Universität Zürich[UZH]

UZH Blockchain Center

Blockchain & DLT Research Group

# MicroVelocity

*Rethinking the velocity of money for digital currencies*

Carlo Campajola

*Universität Zürich*
*UZH Blockchain Center*

*Marco D'Errico (ECB), Claudio J. Tessone (UZH BCC)*

# Key ideas

- Digital currency opens to new analytics and policy channels
- Measure Velocity of Money from micro-level?
- Cryptocurrencies are an ideal sandbox

# Key ideas

- Digital currency opens to new analytics and policy channels
- Measure Velocity of Money from micro-level?
- Cryptocurrencies are an ideal sandbox

# Key ideas

- Digital currency opens to new analytics and policy channels
- Measure Velocity of Money from micro-level?
- Cryptocurrencies are an ideal sandbox

# Key ideas

- Digital currency opens to new analytics and policy channels
- Measure Velocity of Money from micro-level?
- Cryptocurrencies are an ideal sandbox

Some research questions:

- Do different economic agents contribute differently to the overall velocity?
- Does this relate to other factors (wealth, centrality, ...)?

# Key ideas

- Digital currency opens to new analytics and policy channels
- Measure Velocity of Money from micro-level?
- Cryptocurrencies are an ideal sandbox

Some research questions:

- Do different economic agents contribute differently to the overall velocity?
- Does this relate to other factors (wealth, centrality, ...)?

# Velocity of Money

**Velocity of Money**

Fisher's equation of exchange states

$$MV = PQ$$

- $M$ = monetary Mass (# of coins in the economy)
- $V$ = Velocity
- $P$ = Price level (avg. unit price of goods/services)
- $Q$ = Nominal economic output (# units of goods/services)

*$V$ represents the average number of times a unit of currency changes hands over a time period*

# Measuring $V$

*$V$ cannot be directly observed*

However Wang et al.[ , *Physica A* (2003)] give microeconomic foundations to construct the macroeconomic $V$

---

Let's call:

- $\tau$ - random time ("holding time") a coin stays idle between transactions
- $p(\tau)$ - its probability distribution
- hence $Mp(\tau)d\tau$ is the fraction of coins with holding time $\tau$

# Measuring $V$

*$V$ cannot be directly observed*

However Wang et al.[ , *Physica A* (2003)] give microeconomic foundations to construct the macroeconomic $V$

---

Let's call:

- $\tau$ - random time ("holding time") a coin stays idle between transactions
- $p(\tau)$ - its probability distribution
- hence $Mp(\tau)d\tau$ is the fraction of coins with holding time $\tau$

# Measuring $V$

*$V$ cannot be directly observed*

However Wang et al.[ , *Physica A* (2003)] give microeconomic foundations to construct the macroeconomic $V$

---

Let's call:

- $\tau$ - random time ("holding time") a coin stays idle between transactions
- $p(\tau)$ - its probability distribution
- hence $Mp(\tau)d\tau$ is the fraction of coins with holding time $\tau$

# Measuring $V$

*$V$ cannot be directly observed*

However Wang et al.[ , *Physica A* (2003)] give microeconomic foundations to construct the macroeconomic $V$

---

$Mp(\tau)d\tau$ is the fraction of coins with holding time $\tau$

# Measuring $V$

*$V$ cannot be directly observed*

However Wang et al.[ , *Physica A* (2003)] give microeconomic foundations to construct the macroeconomic $V$

---

$Mp(\tau)d\tau$ is the fraction of coins with holding time $\tau$

Then the *money flow* (in stationary state) they generate is

$$F(\tau) = Mp(\tau)\frac{1}{\tau}d\tau$$

# Measuring $V$

*$V$ cannot be directly observed*

However Wang et al.[ , *Physica A* (2003)] give microeconomic foundations to construct the macroeconomic $V$

---

But by definition $\int_0^{+\infty} F(\tau) = PQ = MV$, then

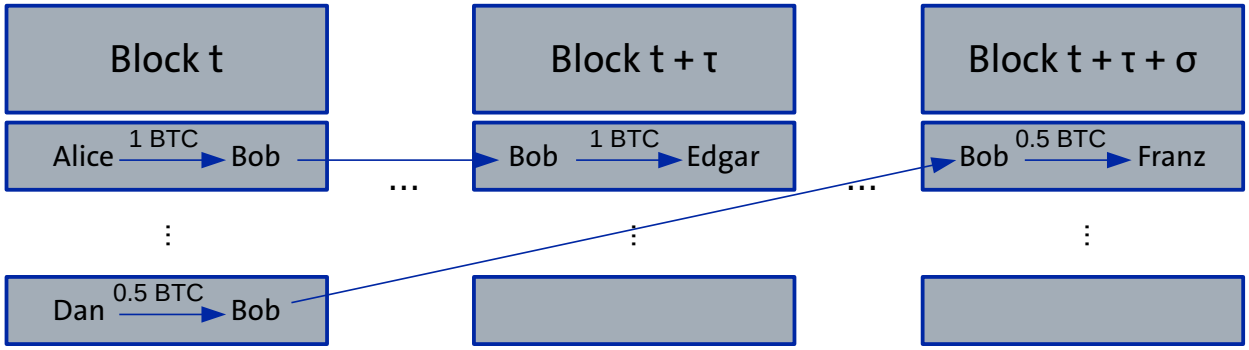
$$V = \int_0^{+\infty} \frac{1}{\tau} p(\tau) d\tau$$

*Problem becomes: how to measure $p(\tau)$?*

# Here comes crypto

With blockchains you have access to full transaction history

*In UTXO currencies you can measure τ for all coins!*



# Here comes crypto

With blockchains you have access to full transaction history

*In UTXO currencies you can measure $\tau$ for all coins!*

---

Two additional considerations...

