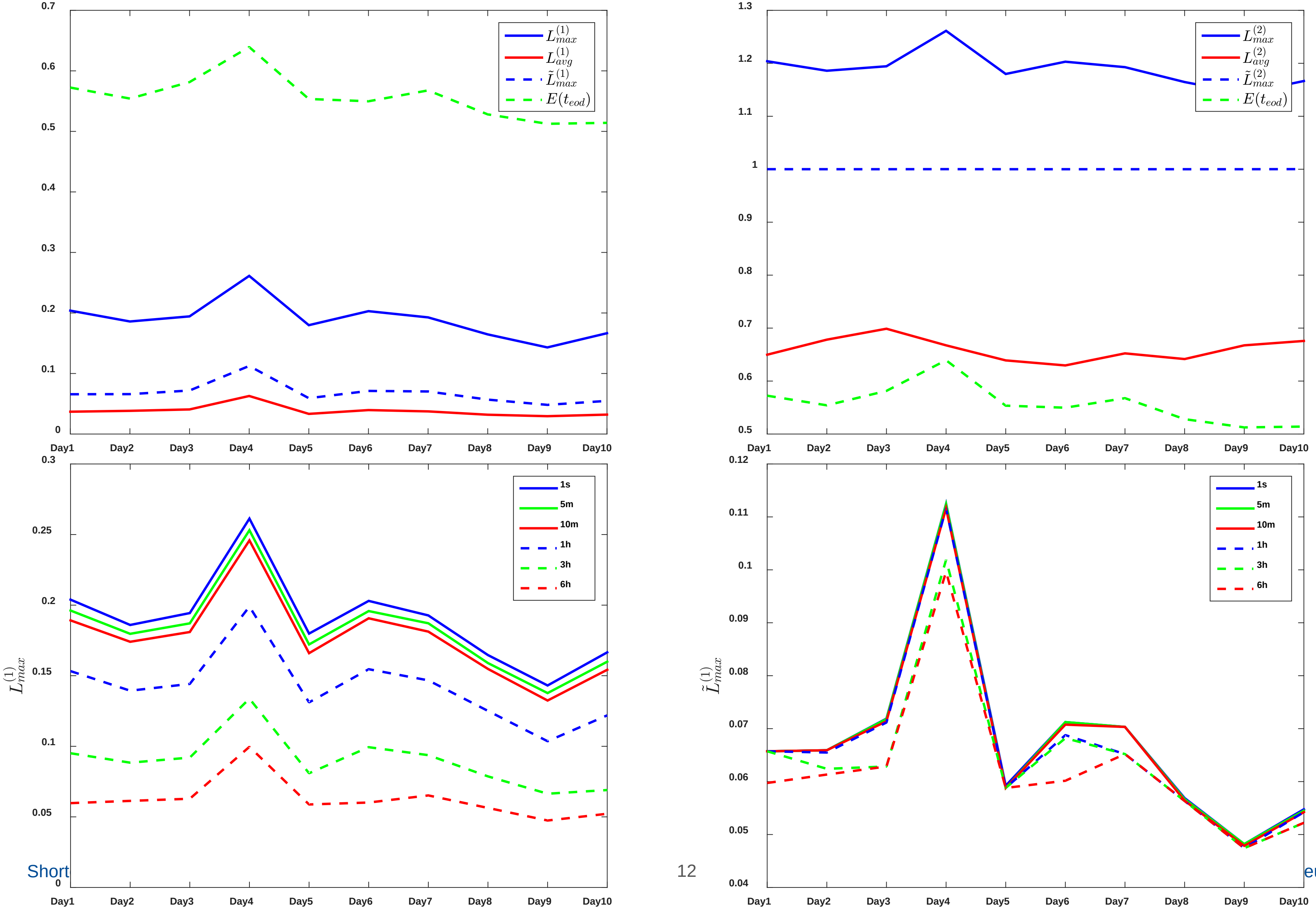
$$L^{(2)}_{max} = \frac{\sum_{i=1}^{N_{ctp}} L^{(2)}_{i,max}}{L_{tot}}$$

- Extra liquidity that has to be injected in the system to allow real-time settlement
- Extra liquidity that has to be in the counterparties accounts in different moment in time.
- $L^{(1)}_{avg}$ and $L^{(2)}_{avg}$ can be defined in the same way.

Cash extra liquidity needs



Securities extra liquidity needs



Definitions

- We want to understand how the additional liquidity is distributed amongst the participants.
- We define a concentration index that is 0 when the additional liquidity is concentrated in one participant and 1 when it is equally shared between participants
- "Pure" indicator vs weighted indicators

$$H(\bar{f}) = -\frac{1}{\log(N_{ctp})} \sum_{i=1}^{N_{ctp}} f_i \log(f_i)$$

$$f_i^a = L_{i,max}^{(1)} / \sum_{i=1}^{N_{ctp}} L_{i,max}^{(1)}$$

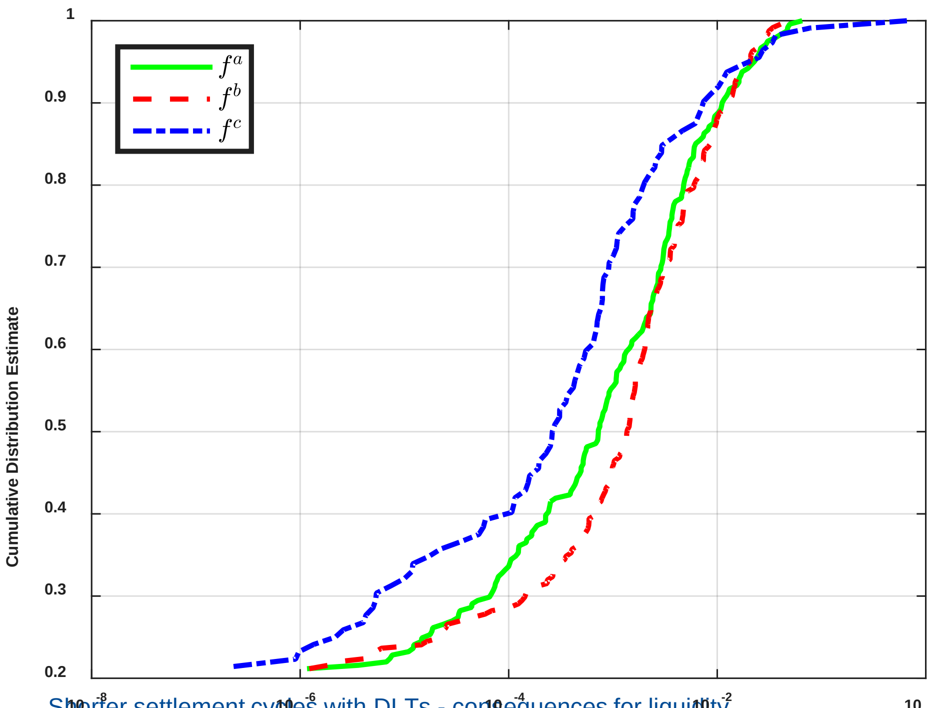
$$f_i^b = \frac{L_{i,max}^{(1)}}{\sum L_{i,max}^{(1)}} \cdot \frac{\sum D_i(t_{eod})}{D_i(t_{eod})}$$

