weizenbaum institut

Cryptocurrencies and the Velocity of Money

Ingolf Pernice, Georg Gentzen, Hermann Elendner · March 7, 2020

Research Questions

We **operationalize a novel measure** for the velocity of money **based on effectively circulation coins**.

We test how well the simple **proxy-variables used so far** really are.

[Fisher, Irving: The Equation of Exchange. 1911.]

“Velocity” of money?

How are transactions executed using money?

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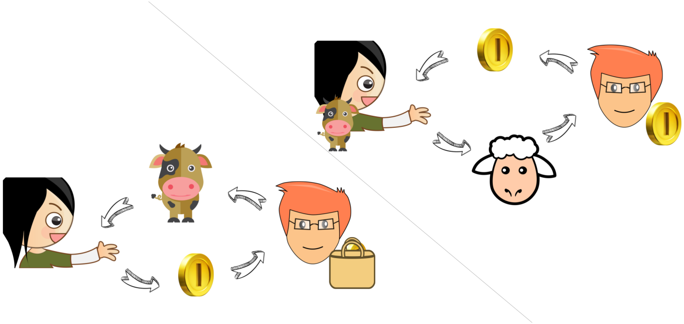
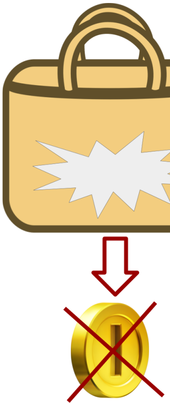


$$\text{Transaction volume} = \left\langle \underbrace{\begin{pmatrix} 1\,\frac{\text{coins}}{\text{sheep}} \\ 1\,\frac{\text{coins}}{\text{cow}} \end{pmatrix}}_{\text{Price Vector}}, \underbrace{\begin{pmatrix} 1\,\text{sheep} \\ 1\,\text{cow} \end{pmatrix}}_{\text{Transact. Vector}} \right\rangle = 2\,\text{coins}$$

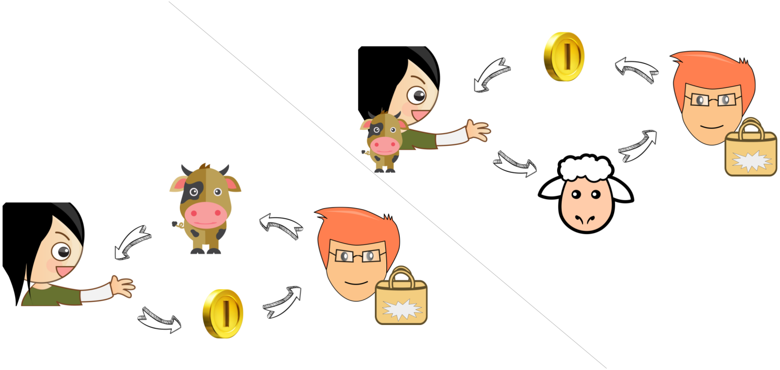
"Velocity" of money?

Can we still do the same deals with just one coin?



“Velocity” of money?

Yes! We just spin the leftover coin for a second time within this period!



How does this work?

“Velocity” of money

Before the loss: $\underbrace{2\,\text{coins}}_{\text{Money in circ.}} \cdot \underbrace{1}_{\text{Avg. turnovers}} = \text{Transaction volume} = 2\,\text{coins}$

After the loss: $\underbrace{1\,\text{coins}}_{\text{Money in circ.}} \cdot \underbrace{2}_{\text{Avg. turnovers}} = \text{Transaction volume} = 2\,\text{coins}$

Velocity is the “average number of turnovers during a period of time”.

$$\text{Velocity} = \frac{\text{Transaction volume}}{\text{Money in circulation}}$$

"Velocity" a bit more formal:

$$V_p = \frac{\overbrace{\langle P_p, T_p \rangle}^{\textbf{T}\text{ransaction volume (in coins)}}}{\underbrace{M_p}_{\textbf{M}\text{oney in circulation (in coins)}}} \text{ with } M_p, V_p \in \mathbb{R}_{\geq 0}, \text{ and } P_p, T_p \in \mathbb{R}^n_{\geq 0}.$$

Velocity can be measured for UTXO-based cryptocurrencies like Bitcoin.

[Fisher, Irving: The Equation of Exchange. 1911.]

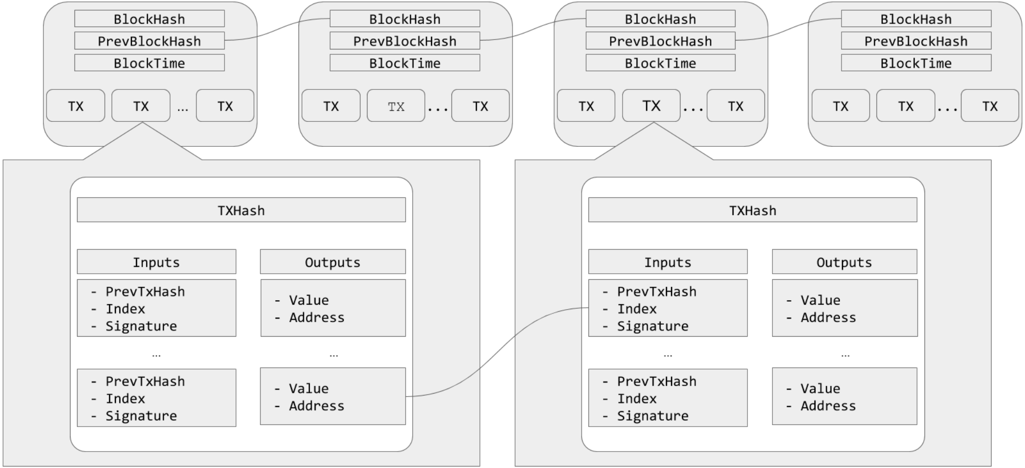
Well now—which measures can we build on?