*Time is discrete in blockchain-based systems - block time*

*Coins have different $p(\tau)$ depending on their owner*

# MicroVelocity

We can define the user-based **MicroVelocity**

$$V_i(t) = \sum_{\tau=1}^{\infty} \frac{M_i(t)}{M} \frac{1}{\tau} P_i^{(t)}(\tau)$$

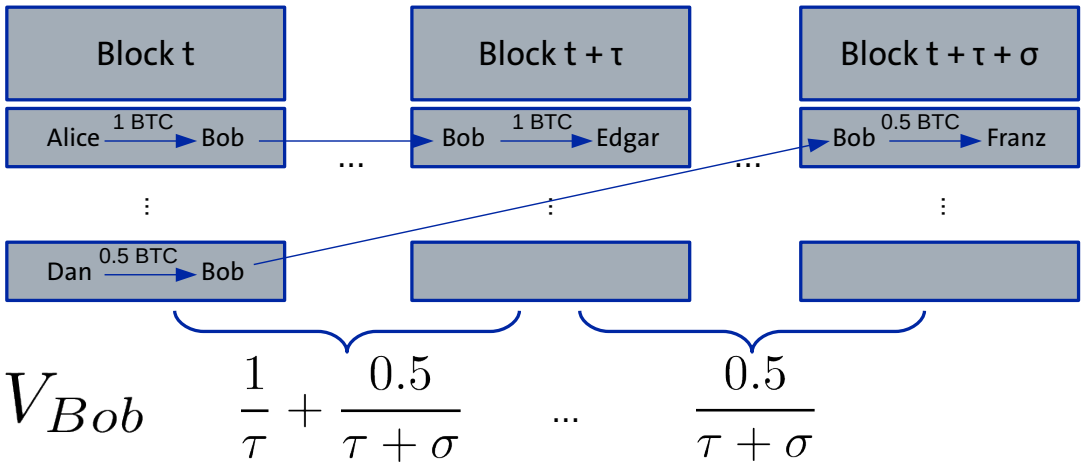
where

- $M_i(t)$ is the wealth of $i$ at time $t$
- $P_i^{(t)}(\tau)$ is the fraction of coins held for $\tau$ blocks by $i$
- $V(t) = \sum_i V_i(t)$ by design

# MicroVelocity

We can define the user-based **MicroVelocity**

$$V_i(t) = \sum_{\tau=1}^{\infty} \frac{M_i(t)}{M} \frac{1}{\tau} P_i^{(t)}(\tau)$$



# Data

We implement our analysis for four alt-coins

MonaCoin

- Genesis block 2013-12-31 8:44:32 UTC
- $\sim$ 2.2M blocks since genesis (one every 1.5 minutes)
- $\sim$ 1.3M "agents"



FeatherCoin

- Genesis block 2013-04-16 21:17:40 UTC
- $\sim$ 3.5M blocks since genesis (one every minute)
- $\sim$ 600K "agents"

# Data

We implement our analysis for four alt-coins

DogeCoin

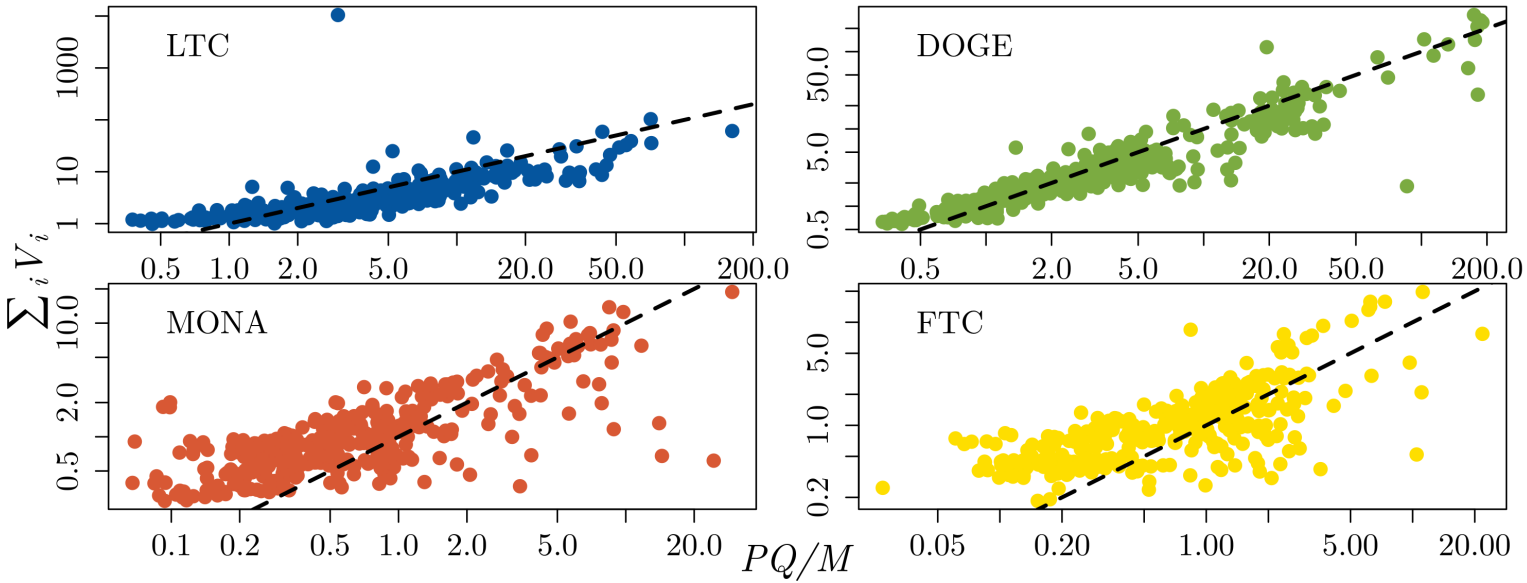
- Genesis block 2013-12-06 10:25:40 UTC
- ~ 2.7M blocks since genesis (one every 1.5 minutes)
- ~ 5M “agents”

