DEUTSCHE BUNDESBANK
EUROSYSTEM

Measuring Free-Riding in LVPS

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BIS workshop on monitoring indicators, Basle, 9 October 2012

Agenda

1. The concept of free-riding in payment systems. Or: Is liquidity a public good?
2. Epistemological postulates for measurement
3. Empirical measures
    a) Cost-based measure of Denbee et al.
    b) Risk-based measure of Denbee et al.
    c) Time-based measure
    d) Early payment indicator
    e) Relative net-sending indicator
4. Comparing the various measures
5. Economic interpretation

Concept of free riding in payment systems (1)

- payment economics deals with the smooth flow of liquidity
- banks rely heavily on incoming funds / liquidity efficiency easily reaches double digit values
- liquidity is costly, a bank may attempt to reserve liquidity
  - higher uncertainty provides incentives to postpone payments
  - rationale for the liquidity manager of a commercial bank
    - have a buffer for possible liquidity-shocks
    - limit bi- or multilateral outstanding claims and to reduce liquidity risk in case of a failure.
- reaction of the operators of LVPS is two-fold:
  - some operators introduced liquidity-saving mechanisms into their RTGS
  - some have implemented institutional features to induce early payment
- operators of a LVPS need to measure the degree of strategic free-riding

Concept of free riding in payment systems (2)

- Denbee/Garratt/Zimmermann at the Bank of Finland 8th Simulator Seminar in 2010
  - construct two measures and provide indicators for free-riding in CHAPS
  - simulate CHAPS / compare the measures after randomly rearranging the sequence
  - conclude: *"Therefore strategic delay and urgent payments do not appear to be a problem for liquidity at a system-wide level. However, at the level of individual settlement banks there may still be apparent inequitable distributions of liquidity usage."*
- This research follows the initiative of Denbee/Garratt/Zimmermann (2010)
  - develops various measures of free-riding in LVPS
  - works for better understanding of the level of free-riding
  - and the necessity of operators' intervention
  - data shed some insights on payment behaviour of the participants.
- translation of the theoretical concept of free-riding into a single numerical figure is not at all simple or unambiguous

Concept of free riding in payment systems (3)

- Mancur Olson defined as a free-rider someone who benefits from a collective activity without participating in it
- liquidity itself cannot be called a public good
  - right to exclude
  - subject to rivalry
- the level of liquidity used in a payment system at an early time in the business day has positive external effects
  - someone who pays early, contributes positively to the common good “early liquidity”
- quick reuse of incoming payments would produce external effects
  - someone who withholds large amounts of incoming liquidity produces negative external effects
- Therefore: deliberate late payers and deliberate holder of large liquidity pools may be free-riders

Concept of free riding in payment systems (4)

- Two problems occur
  - define clearly what is “relatively” late and “withholding large amounts”
  - condition of “everything else constant” creates some pitfalls
    - distribution of the “natural” payment times is from the view of the system operator not observable
    - perceived credibility. A bank with a high credibility may not be subject to so many limit restrictions by others

- after measuring free-riding the possible reasons for the outcome have still to be explored before using the label “free-rider”.

Epistemological postulates for liquidity measures (1)

- Postulate of scale-invariance:
  - The measure should be scale-invariant as to the value and volume of the respective LVPS and to the value and volume of the participant in question. The measurement should not differ if the sum of transferred values or the number of submitted payments is multiplied by any constant.
- Postulate of participant-invariance:
  - The measure should be invariant as to the number of participants of the LVPS and the number of participants included in the measurement.
- Postulate of institution-invariance:
  - The measure should be invariant as to the institutional setting of the LVPS in question to enable a cross-LVPS comparison.
- Anonymity-principle
- Transfer-principle:
  - The measure should be reactive as to any transfer in timing. For operational reasons this may in practice not hold for any shift of a payment value below a threshold to be defined over a period shorter than a time-span to be defined.

Epistemological postulates for liquidity measures (2)

- Relevance-principle:
  - The measure should concentrate on the payments potentially under influence of decisions of the participants.
- Postulate of full coverage:
  - The measure should be defined for the full range of possible payment behaviours and payment-network features, i.e. it should be invariant as to questions whether the participant is a net-sender or net-receiver on that day, whether the participant has many or just a few links, whether the system has many or only a few ancillary systems etc.
- Postulate of ordinal or ratio scale:
  - The measure should at least result in an ordinal scale, preferably in a ratio scale such that further econometric studies with the result are possible.
- Postulate of true measurement:
  - The measures should be free of any technically implied jumps in value.
- Postulate of operability

Empirical measures

- data description
- real data of TARGET2-BBK
- measures of free-riding were calculated for 10 participants in the national component of TARGET2-BBK
- calculated on a daily basis for the period from November 2007 through March 2012
- relevant time-band is defined as one minute: total number of 660 time-bands is taken into account
- time-span of one minute is shorter than the time necessary for manual interference of a payment manager with the objective to manipulate the sequence of payments
- random calculation: simulation of measures by randomly rearranging the sequences

Empirical measures: Cost-based measure of Denbee et alii

- liquidity provision for bank i is the largest net debit position during the day, L_i

$$L_i = max_t \left[\sum_{s=0}^{t} \left(x_{i,s}^{sent} - x_{i,s}^{rec} \right) \right]$$

- If the bank was a net receiver, i.e. $L_i < 0$, it would be assigned a value of 0.
- L_i represents the cost burden of bank i for payments, since it reflects the largest net debit position equaling the maximum amount of own liquidity of bank i used for payments on that day.
- definition of a free-rider as a bank that uses a larger share of liquidity than it provides.