$$\text{Velocity} = \frac{\text{Transaction volume}}{\text{Money in circulation}}$$

1. Just using **raw on-chain transaction volume** and **total coin supply**
   —Literature: Bolt and Van Oord (2016), Ciaian et al. (2018)
2. Adjusting the on-chain transaction volume for **change transactions**
   —Literature: Athey et al. (2016), Kalodner et al. (2017)

"What is desired is the rate at which money is used for purchasing goods, not for making change."—Fisher (1911)

UTXO-based cryptocurrencies



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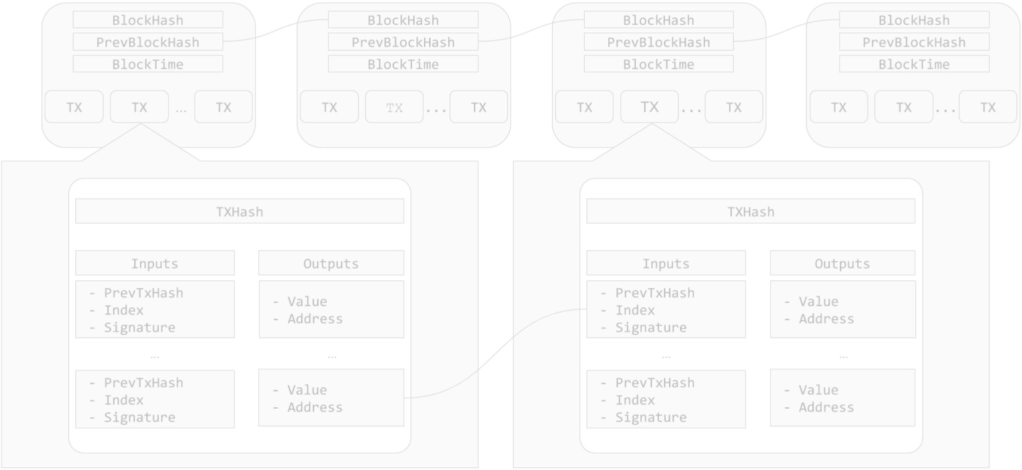

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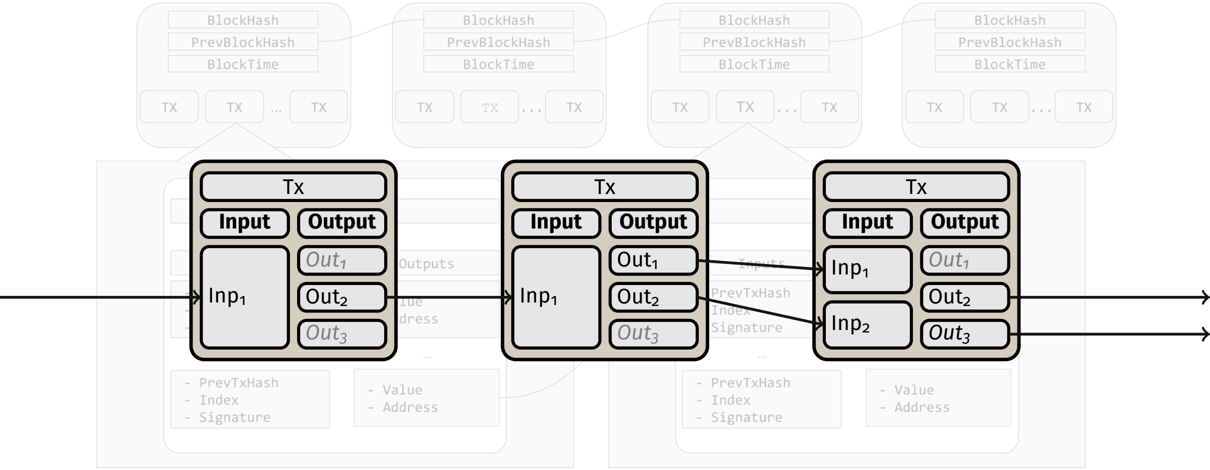

UTXO-based cryptocurrencies

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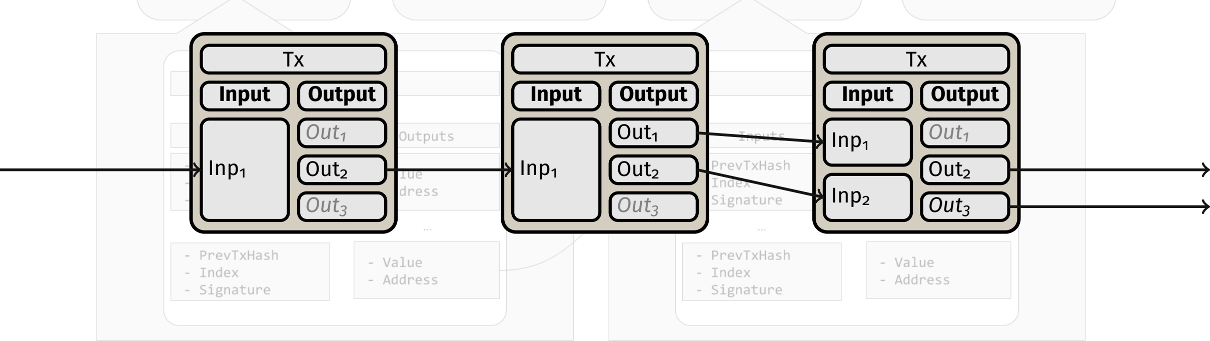