LiteCoin

- Genesis block 2011-10-07 07:31:05 UTC
- ~ 2M blocks since genesis (one every minute)
- ~ 22M “agents”

# From micro to macro

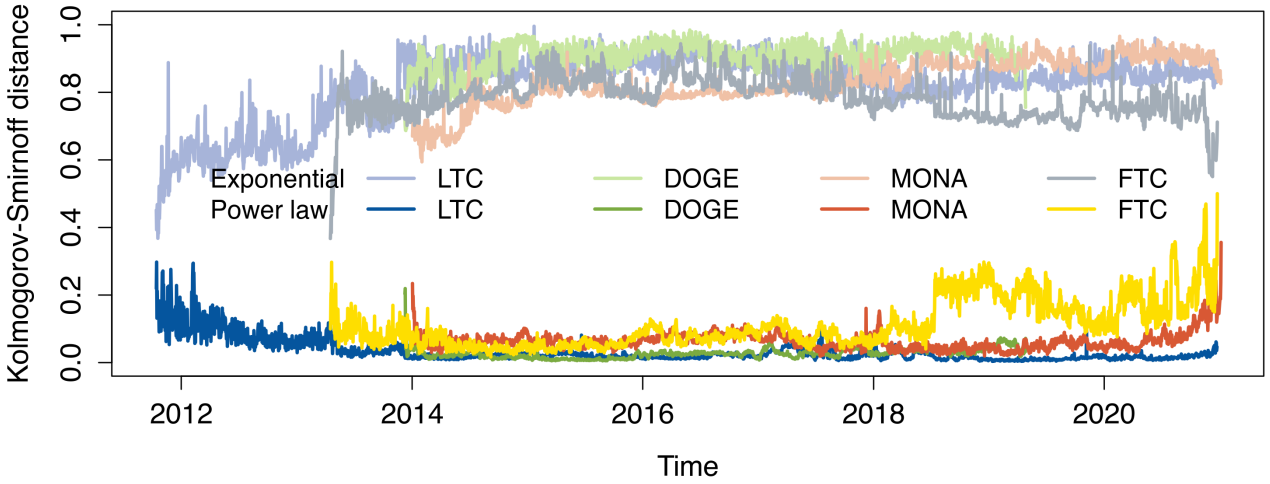
First let's check if $\sum_i V_i \rightarrow V = PQ/M$ as predicted



# How is $V_i$ distributed?

- Thin-tailed distributions in general fit poorly
- Fat-tailed distributions have good fits

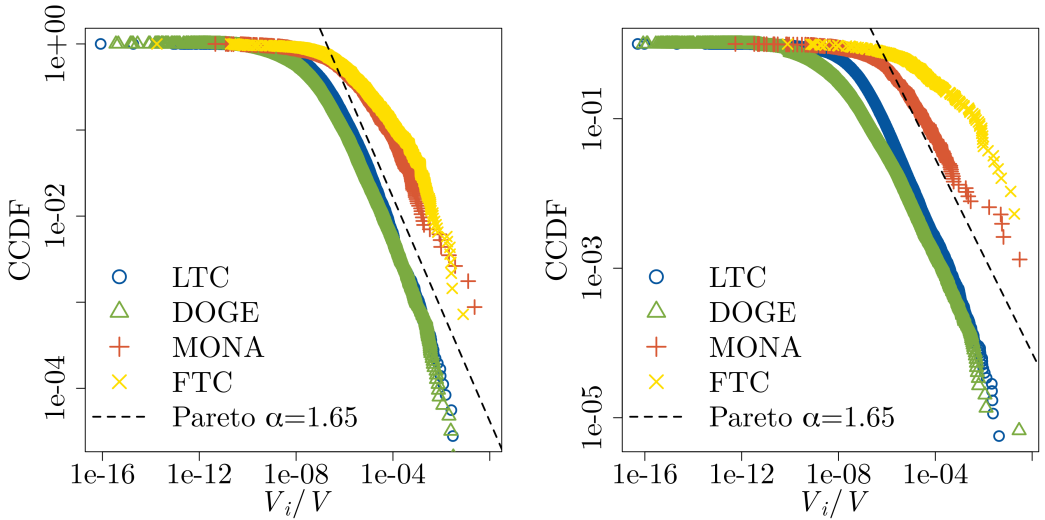
*Most of the velocity is determined by few agents!*