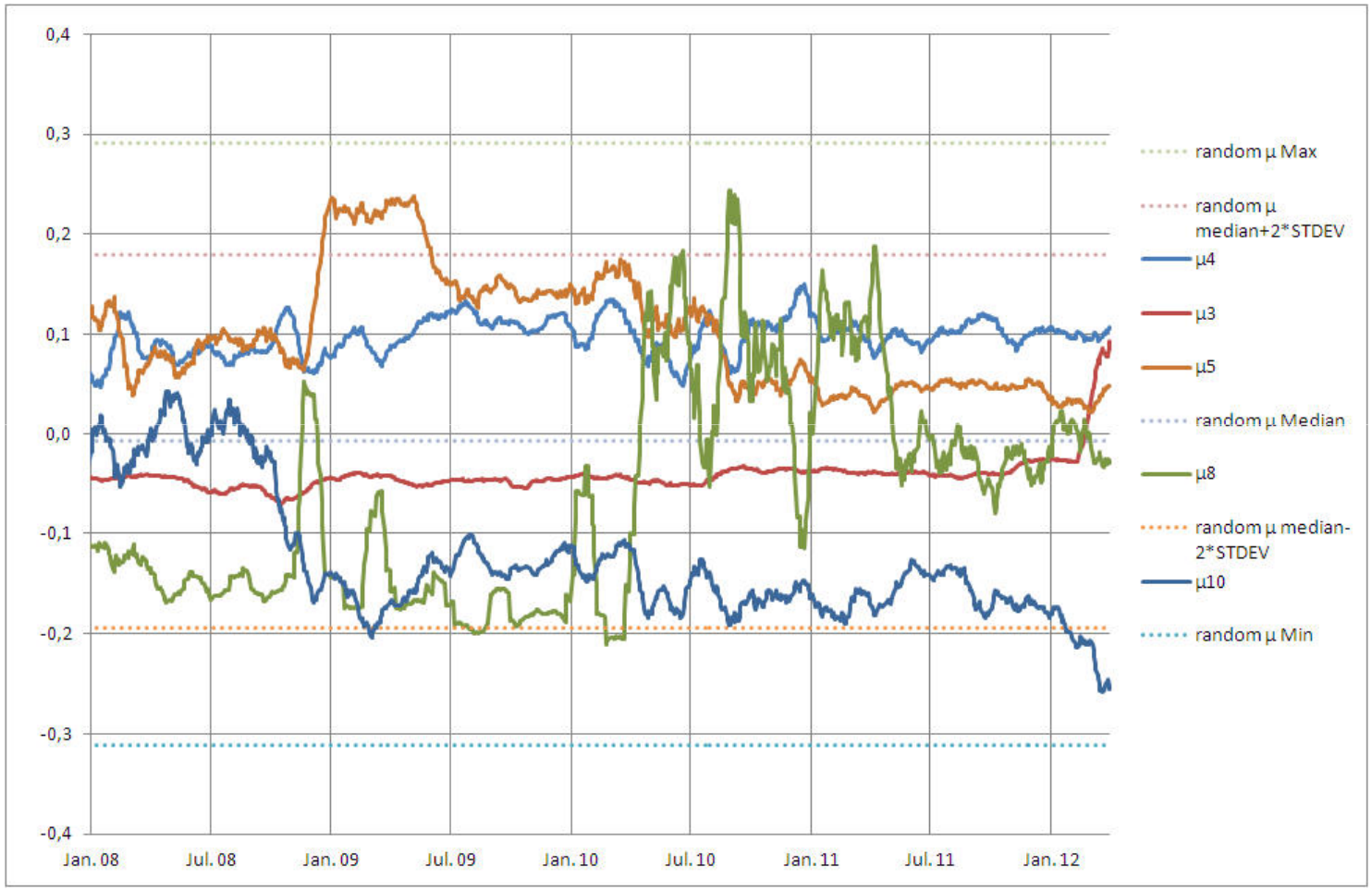
$$\mu_i = \frac{L_i}{\sum_{i=1}^{n} L_i} - \frac{P_i}{\sum_{i=1}^{n} P_i}$$

- values range from -1 (one bank made almost all payments but provided almost no liquidity) to 1 (one bank provided almost all liquidity but made almost no payments).
- Whenever $\mu_i < 0$ Denbee/Garratt/Zimmermann call bank i a free-rider.

Empirical measures: Cost-based measure of Denbee et alii

- cost-based measure fulfills most of the given postulates, but clearly not all
- transfer-principle is not met since any significant transfer in timing changes the measure only if it affects the maximum net debit position
- The principle of full coverage is violated since the measure is only defined for banks which are net sender on that day.
- In addition, the technical jump, incurred by the definition of $L_i=0$ for net receivers is a violation against the postulate of true measurement.
- The measure implies more technical jumps if not all participants are taken into calculation.
- However, once not all participants are taken into account μ_i will be different for different n.
- Therefore, the postulate of participant-invariance is also violated unless one provides a full coverage of all participants.

Empirical measures: Cost-based measure of Denbee et alii



Empirical measures: Risk-based measure of Denbee et alii

- According to Denbee/Garratt/Zimmermann (2010) the total risk, τ, is defined as the sum of all average positions when a bank is a net sender.

$$N_{i,t} = \sum_{s=0}^{t} x_{i,s}^{sent} - \sum_{s=0}^{t} x_{i,s}^{rec} \qquad N_i = \frac{\sum_{t=0}^{T} N_{i,t}}{T} \qquad \tau = \sum_{i:N_i>0} N_i$$

- they concentrate on net-senders only
- banks who are not net-senders do not contribute share a part of the total risk in the system: Henceforth, the risk-based measure for free-riding of bank i, σ_i, according to the share of total risk a bank is taking