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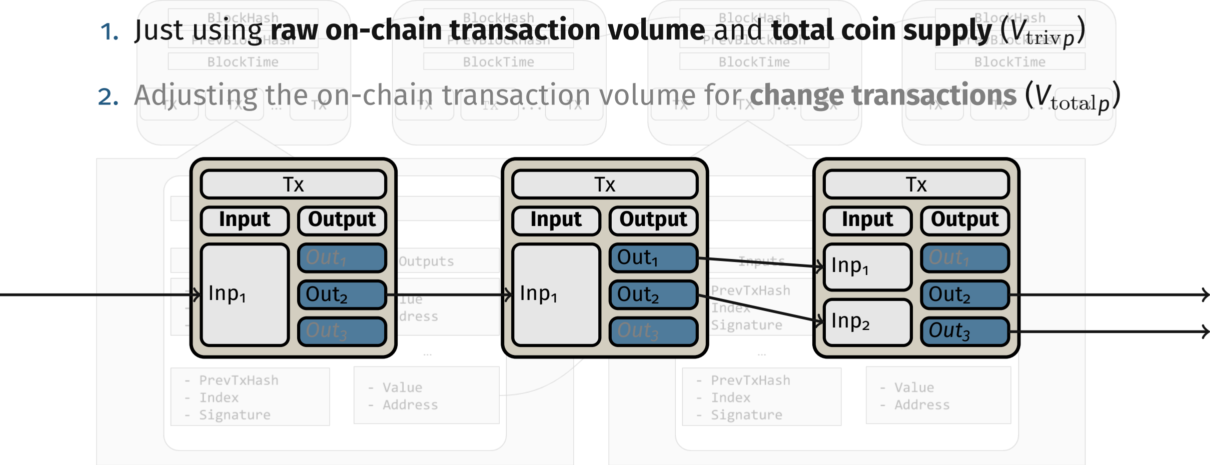

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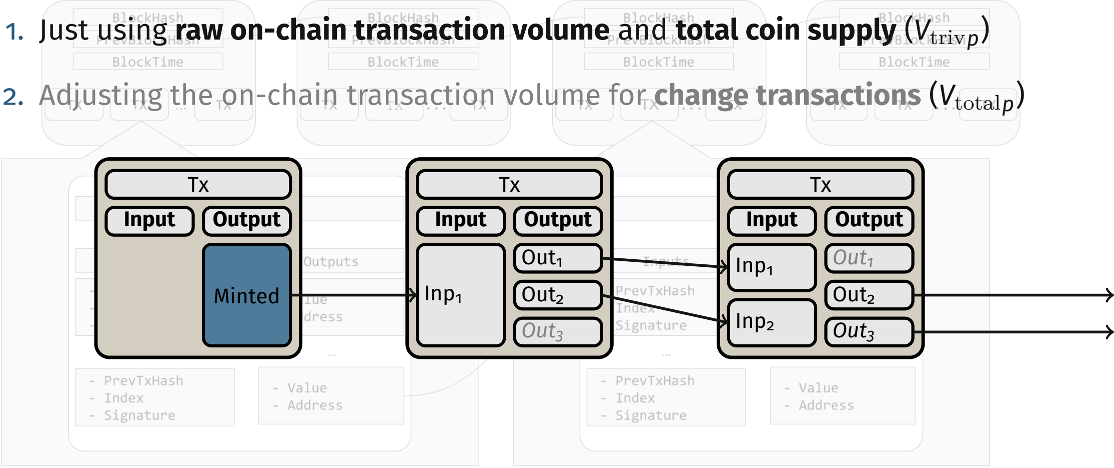

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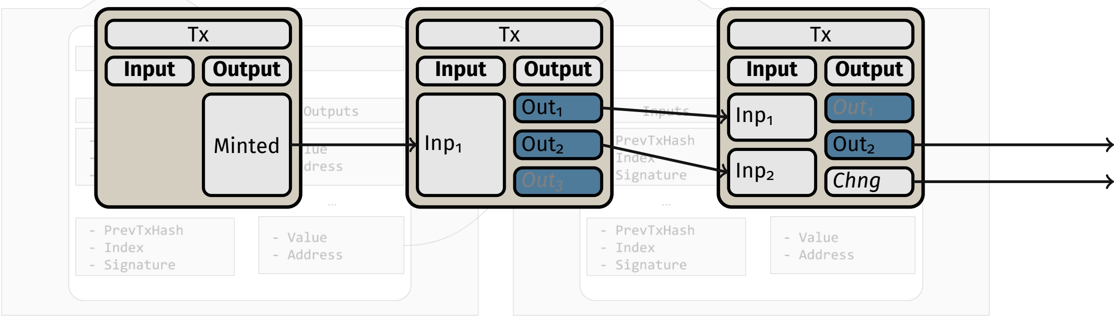


Adjusting the money supply for artefacts is the next logical step

Total coin supply as “**M**oney in circulation”?

$$\textbf{V}\text{elocity} = \frac{\textbf{T}\text{ransaction volume}}{\textbf{M}\text{oney in circulation}}$$

From total money supply. . .