# How is $V_i$ distributed?

- Thin-tailed distributions in general fit poorly
- Fat-tailed distributions have good fits

*Most of the velocity is determined by few agents!*

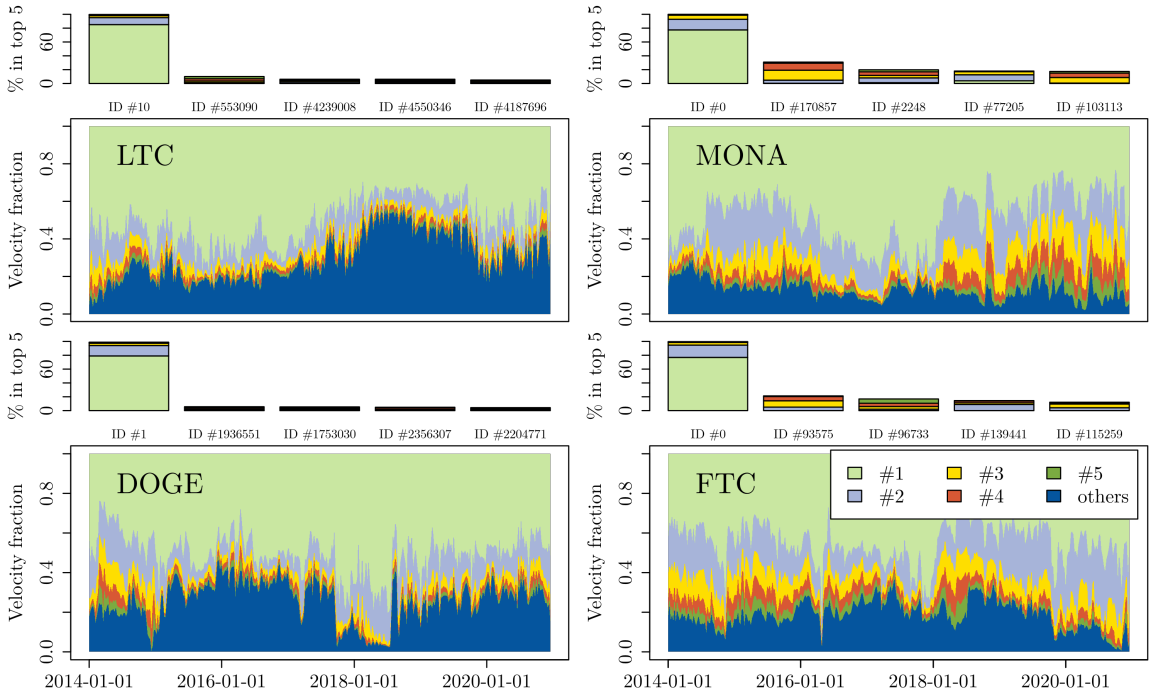


# Pareto $\alpha$s and KS tests

| | | LTC | DOGE | MONA | FTC |
|---|---|---|---|---|---|
| $\alpha$ | Mean | 1.69 | 1.65 | 1.56 | 1.62 |
| | Min. | 1.44 | 1.52 | 1.28 | 1.27 |
| | Q1 | 1.64 | 1.61 | 1.52 | 1.52 |
| | Median | 1.70 | 1.65 | 1.55 | 1.59 |
| | Q3 | 1.74 | 1.68 | 1.61 | 1.69 |
| | Max. | 1.92 | 1.80 | 2.29 | 2.20 |
| $D_{Par}$ | Mean | 0.03 | 0.03 | 0.08 | 0.11 |
| | $p > 0.2$ | 92.96% | 100.00% | 99.92% | 94.07% |
| $D_{Exp}$ | Mean | 0.83 | 0.86 | 0.83 | 0.78 |
| | $p > 0.2$ | 0% | 0% | 0% | 0% |

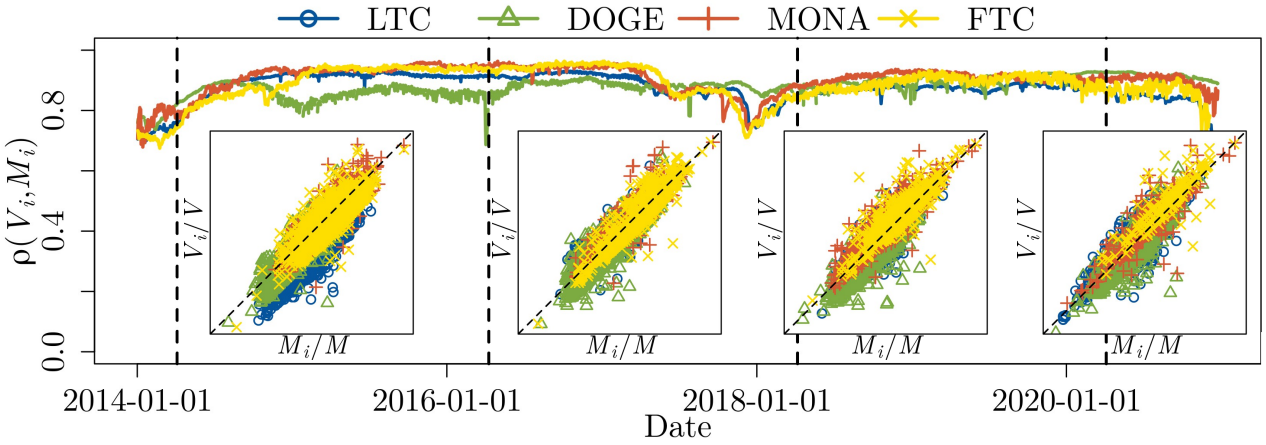
# How is $V_i$ distributed?