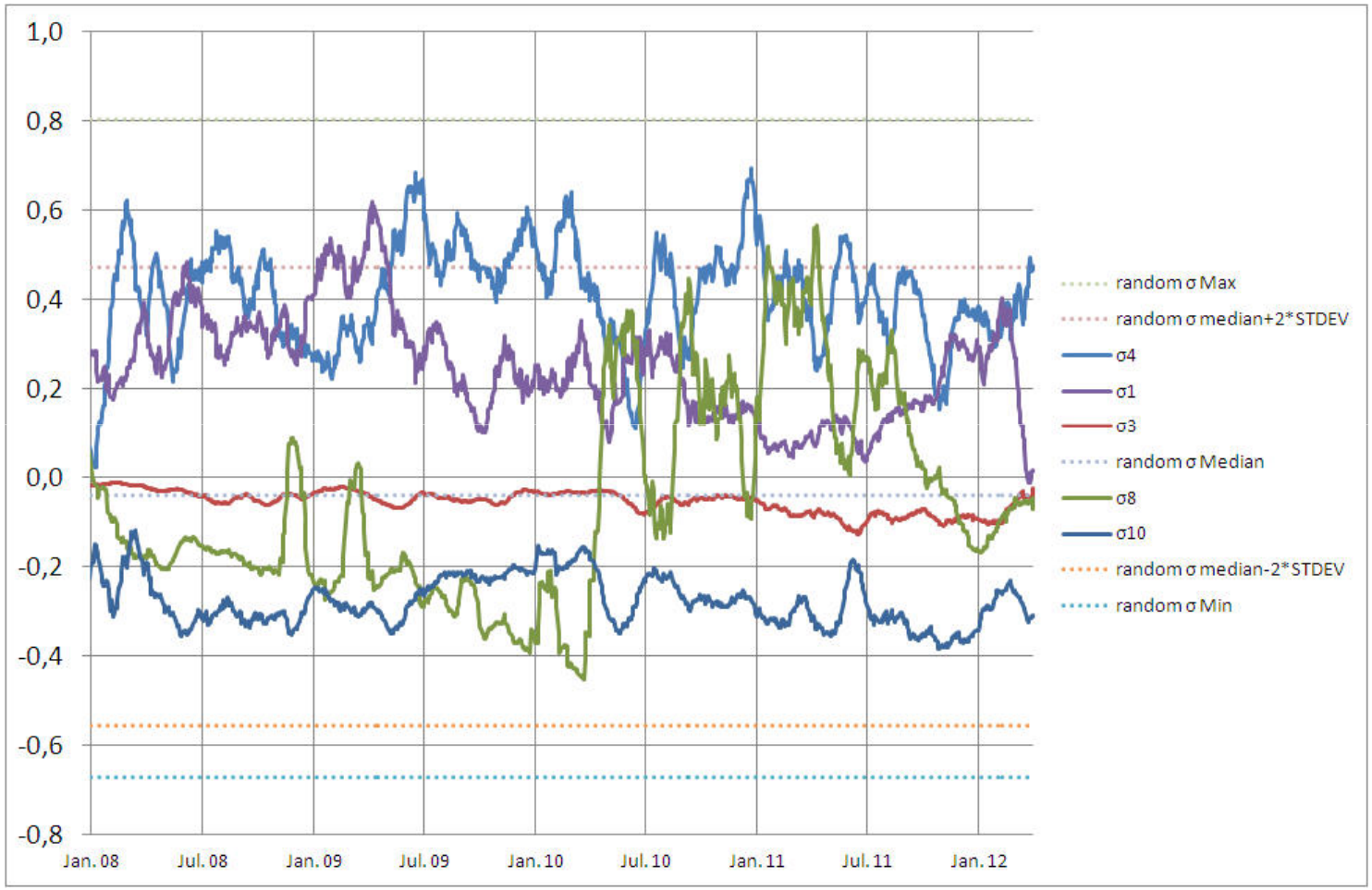
$$\sigma_i = \frac{N_i}{\tau}$$

- A free-rider is considered to hold on average the liquidity of other banks in the system and will display $\sigma_i<0$.

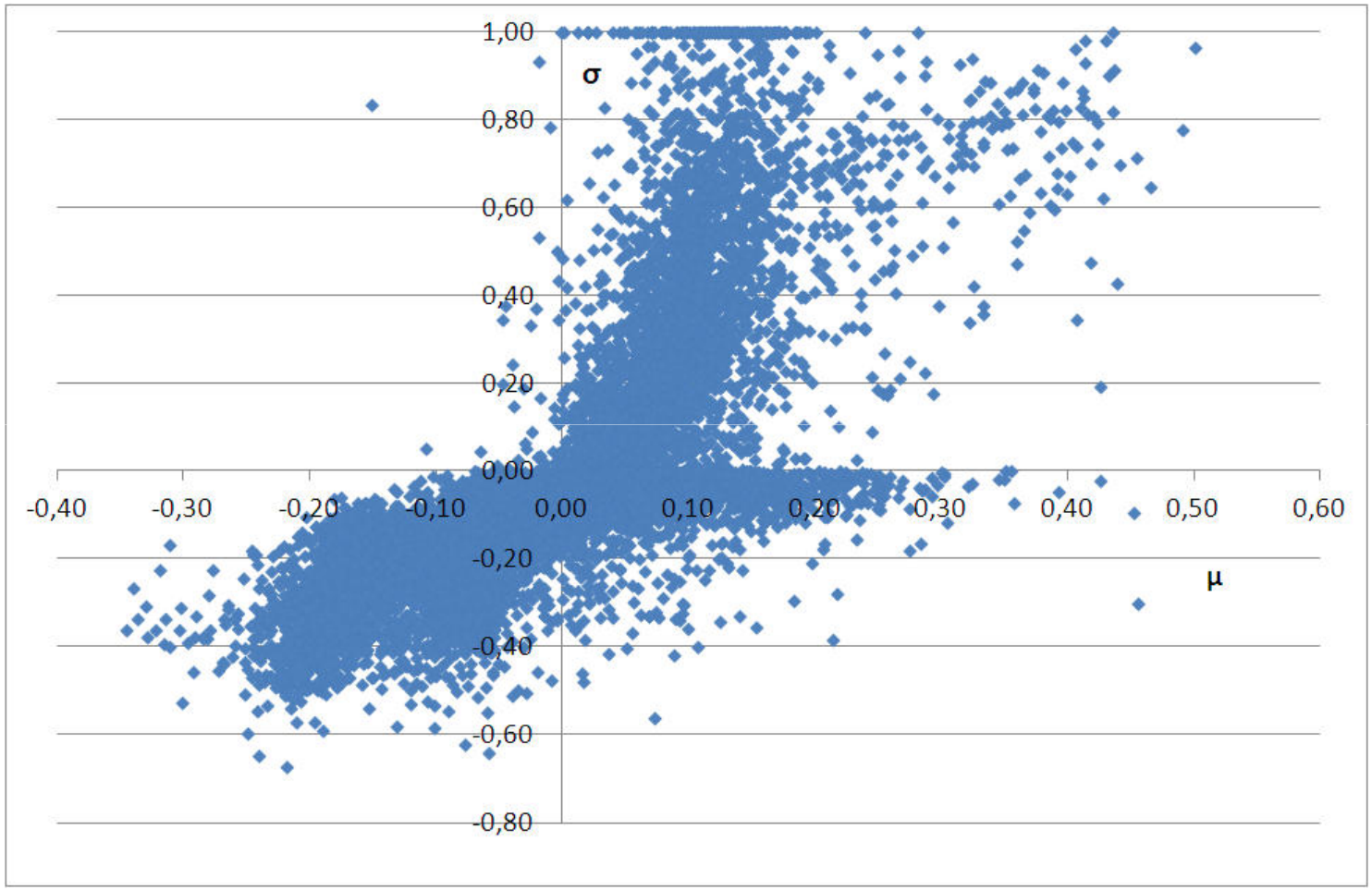
Empirical measures: Risk-based measure of Denbee et alii