"All units issued are components of the money supply."

VS

"[...] money is what money does."—Dalton (1965)

Functionality

- 3 functions not fulfilled
- supply split also in f.e. Fisher (1922), Keynes (1973), Commons (1973)

Feedback Loops

- Expected increases of prices and "hodling"
- Athey et al. (2016) , Bolt et al. (2016)

Technical

- lost crypto keys
- destroyed coins

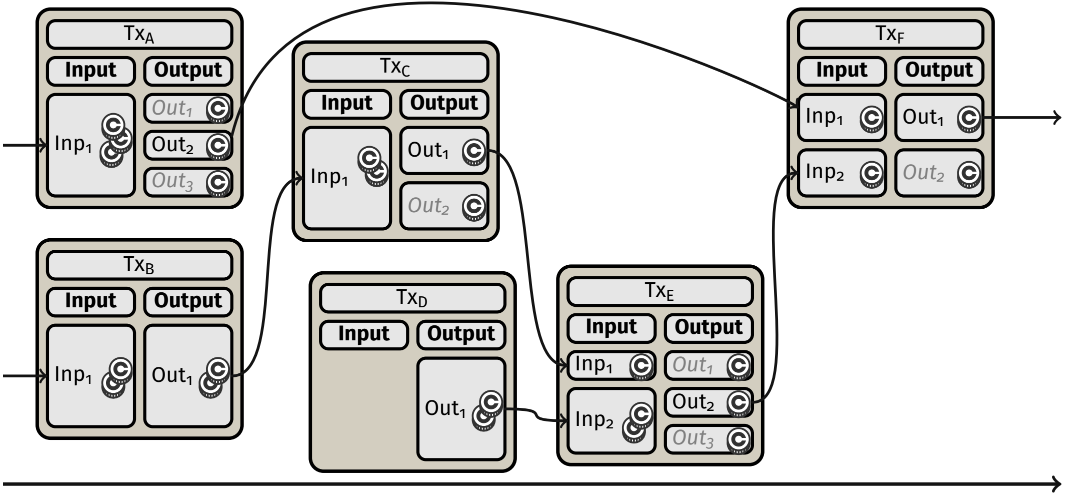
. . . to money supply in effective circulation

$$V_{\mathrm{circ}\,p} = \frac{\langle P_p, T_p \rangle}{M_{\mathrm{circ}\,p}}$$

- Interpretation $V_{\mathrm{circ}\,p}$: average number of turnovers for **effectively circulating money** units (in period p)
- Effectively circulating money $M_{\mathrm{circ}\,p}$ has been moved within a certain time period (e.g. in the last year or day).

Measuring money in effective circulation

Measuring money in effective circulation—whole bill approach



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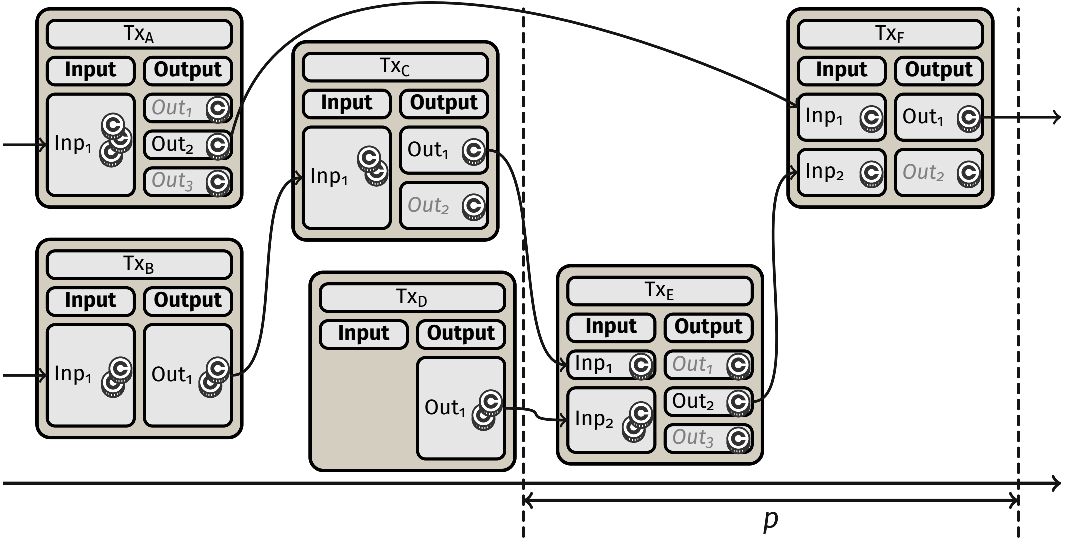