*...VERY fat tailed!*



# $V_i$ and wealth

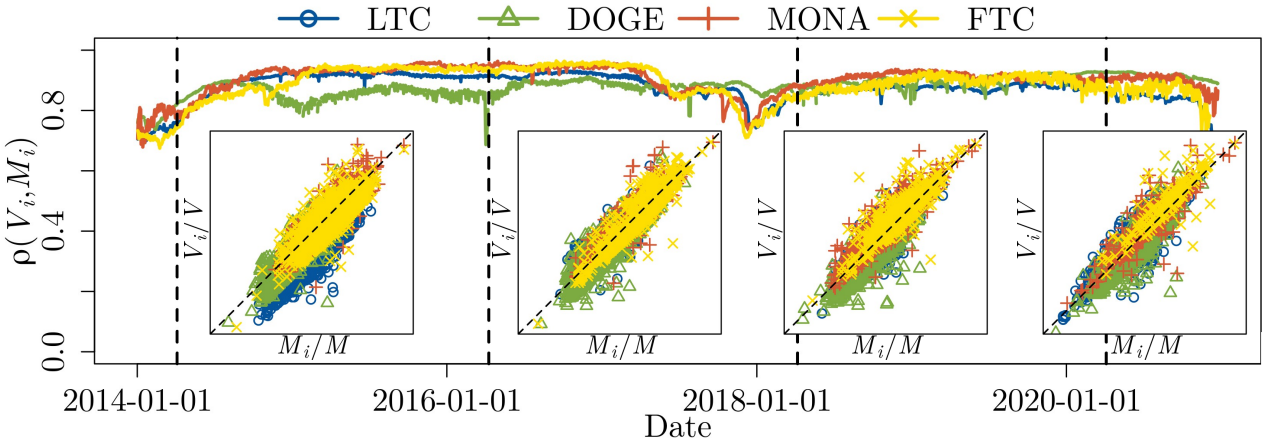
*What is the relation between $V_i$ and agent's wealth $M_i$?*




$$V_i(t) = \sum_{\tau=1}^{\infty} \frac{M_i(t)}{M} \frac{1}{\tau} P_i^{(t)}(\tau)$$