- The risk-based measure does also not fulfill all postulates.
- First of all, the postulate of scale-invariance is not met unless all participants are taken into account.
  - If in LVPS with many participants the analysis is to concentrate on systemic important participants the degree of free-riding differs according to the selection of participants.
  - Moreover, given the same relative size of the average net sending positions of two participants (in relation to the total value sent) the larger of the two will display a higher σ.
- The transfer-principle is violated since all transfers not happening at a time when the bank is a net sender do not affect the measure.
- measure is not indifferent as to the share of participants taken into account unless all participants are looked at simultaneously.
- Finally, in a smaller group looked at, the measure may jump for technical reasons on days when the number of banks which are on average net senders declines into low figures.

Empirical measures: Risk-based measure of Denbee et alii



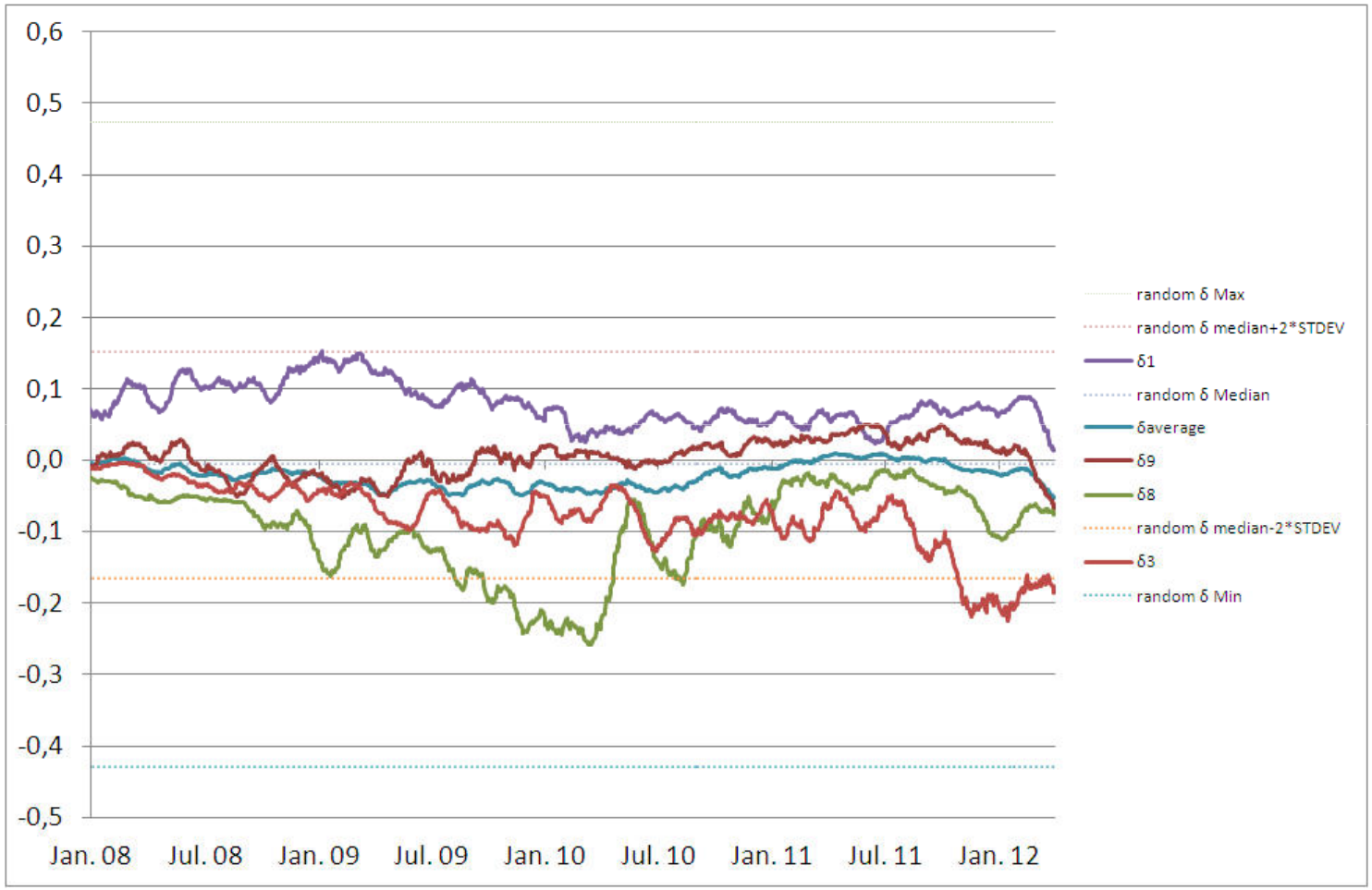
Empirical measures:
Comparison of Cost- and Risk-based measure