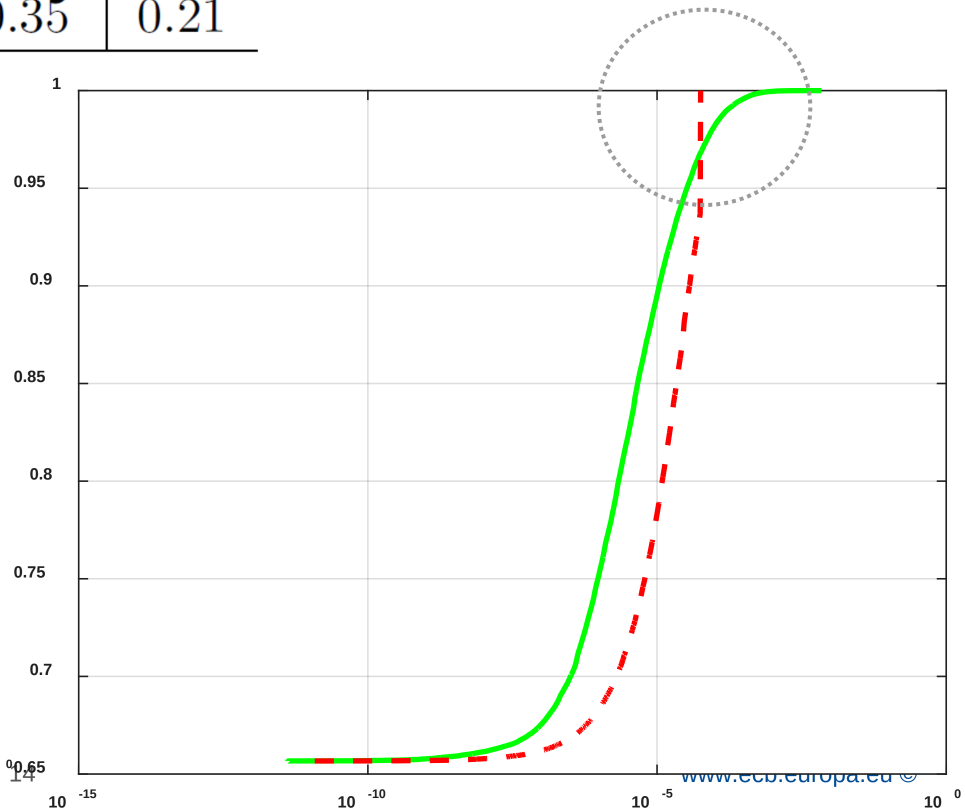
$$f_i^c = \frac{L_{i,max}^{(1)}}{\sum L_{i,max}^{(1)}} \cdot \frac{\sum L_i^{(2)}(t_{eod})}{L_i^{(2)}(t_{eod})}$$

Cumulative distribution

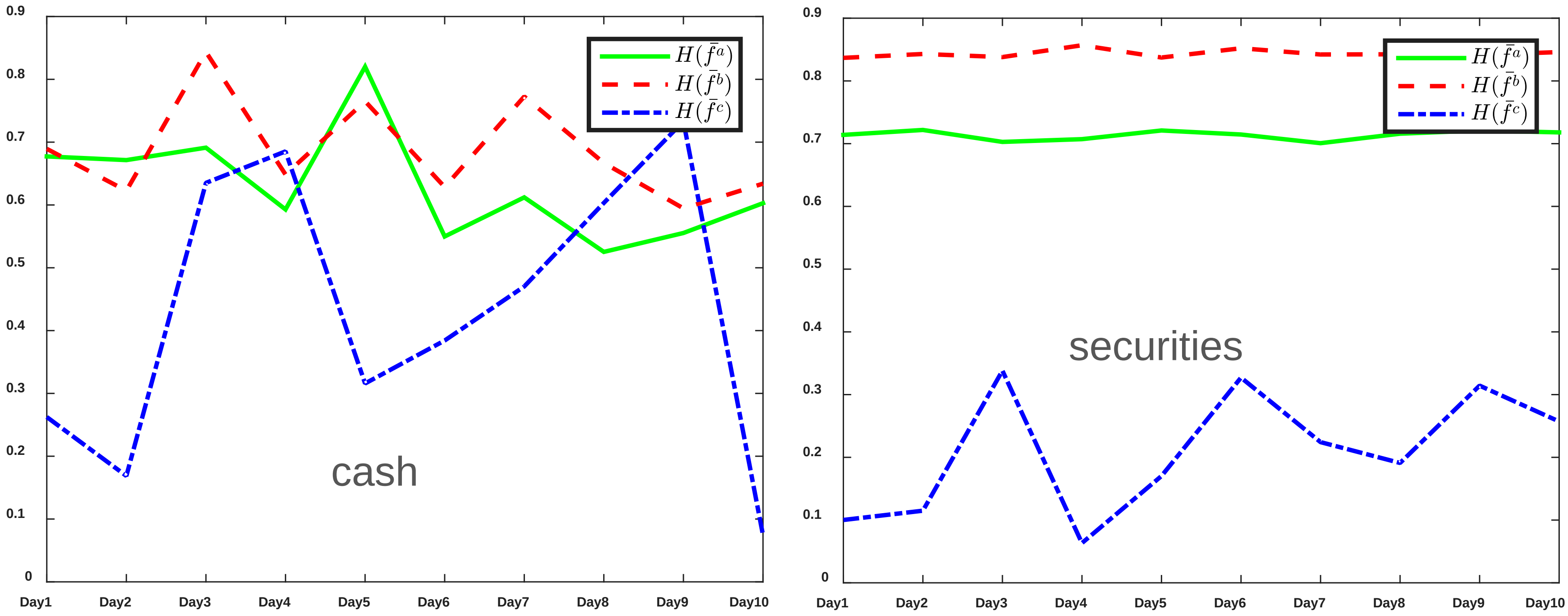
- Cumulative distribution function of the three indicators components (f^a_i,f^b_i,f^c_i)