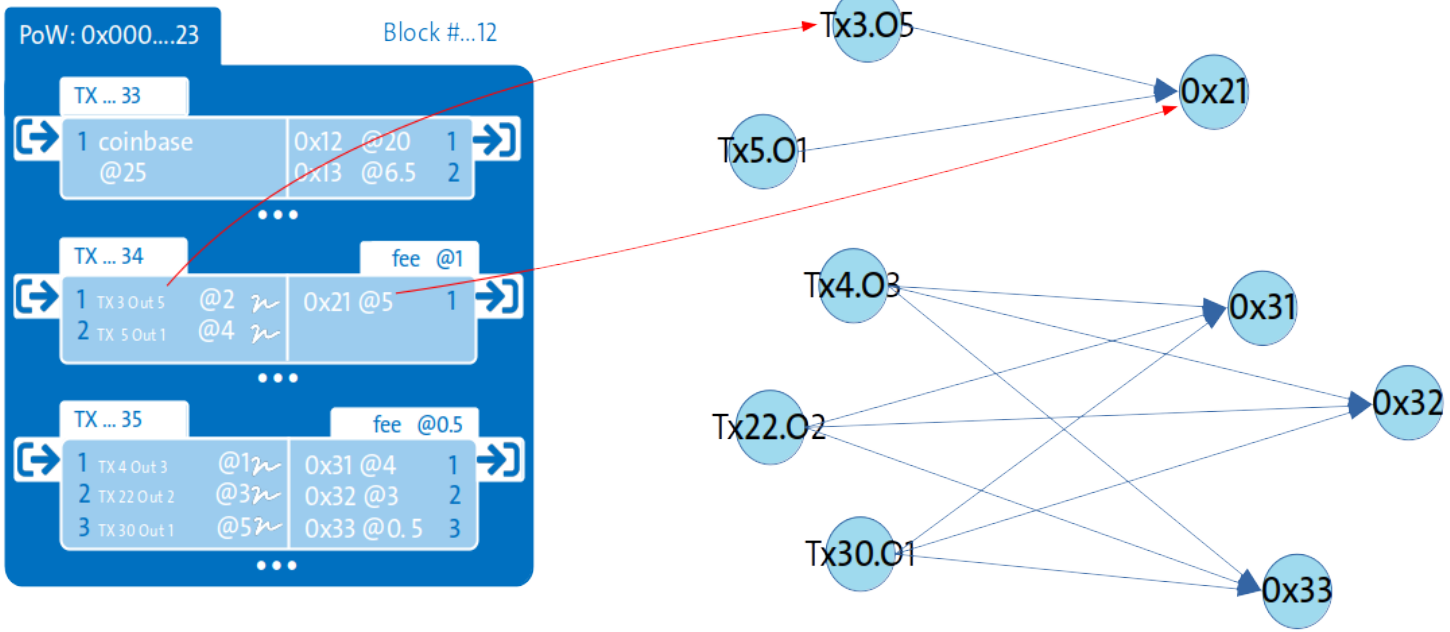
# $V_i$ and wealth

*What is the relation between $V_i$ and agent's wealth $M_i$?*

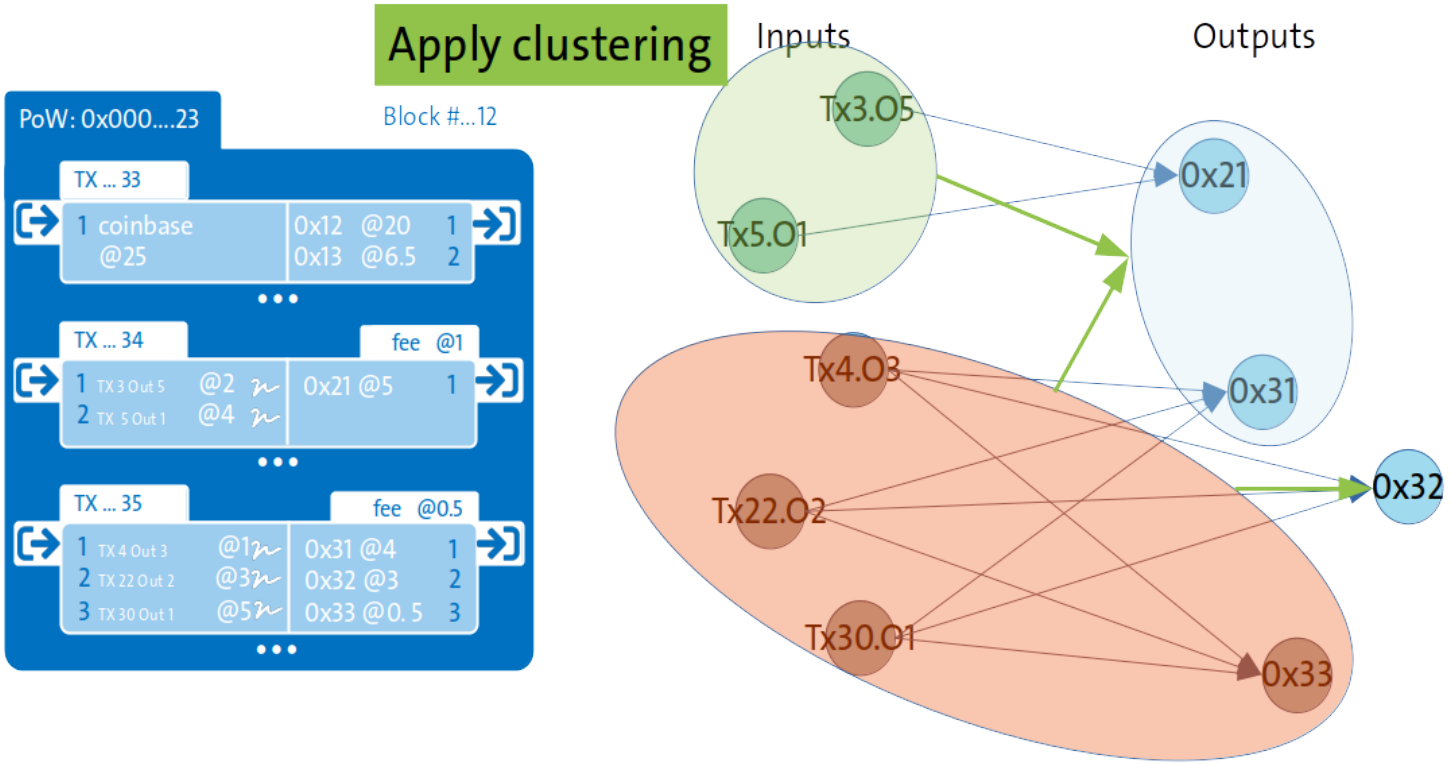



$$V_i(t) = \sum_{\tau=1}^{\infty} \frac{M_i(t)}{M} \frac{1}{\tau} P_i^{(t)}(\tau)$$