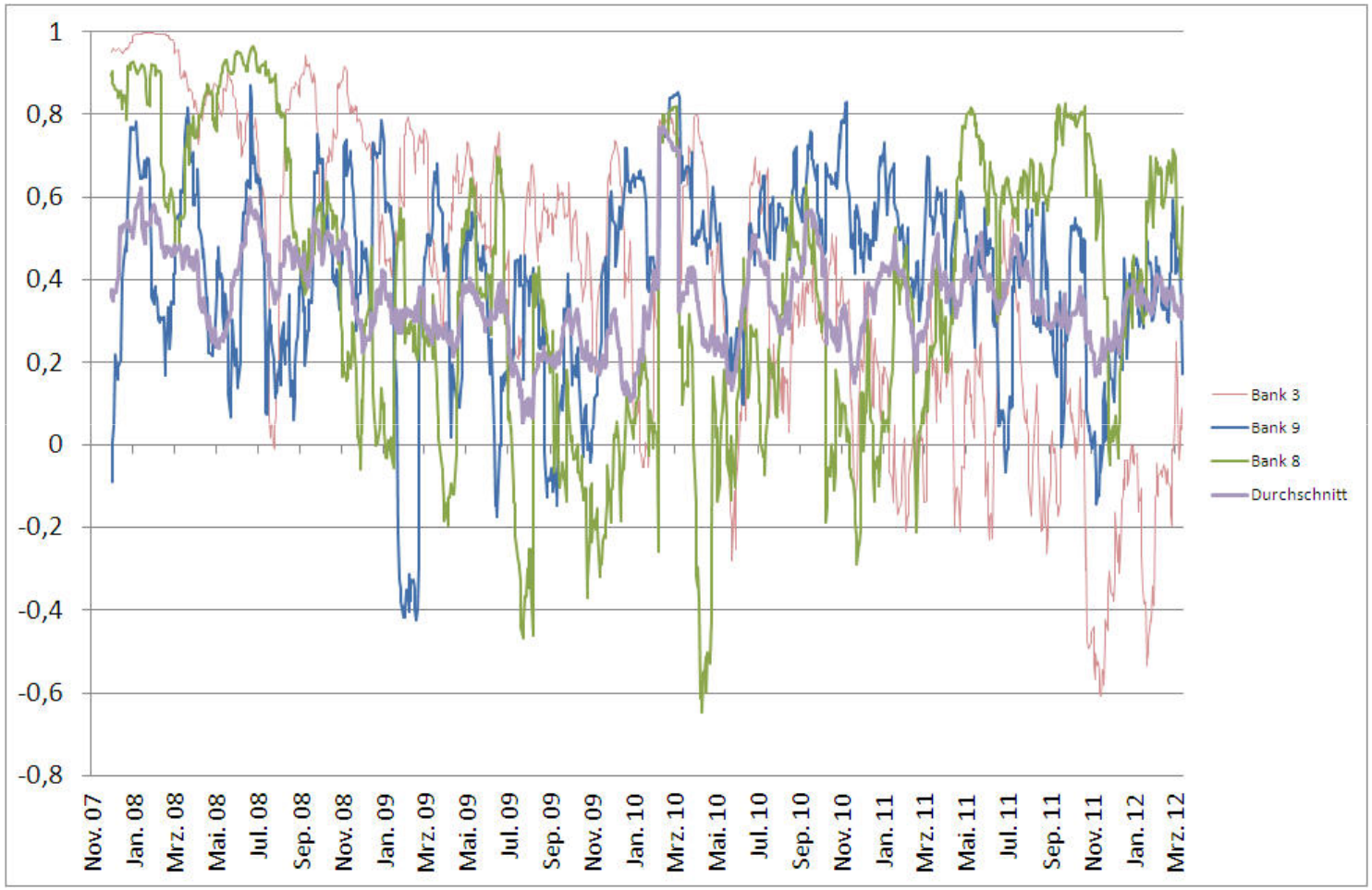
Empirical measures: Time-based measure

- The time-based measure of free-riding for a bank i, δ_i, is defined as: δ_i=average reception time index$_{\text{bank i}}$ – average payment time index$_{\text{bank I}}$
- δ_i is negative for a free rider which needs a larger share of the business day to send half of her payments than to receive half of the incoming payments
- measure is applicable to any number of participants
- it fulfils the transaction-principle to the extent that every transaction changing the settlement time of a certain payment such that it shifts to the next minute-time-band will has an effect on the measure.
- Given the limitation to 660 time-bands the measure is still operationally.