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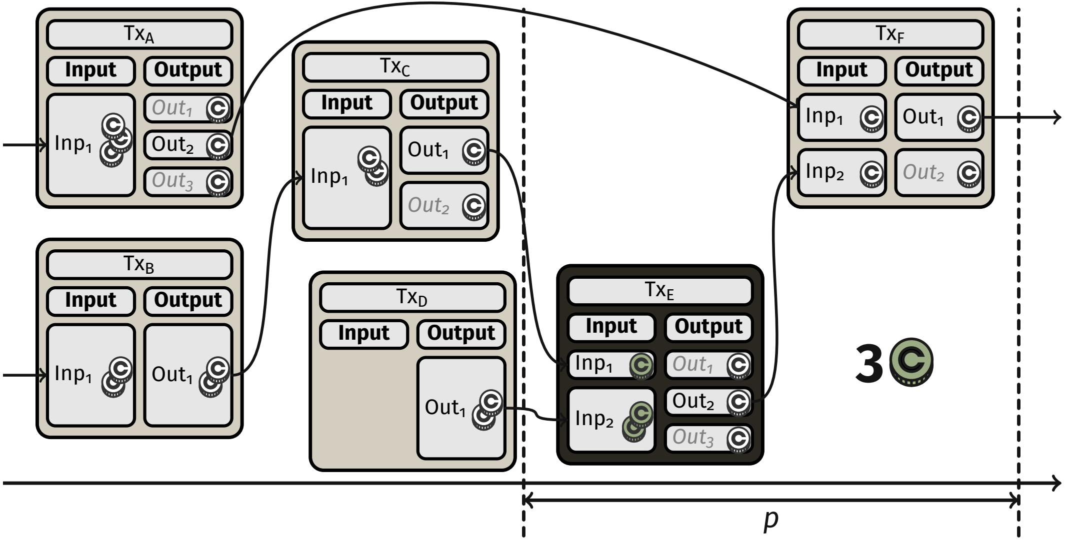

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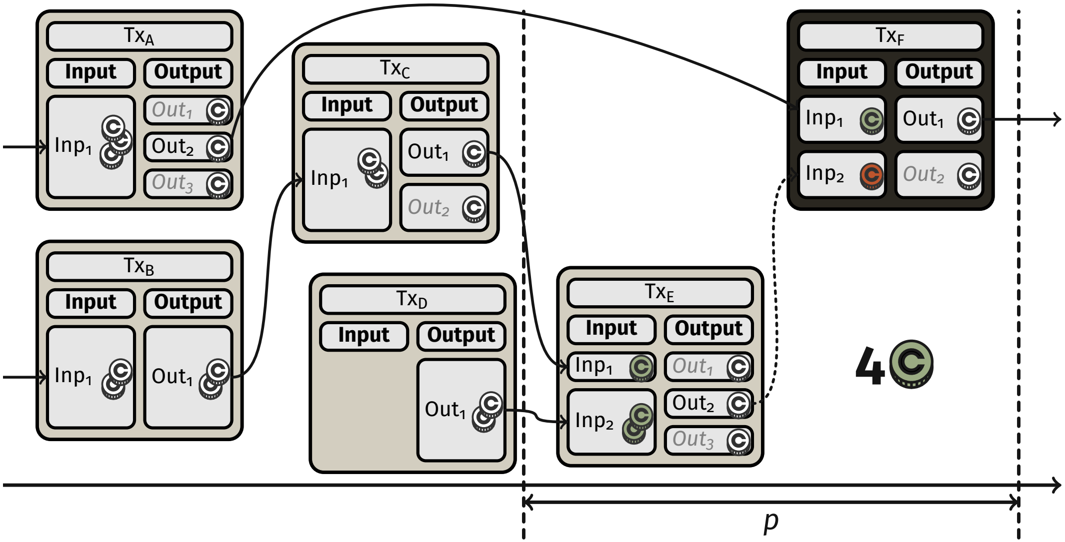

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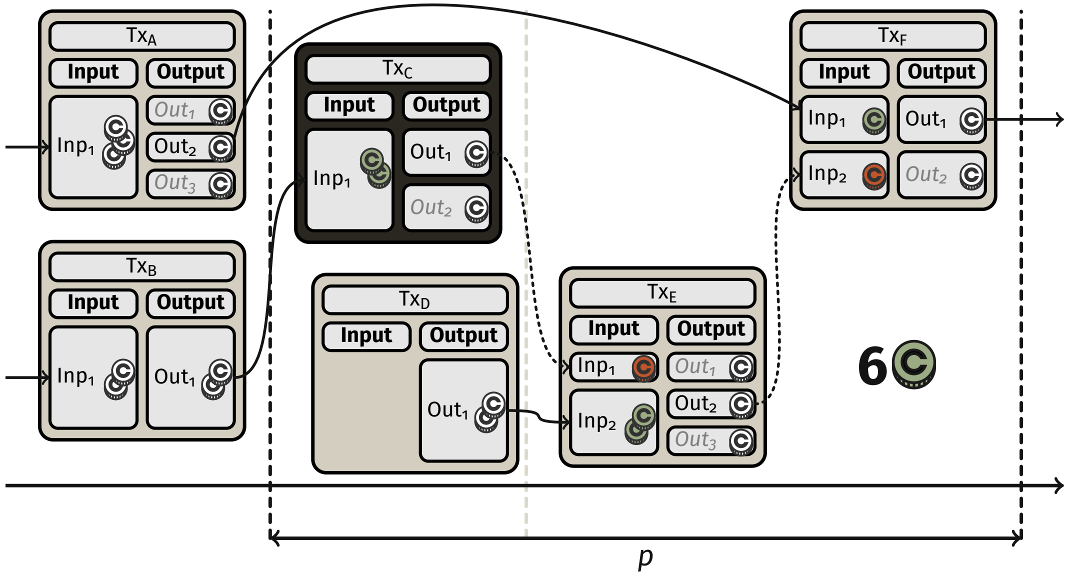