# Transaction networks

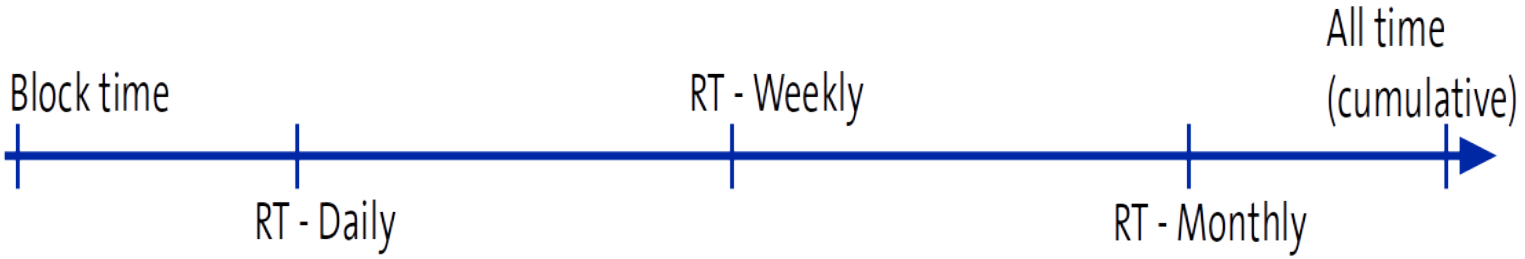


# Transaction networks



# Time aggregation

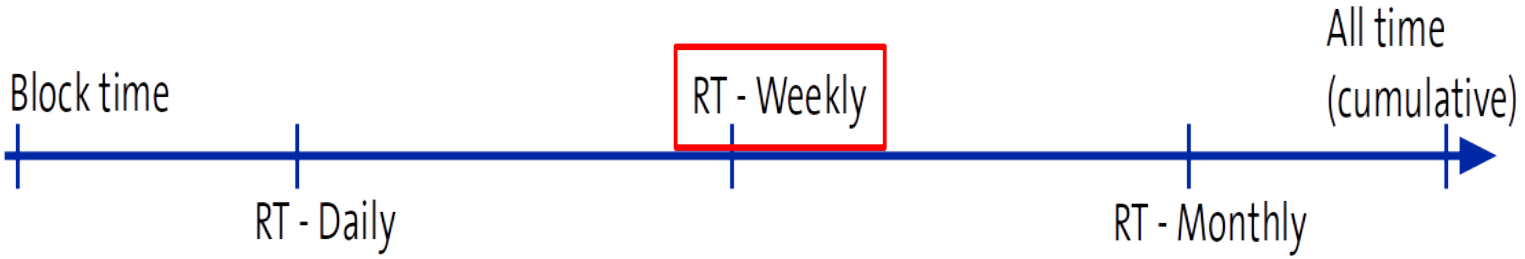
The time aggregation is largely arbitrary




*The larger the time aggregation, the least "causal" the network is. Need to make choices depending on research questions.*

# Time aggregation

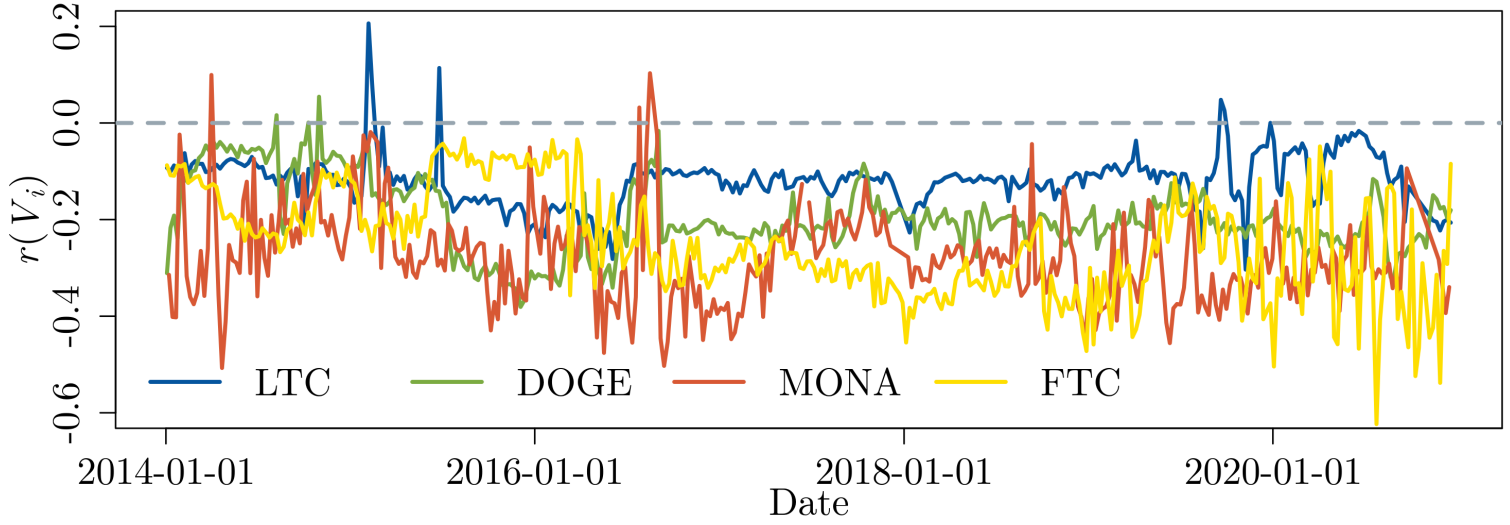
The time aggregation is largely arbitrary




*The larger the time aggregation, the least "causal" the network is. Need to make choices depending on research questions.*