Empirical measures: Time-based measure

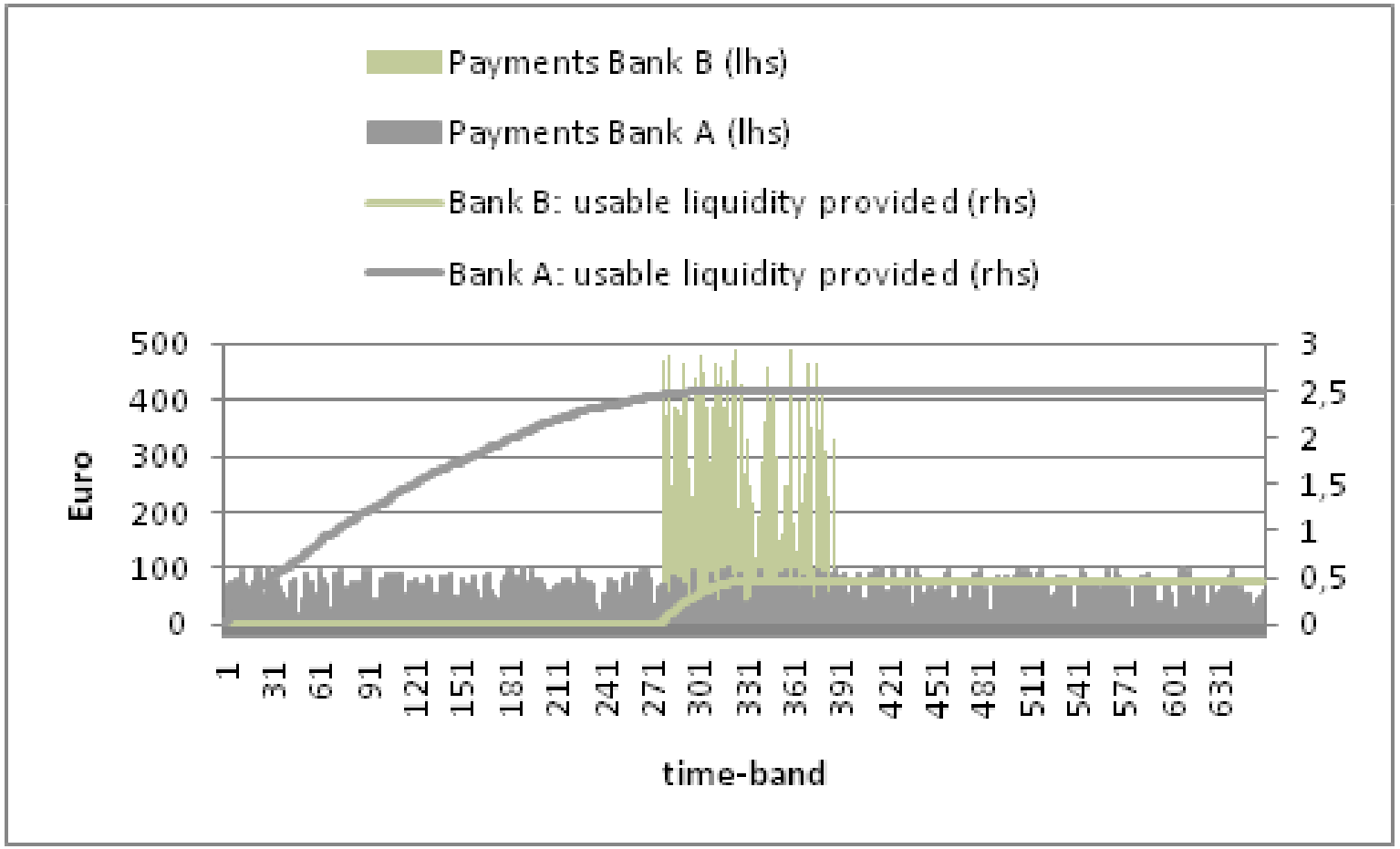


Empirical measures: Korrelation (22-days) of payment time index and reception time index



Empirical measures: Early-payment indicator

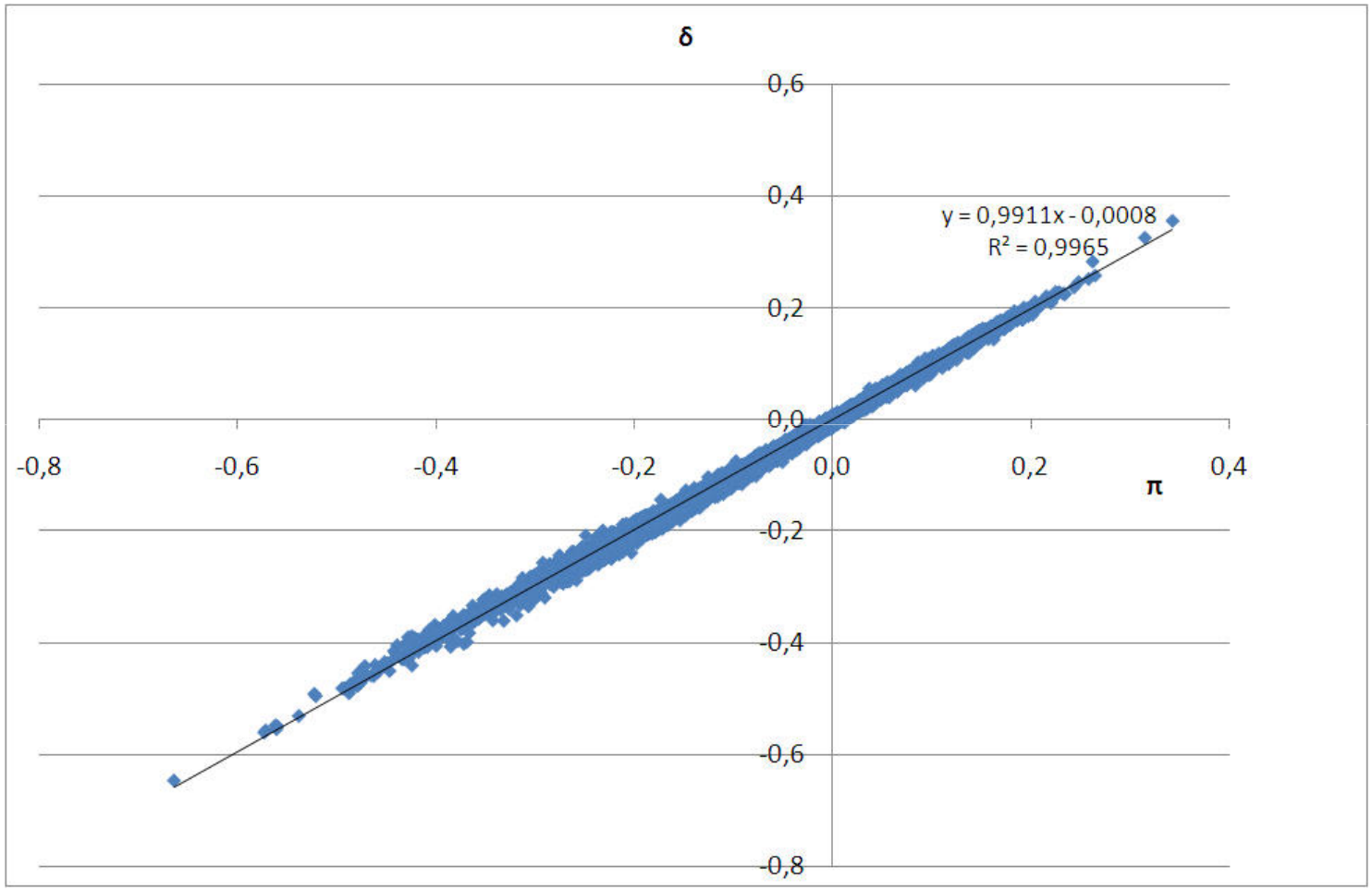
Graph: Distribution of payments on time-bands for two fictitious banks
Explanation: The business-day is divided into 660 time-bands. The usable liquidity is calculated by the sum of the products of the liquidity sent times the time-band specific turnover rate. The turnover rate is 10 for the first time-band, decreases proportionately with time-bands and stays at zero from time-band 330 onwards.