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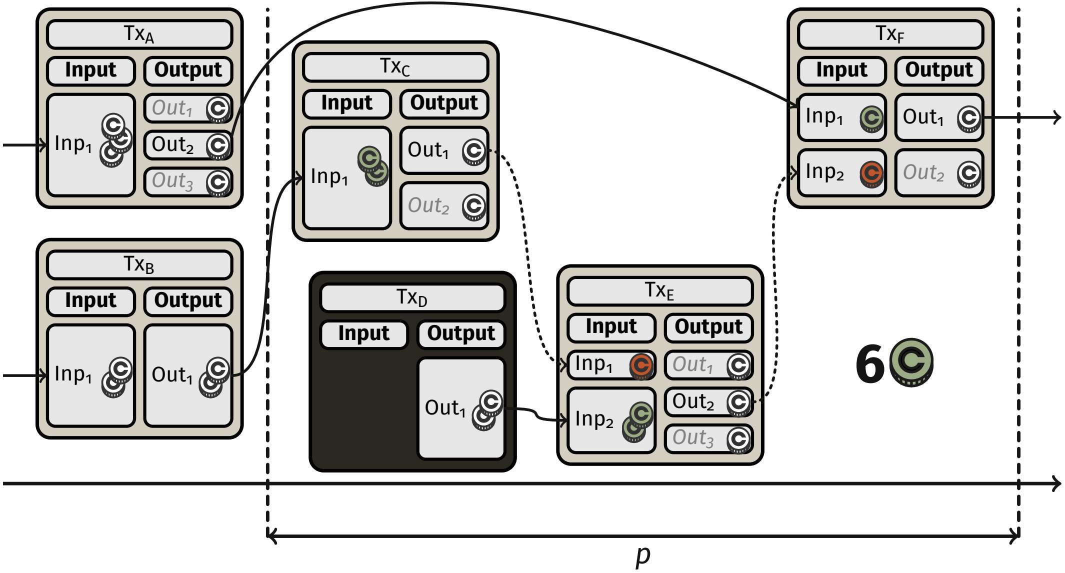

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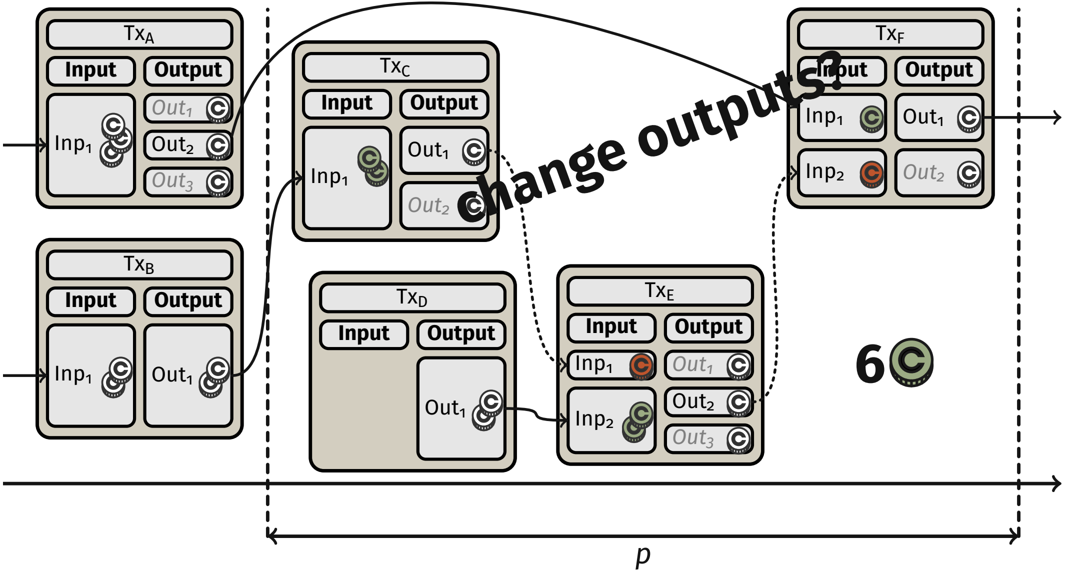
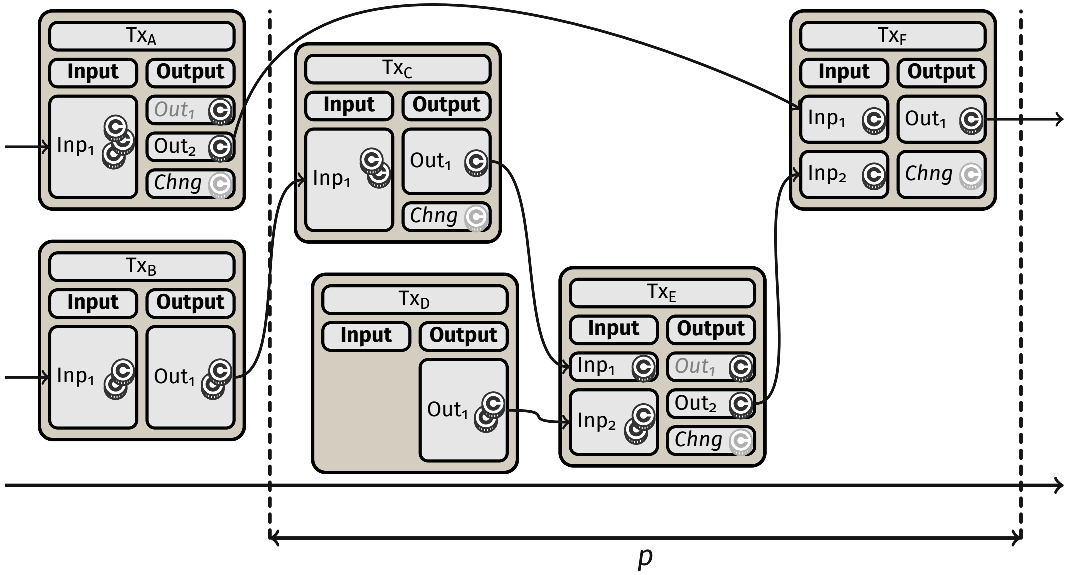