	cash	sec
$H(f^a)$	0.77	0.77
$H(f^b)$	0.81	0.87
$H(f^c)$	0.35	0.21



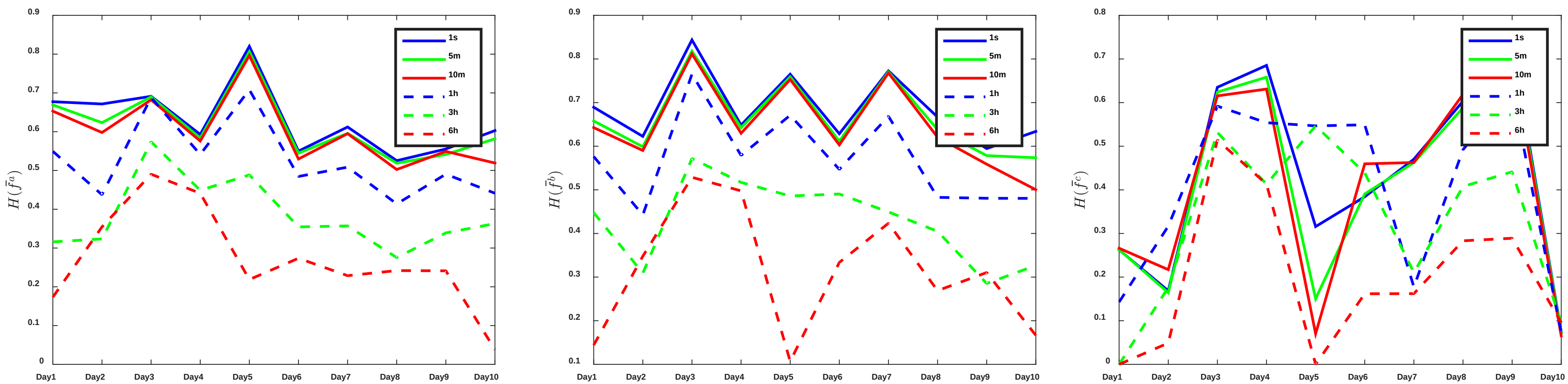


Comparison across asset classes

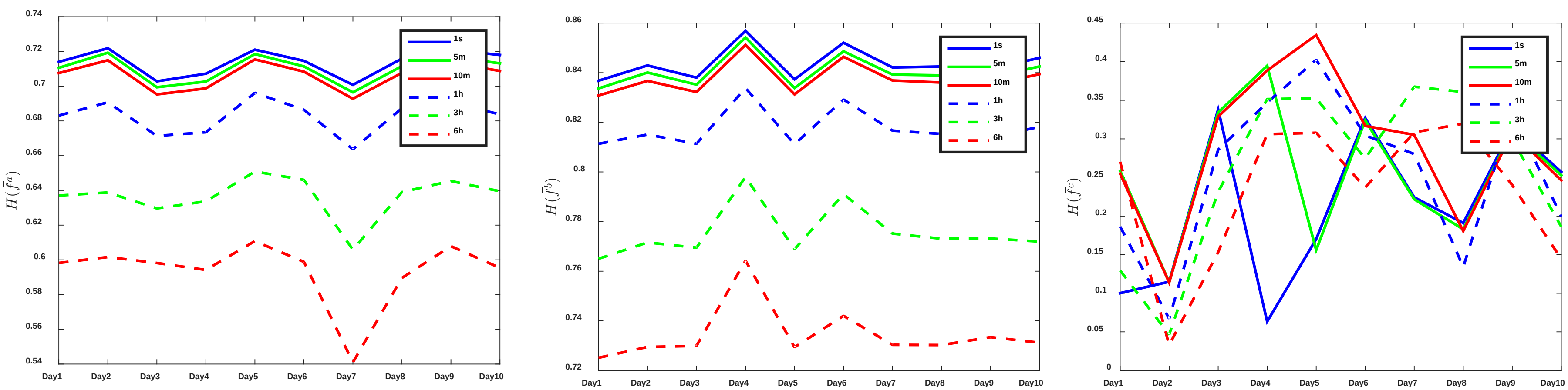


Comparison across intraday cycles

CASH



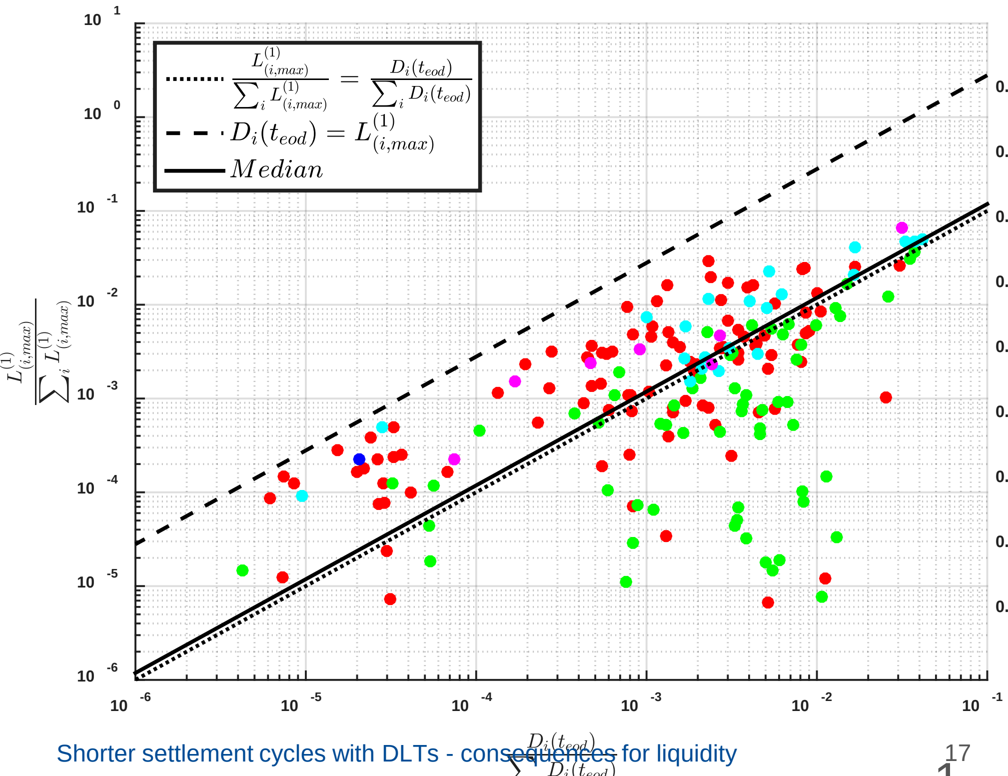
SECURITIES

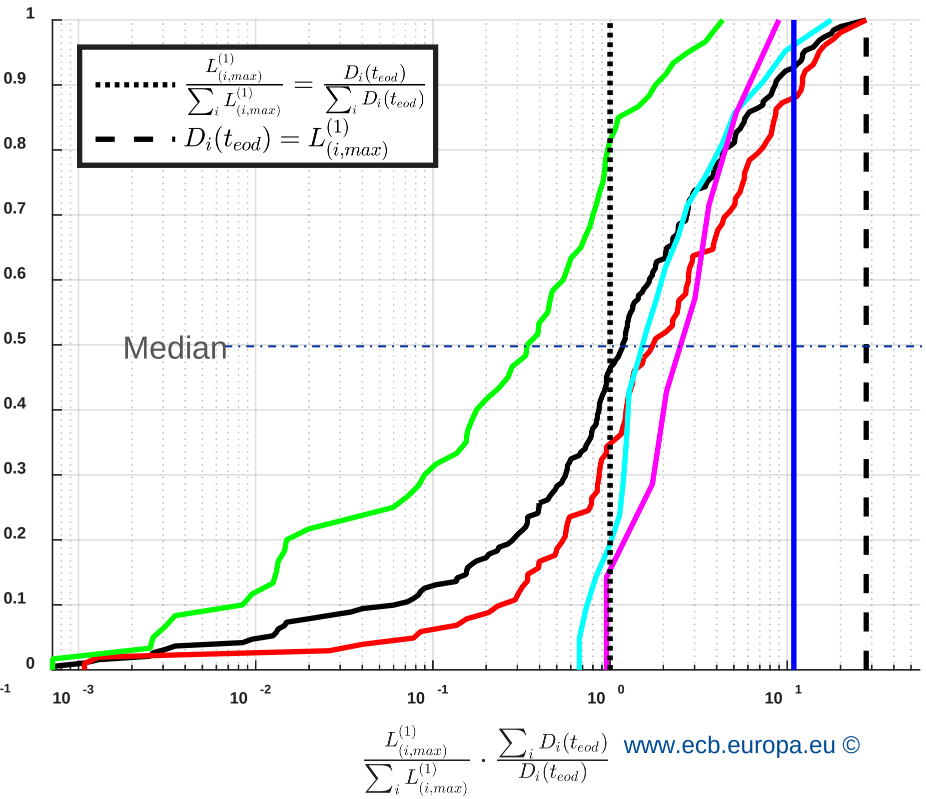


Cash

$L^{(1)}_{i,max} > 0$

		cash	sec	cash	sec
	$L^{(1)}_{i,max} = 0$	20.8%	65.7%		
● (green)	$L^{(1)}_{i,max} \leq L^{(2)}_i(t_{eod})$	24.9%	5.5%	31.4%	15.9%
● (cyan)	$L^{(2)}_i(t_{eod}) < L^{(1)}_{i,max} \leq 10 \cdot L^{(2)}_i(t_{eod})$	8.7%	6.5%	11.0%	19.0%
● (magenta)	$10 \cdot L^{(2)}_i(t_{eod}) < L^{(1)}_{i,max} \leq 100 \cdot L^{(2)}_i(t_{eod})$	2.9%	2.6%	3.7%	7.6%
● (blue)	$L^{(1)}_{i,max} > 100 \cdot L^{(2)}_i(t_{eod})$	0.4%	1.4%	0.5%	4.1%
● (red)	$L^{(2)}_i(t_{eod}) = 0$	42.3%	18.3%	53.4%	53.4%