Empirical measures: Early-payment indicator

- payments at different time-bands are taken into account at a disproportionate factor
  - factor for the last time-band is taken as zero.
  - For all other time-bands, t, the factor is calculated as: $factor_t=(1.001^{660-t})-1$.
  - $0 < EPI < 1$
  - Equally an early reception indicator is calculated using the same factors
- early payment time indicator for free-riding, π_i , is defined as the difference between early payment indicator and early reception indicator.
  - A negative difference is considered to indicate free-riding.
- early payment indicator fulfils all postulates, especially the transfer-principle and the full coverage postulate
- empirics
  - difference between the time-based measure of free riding and the early payment indicator of free-riding is small
  - ranking of banks is equal / the level of indicated free-riding matches very well
  - although not perfect
  - early payment indicator is more sensitive to shifts in the more important early hours

Empirical measures:
Comparison of Time-based and early payment index measure



Empirical measures: Relative net-sending indicator

- time-based measure and early payment indicator of free-riding are superior versus cost-based and risk-based measure in terms of not violating the basic postulates
- However, the special focus on the extreme situations is lost
- another index focussing on the net sending of a bank shall be calculated.
- To overcome some of the weaknesses of risk- and cost-based measures:
  - the outgoing and incoming payments are taken into account at the same time
  - the restriction to deal with net senders or net receivers only is overcome
- Firstly, the largest accumulated amount of net sending at a time-band is calculated and divided by the sum of all incoming payments.
  - rationale: a bank may very well be a net sender if she expects a lot of incoming payments
- Secondly, the largest accumulated amount of net reception at a time-band is divided by the sum of all outgoing payments on that day.
  - a bank displaying a large surplus of net received payments is hoarding liquidity

Empirical measures: Relative net-sending indicator

- relative net sending indicator of free-riding, v_i, is the difference between both.

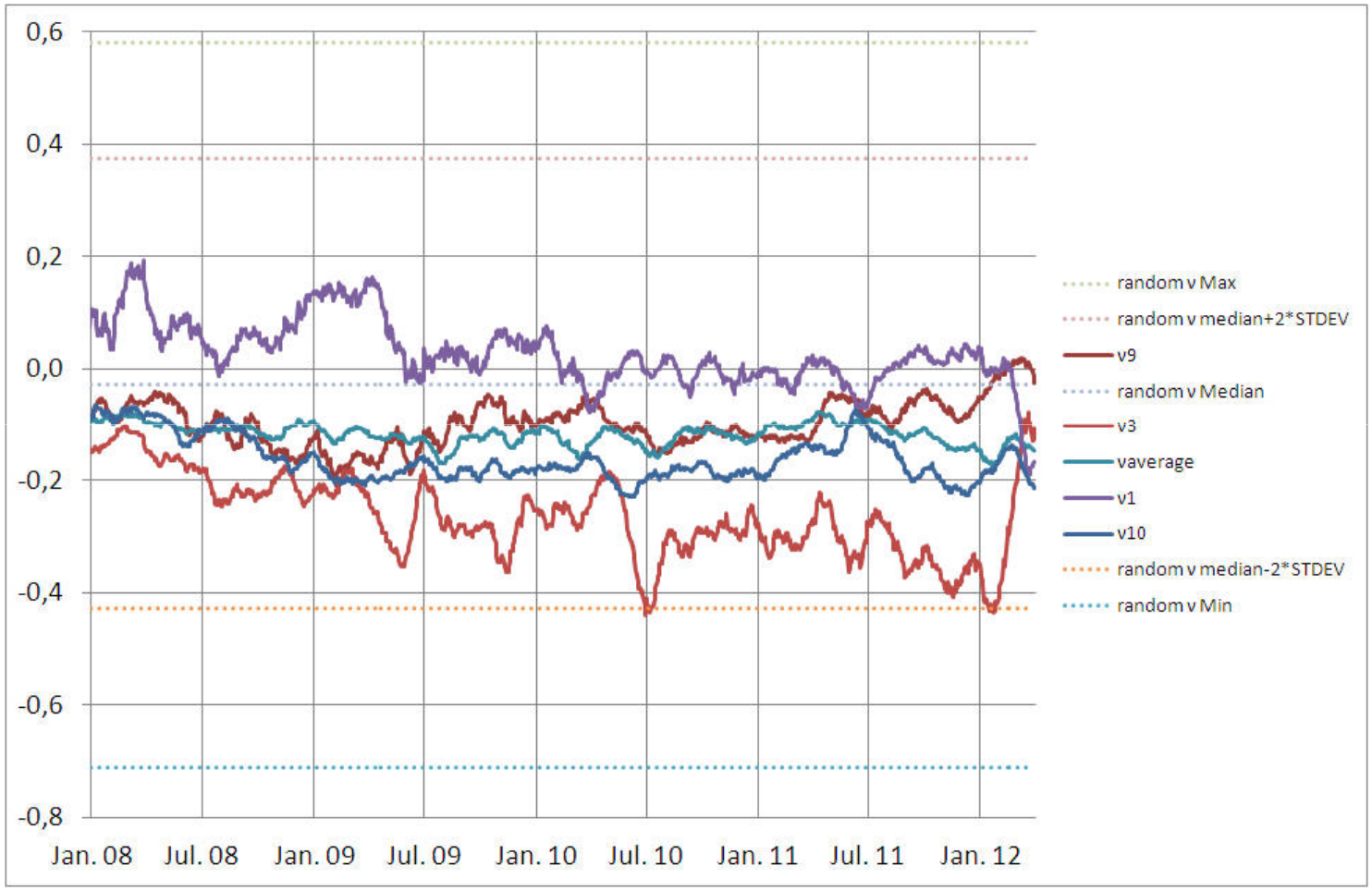
$$v_i = \frac{max_t N_{i,t}}{\sum_{t=0}^{T} x_t^{rec}} - \frac{Abs\left(min_t N_{i,t}\right)}{\sum_{t=0}^{T} x_t^{send}}$$

where:

$$N_{i,t} = \sum_{s=0}^{t} x_{i,s}^{sent} - \sum_{s=0}^{t} x_{i,s}^{rec}$$

- measure violates also the transfer-principle although to a lesser extent, since it entails two possible time-bands.
- is superior to the cost-based and the risk-based measure
  - since it meets the full coverage postulate
  - and the postulate of true measurement (no jumps in value for technical reasons)
  - it is independent of the group size
- obvious weakness: non-reflection on the respective time-bands.
  - If the maximum of net sending is held at a very late time-band and the minimum of net sending (which is the maximum of net reception) is held at a very early time-band, the bank may nevertheless be considered a free-rider, even if v_i is zero or slightly positive.
  - measure cannot be used as a sole indicator