Measuring money in effective circulation—moved coins approach



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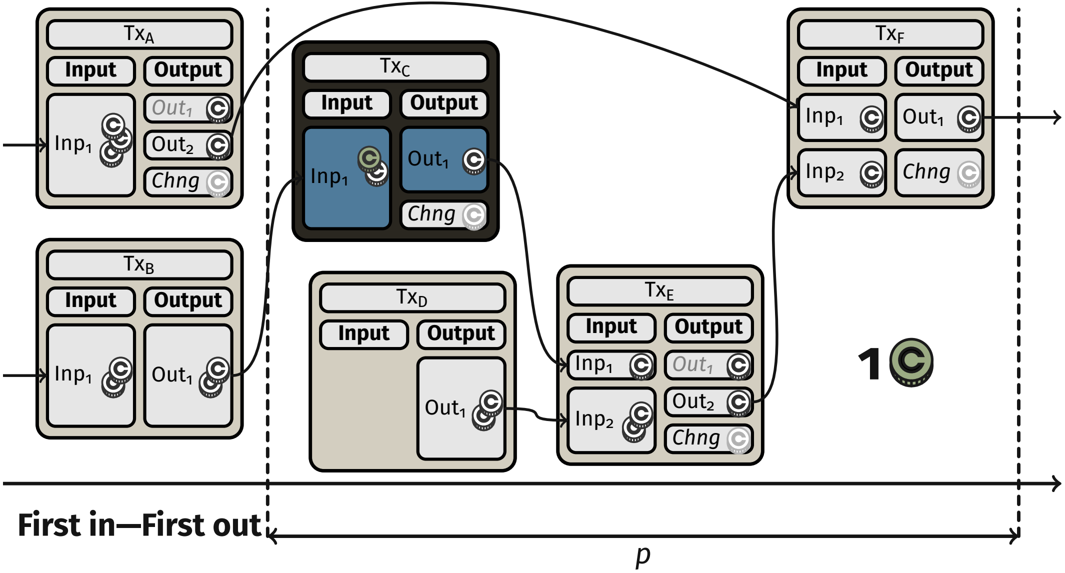

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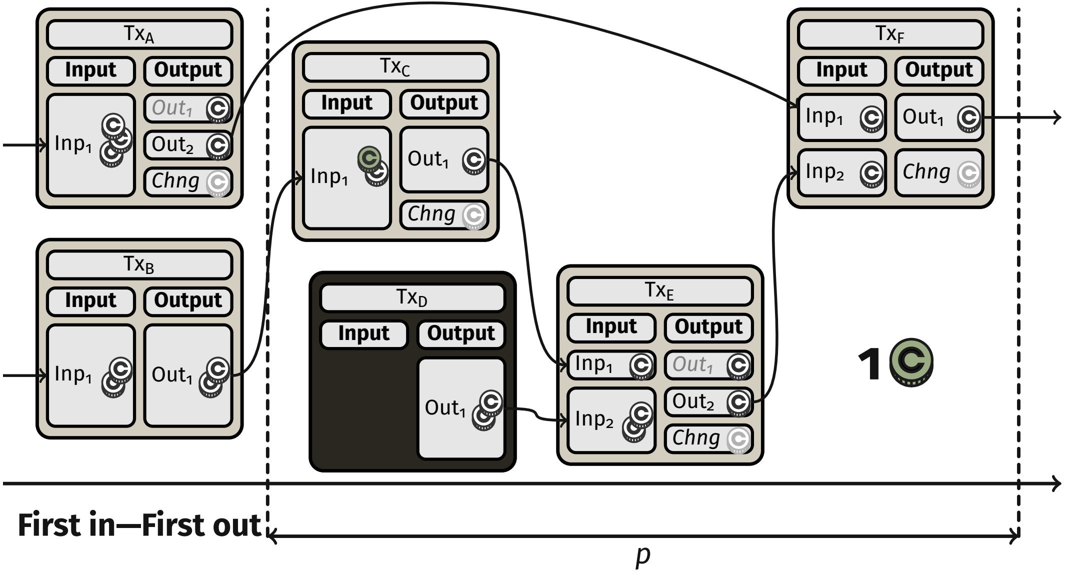