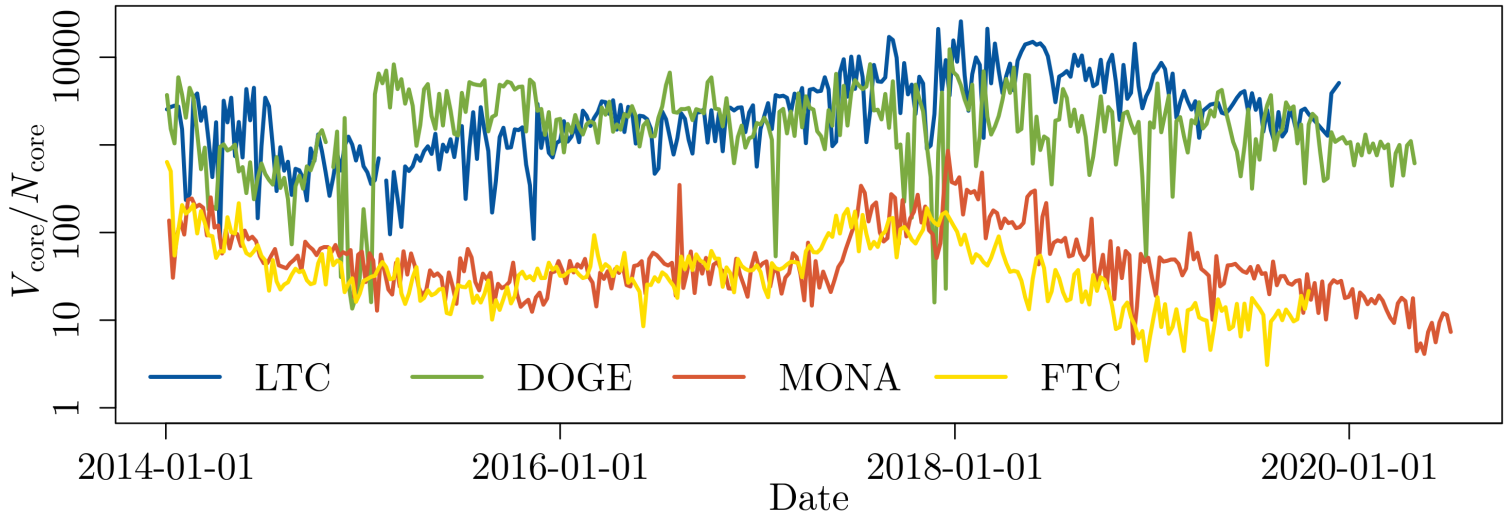
# MicroVelocity is disassortative

On weekly tx networks, we find negative correlation between neighbours' velocities



# MicroVelocity is in the core

The fraction of total velocity in the core is much larger than the fraction of nodes in the core



# In conclusion

Some take-home messages:

- MicroVelocity poses a bridge from micro to macro
- Despite crypto's statutory decentralization, MicroVelocity shows flow is very centralized
- In other words,

*decentralized technology ≠ decentralized economy*

# In conclusion

Some take-home messages:

- MicroVelocity poses a bridge from micro to macro
- Despite crypto's statutory decentralization, MicroVelocity shows flow is very centralized
- In other words,

*decentralized technology ≠ decentralized economy*

# In conclusion

Some take-home messages:

- MicroVelocity poses a bridge from micro to macro
- Despite crypto's statutory decentralization, MicroVelocity shows flow is very centralized
- In other words,

*decentralized technology ≠ decentralized economy*

# In conclusion

Some take-home messages:

- MicroVelocity poses a bridge from micro to macro
- Despite crypto's statutory decentralization, MicroVelocity shows flow is very centralized
- In other words,

*decentralized technology ≠ decentralized economy*

Coming down the line:

- Applications to account-based systems like ETH tokens, banks and credit cards
- Better estimators for time-varying $P_i^{(t)}(\tau)$

# In conclusion

Some take-home messages:

- MicroVelocity poses a bridge from micro to macro
- Despite crypto's statutory decentralization, MicroVelocity shows flow is very centralized
- In other words,

*decentralized technology ≠ decentralized economy*

Coming down the line:

- Applications to account-based systems like ETH tokens, banks and credit cards
- Better estimators for time-varying $P_i^{(t)}(\tau)$

# In conclusion

Some take-home messages:

- MicroVelocity poses a bridge from micro to macro
- Despite crypto's statutory decentralization, MicroVelocity shows flow is very centralized
- In other words,

*decentralized technology ≠ decentralized economy*

Coming down the line:

- Applications to account-based systems like ETH tokens, banks and credit cards
- Better estimators for time-varying $P_i^{(t)}(\tau)$

# References


- Campajola C., D'Errico M., Tessone C.J. (2022); MicroVelocity: rethinking the Velocity of Money for digital currencies.
  *arXiv preprint*, arXiv:2201.13416
- Wang Y., Ding N., Zhang L. (2003); The circulation of money and holding time distribution.
  *Physica A* 324(3-4), 665-677
- Pernice I.G.A., Gentzen G., Elendner H. (2019); Cryptocurrencies and the Velocity of Money.
  *Available at SSRN 3499500*
- Bovet A., Campajola C., Mottes F., Restocchi V., Vallarano N., Squartini T., Tessone C.J. (2019); The evolving liaisons between the transaction networks of Bitcoin and its price dynamics.
  *arXiv preprint*, arXiv:1907.03577

Universität Zürich[UZH]

UZH Blockchain Center

Blockchain & DLT Research Group


Carlo Campajola

Universität Zürich
UZH Blockchain Center

campajola@ifi.uzh.ch
twitter.com/Campa_91