Empirical measures: Relative net-sending indicator

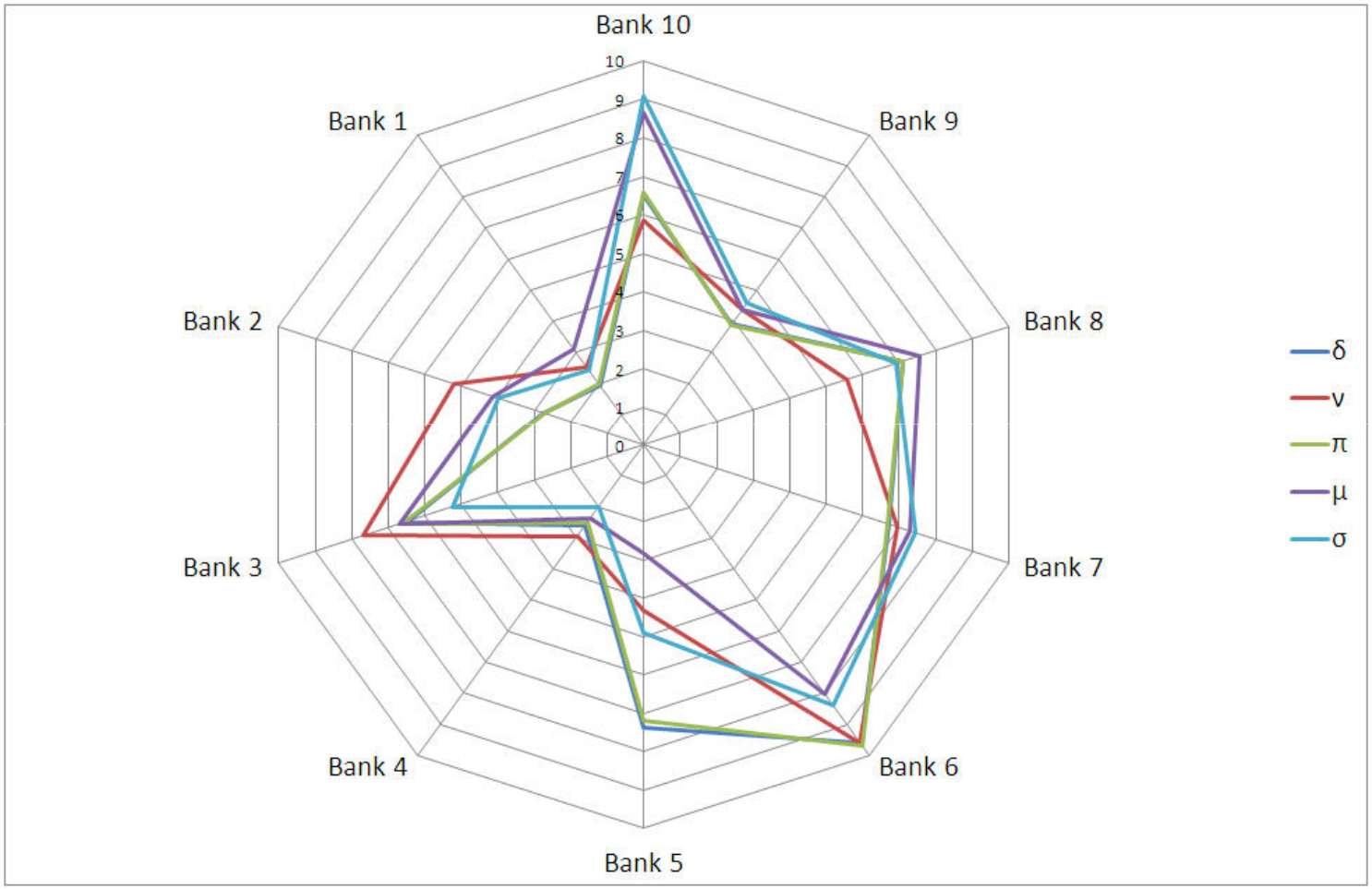


Comparing the various measures

- five measures of free riding as they are:
  - μ: cost-based measure of free-riding
  - σ: risk-based measure of free-riding
  - δ: time-based measure of free-riding
  - π: early payment indicator of free-riding
  - v: relative net sending indicator of free-riding

- Comparing the rank distribution
  - A high rank means that the bank is more prone to be judged a “free-rider”.

Rank distribution of 10 participants in TARGET2-BBK according to average of the various measures, Nov. 2007 - March 2012



Comparing the various measures

- Although appreciating the path-breaking efforts of Denbee/Garratt/Zimmermann (2010) I would in general refrain from using the cost-based measure or the risk-based measure.
- Both violate quite a number of reasonable postulates.
- time-based measure and the early payment indicator of free-riding yield similar results
  - only one should be used
  - prefering the more sensitive measure which is the latter one.
- relative net sending indicator of free-riding
  - violates also the transfer-principle but less
  - meets other postulates, especially, the postulate of true measurement
  - should be used as an additional indicator capturing

Economic interpretation

- Most indicators are pretty stable over time and in a narrow range around a neutral level
- bank specific regimes in payment time etc. are identifiable
- Two interpretations:
  - level of free-riding is low (not recognizable)
  - level of free-riding is high, but tolerated
- Favour the first interpretation:
  - level of free-riding is low as compared to the data of randomly rearranged payment sequence
  - high volatility and regime shifts disturb the observability
  - banks do only observe bilateral limits (and may only watch absolute net-transfers)
  - timing is mainly interesting for rare time-sensitive payments and big transfers
- rise to the assumption that some part of the small differences can be explained by diverse creditworthiness
- issues leave plenty of room for further investigation