Securities

		cash	sec	cash	sec
	$L_{i,max}^{(1)} = 0$	20.8%	65.7%		
● (green)	$L_{i,max}^{(1)} \leq L_i^{(2)}(t_{eod})$	24.9%	5.5%	31.4%	15.9%
● (cyan)	$L_i^{(2)}(t_{eod}) < L_{i,max}^{(1)} \leq 10 \cdot L_i^{(2)}(t_{eod})$	8.7%	6.5%	11.0%	19.0%
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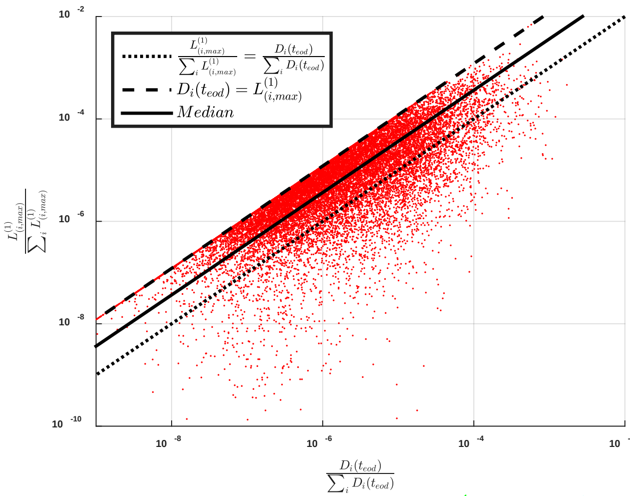
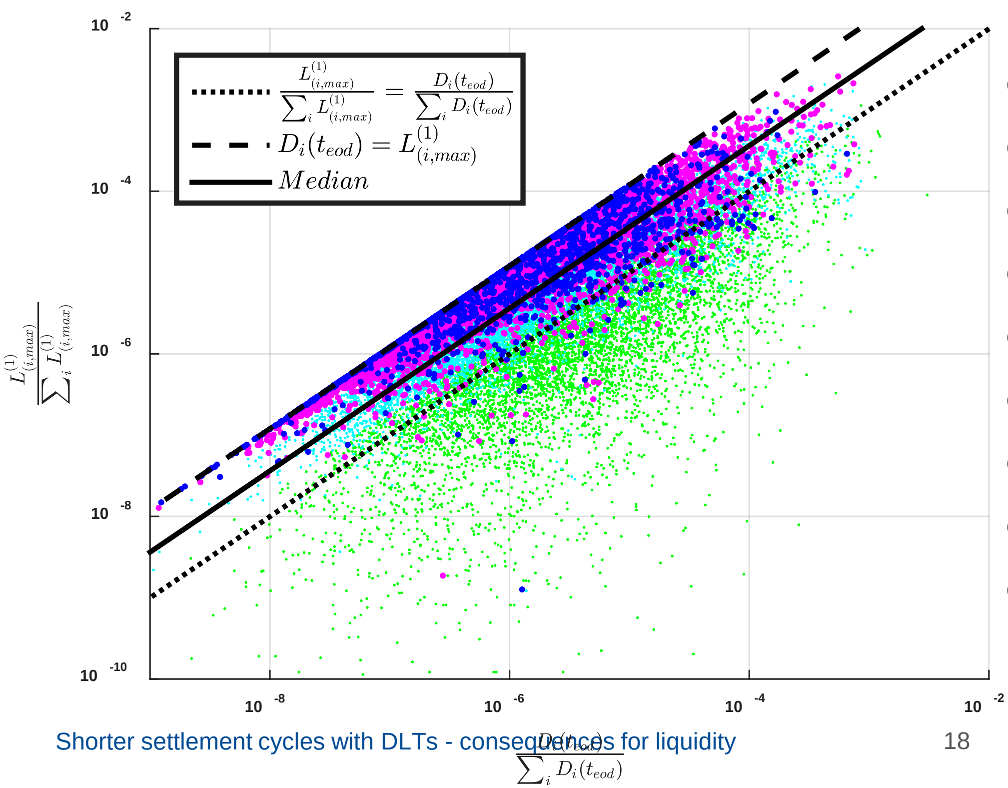
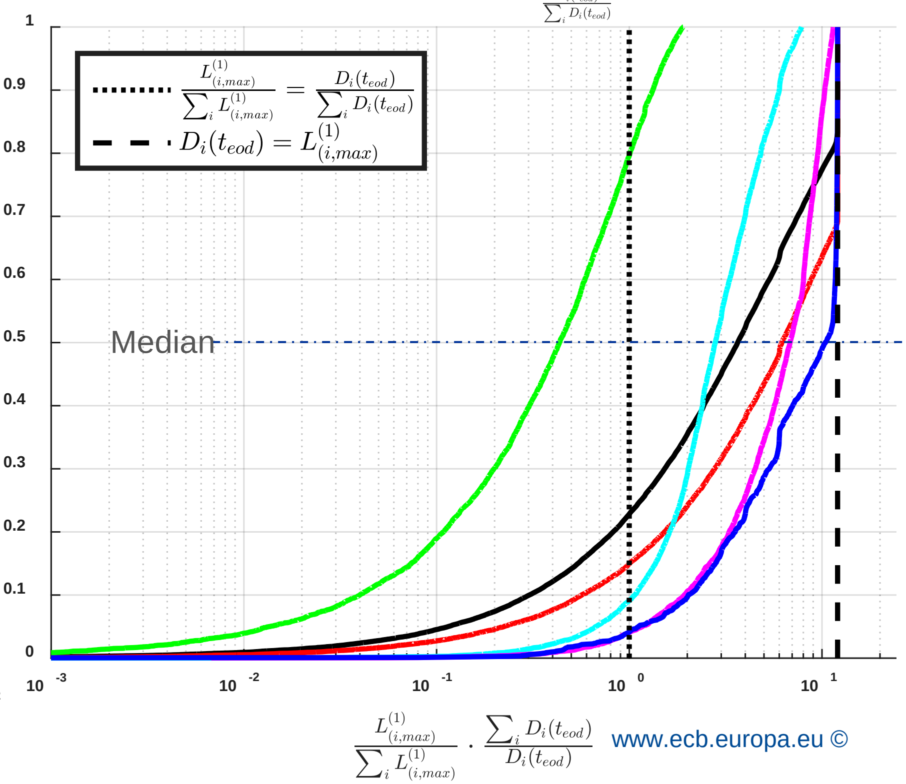






7. Conclusions and further work

- A DLT is a set of tools for recording data, possibly asset holdings or financial transactions data, with no need to interface centralised systems. Its adoption could facilitate straight-through processing.
- We developed an analytical framework to understand the impact that the shortening of settlement cycle to intraday has on the liquidity needs of the system and of participants.
- The methodology has been applied to the dataset of transactions from the Italian stock exchange.
- Results show that in the analysed market, the impact of shortening the settlement cycle is limited at the system level, but at participant level the impact can be higher:
  - On average the impact on participants is not concentrated in few participants and it is distributed homogeneously in participants with all level of debits.
  - However, for participants with low end-of-day liquidity, the extra liquidity is concentrated in few of them.
- Extend the work to different datasets and across days.

Appendix – Generalisation formulas

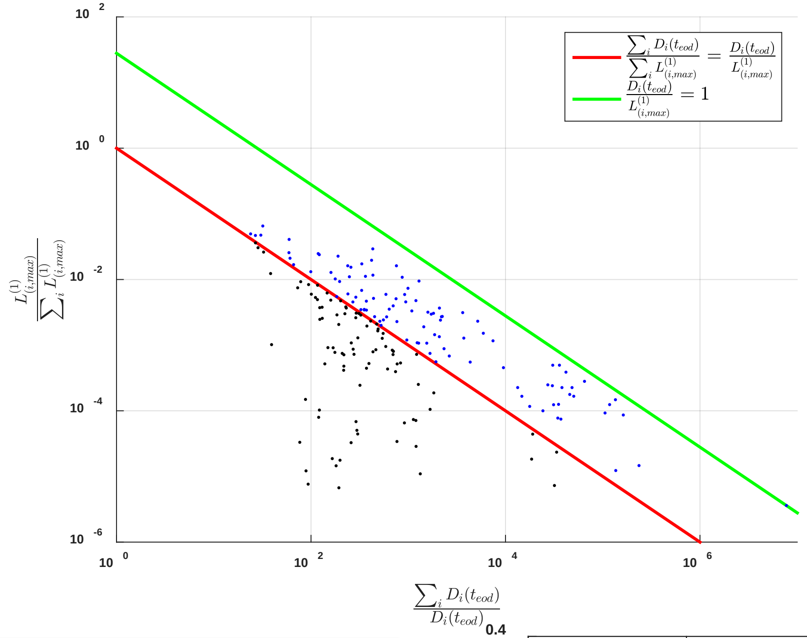
- Equations can be generalised to the case of a discrete number of settlement cycles by sampling the continuous time balances $B_i(t)$ at the instant the settlement cycles would take place.
- Assuming N cycles equally distributed during the day the balance in time is given by:

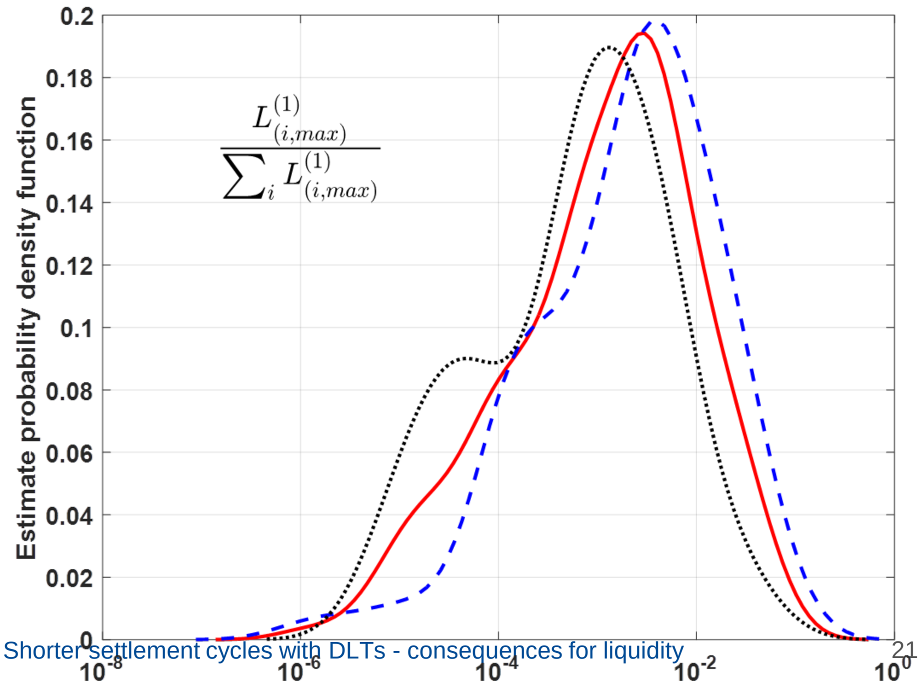
$$B_i^N(t) = \sum_{k=1}^{N} b_{i,k} \cdot rect((t - t_0)/\tau - k + 1/2)$$

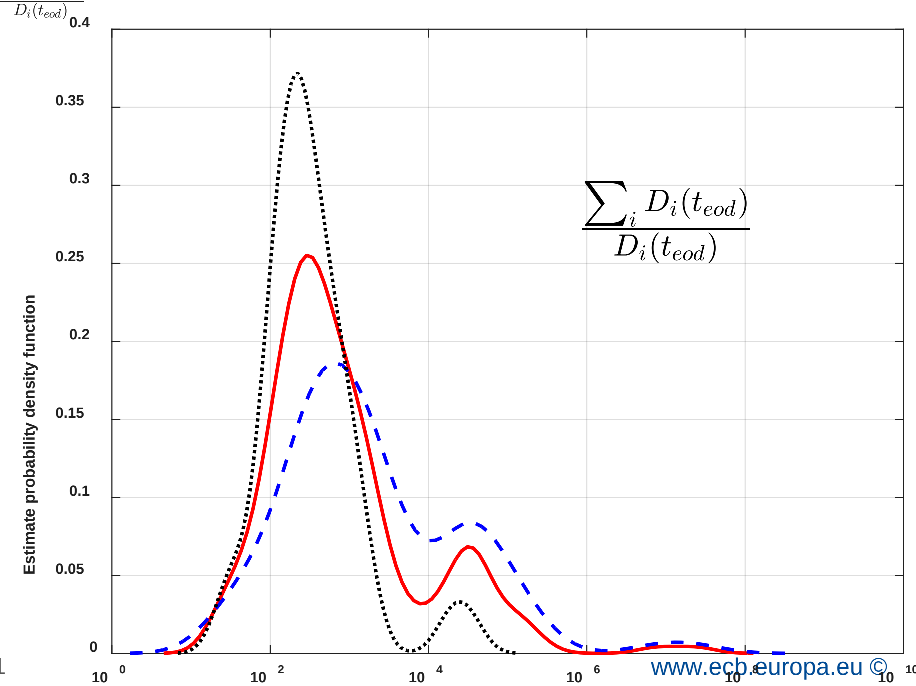
where $\quad b_{i,k} = B_i(t) \cdot \delta(t - k\tau) \quad$ and $\quad \tau = (t_{eod} - t_0)/N$

- The other equations can be derived from $B_i^N(t)$.

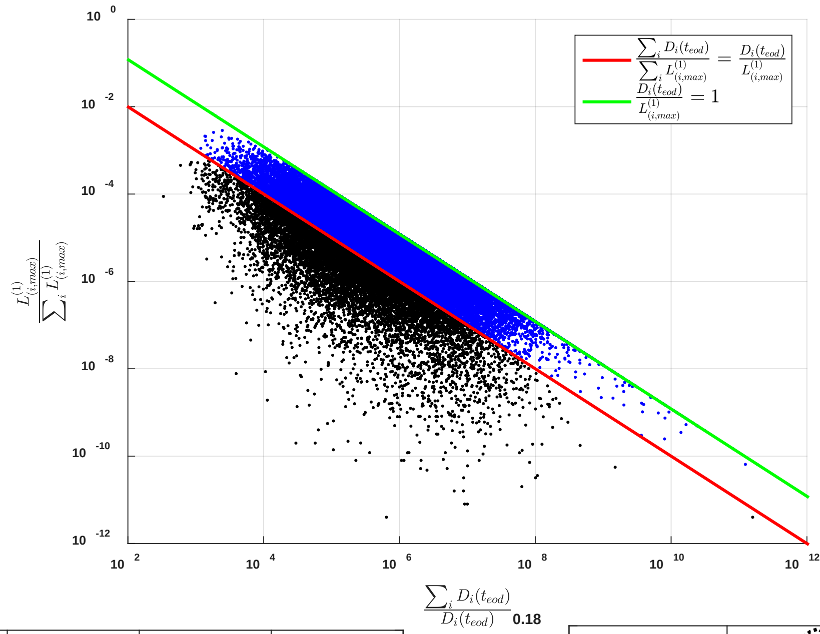
Cash

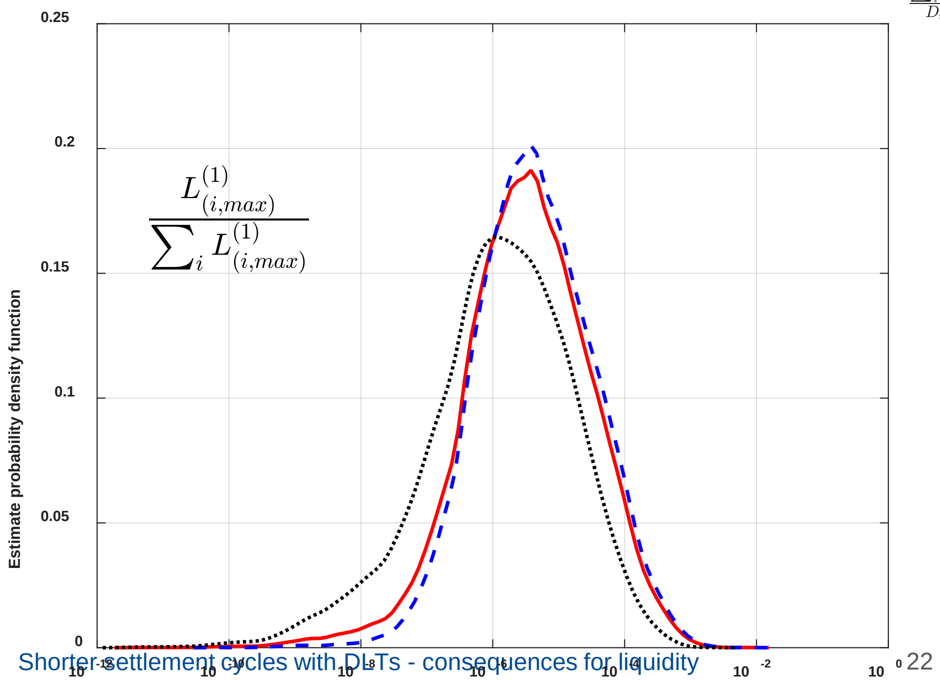

$\frac{\sum_i D_i(t_{eod})}{\sum_i L^{(1)}_{(i,max)}} = \frac{D_i(t_{eod})}{L^{(1)}_{(i,max)}}$
$\frac{D_i(t_{eod})}{L^{(1)}_{(i,max)}} = 1$
$\frac{L^{(1)}_{(i,max)}}{\sum_i L^{(1)}_{(i,max)}}$
$\frac{\sum_i D_i(t_{eod})}{D_i(t_{eod})}$

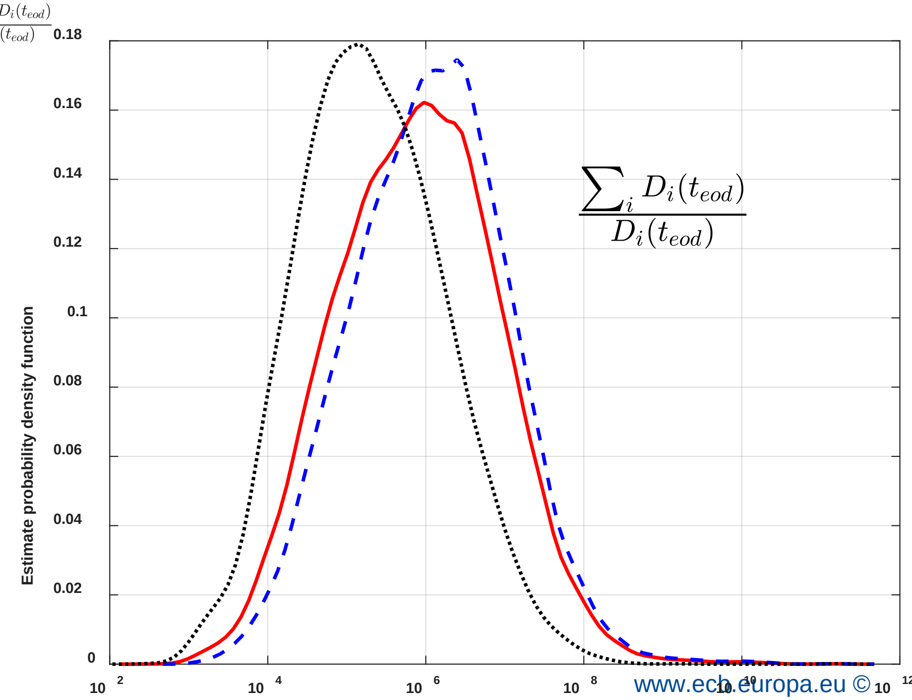

Estimate probability density function
$\frac{L^{(1)}_{(i,max)}}{\sum_i L^{(1)}_{(i,max)}}$

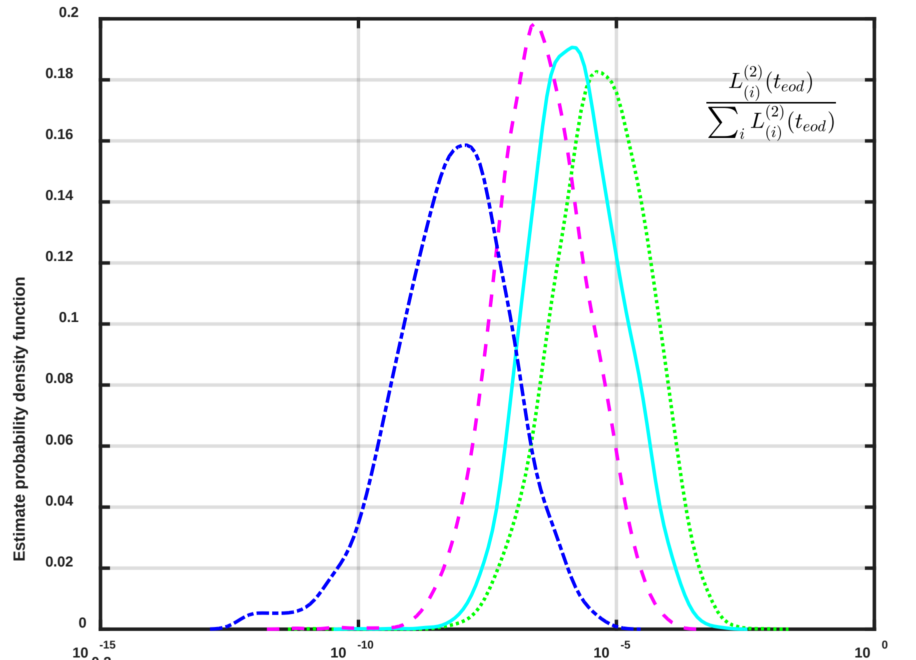

Estimate probability density function
$\frac{\sum_i D_i(t_{eod})}{D_i(t_{eod})}$

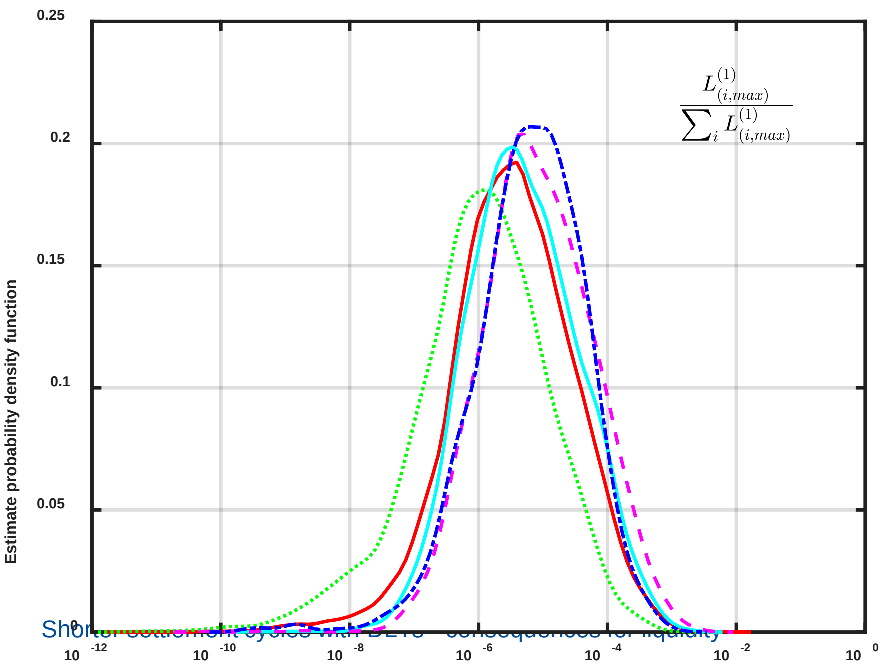
Securities

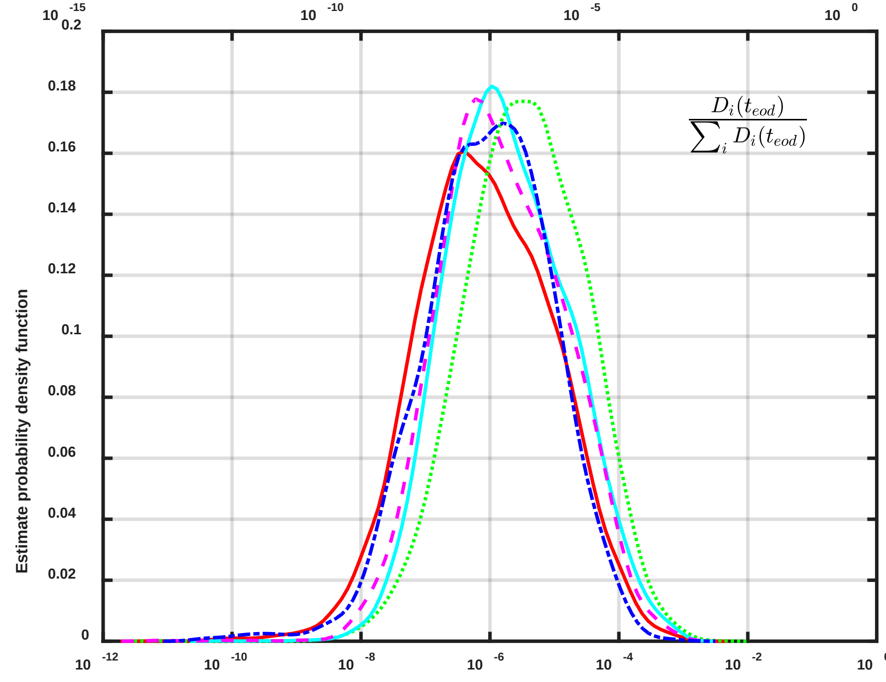

$\frac{\sum_i D_i(t_{eod})}{\sum_i L^{(1)}_{(i,max)}} = \frac{D_i(t_{eod})}{L^{(1)}_{(i,max)}}$
$\frac{D_i(t_{eod})}{L^{(1)}_{(i,max)}} = 1$
$\frac{L^{(1)}_{(i,max)}}{\sum_i L^{(1)}_{(i,max)}}$
$\frac{\sum_i D_i(t_{eod})}{D_i(t_{eod})}$


Estimate probability density function
$\frac{L^{(1)}_{(i,max)}}{\sum_i L^{(1)}_{(i,max)}}$


Estimate probability density function
$\frac{\sum_i D_i(t_{eod})}{D_i(t_{eod})}$


Estimate probability density function
$\frac{L^{(2)}_{(i)}(t_{eod})}{\sum_i L^{(2)}_{(i)}(t_{eod})}$
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
10^{-15}
10^{-10}
10^{-5}
10^{0}


Estimate probability density function
$\frac{L^{(1)}_{(i,max)}}{\sum_i L^{(1)}_{(i,max)}}$
0
0.05
0.1
0.15
0.2
0.25
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10^{0}


Estimate probability density function
$\frac{D_i(t_{eod})}{\sum_i D_i(t_{eod})}$
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}