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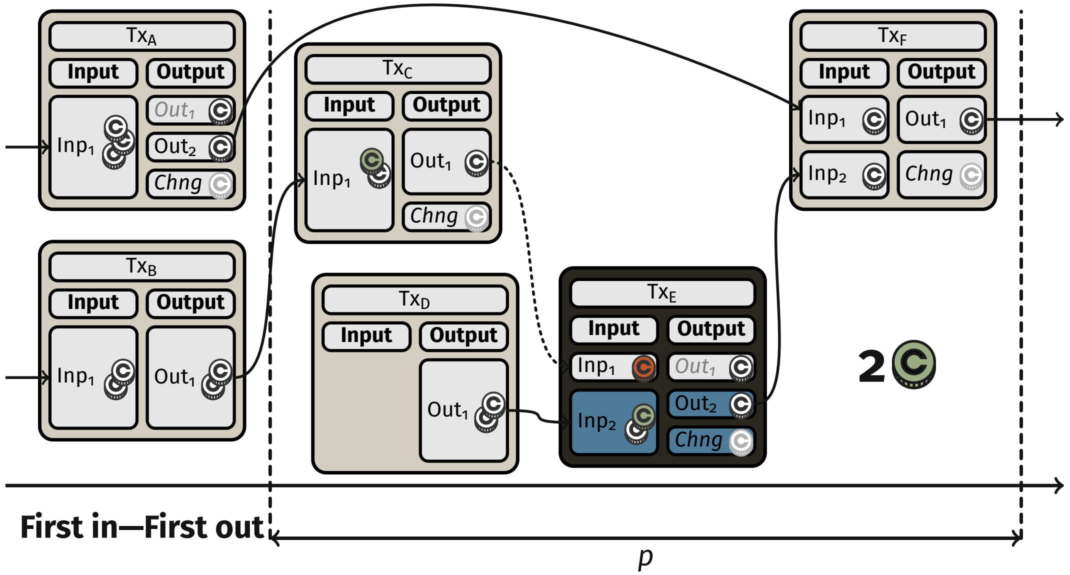

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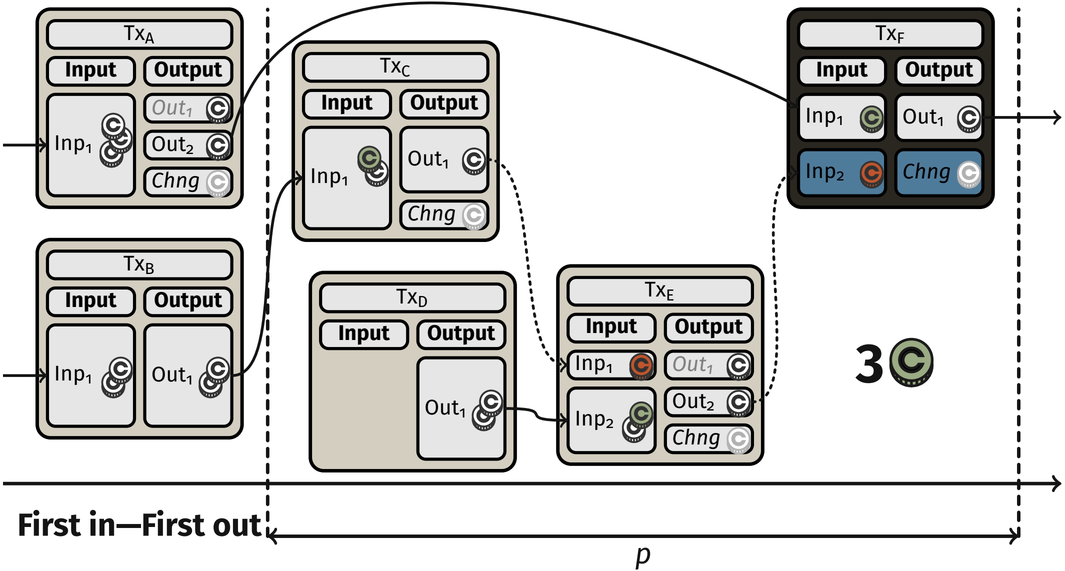

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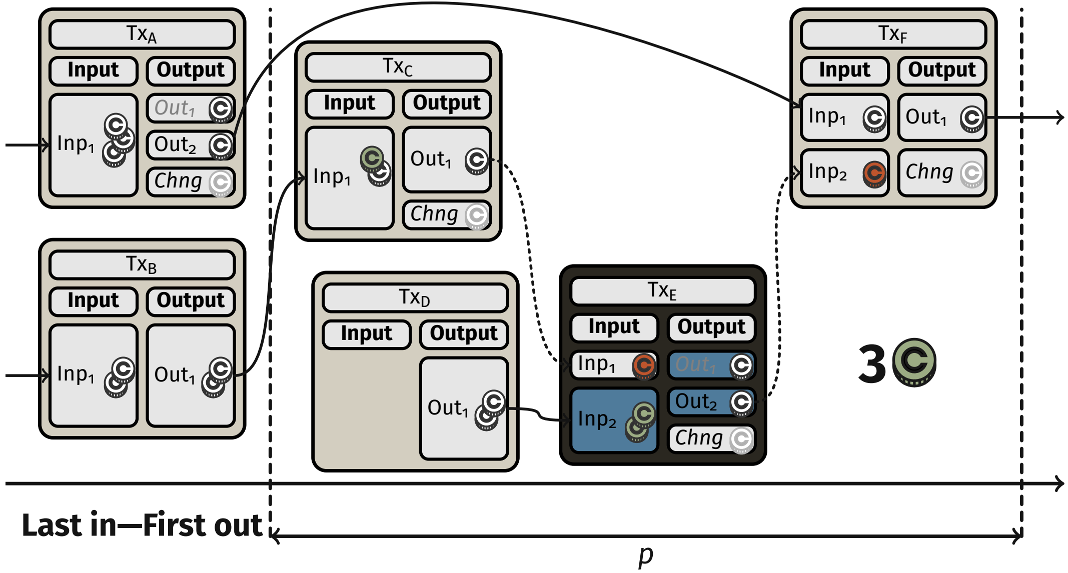

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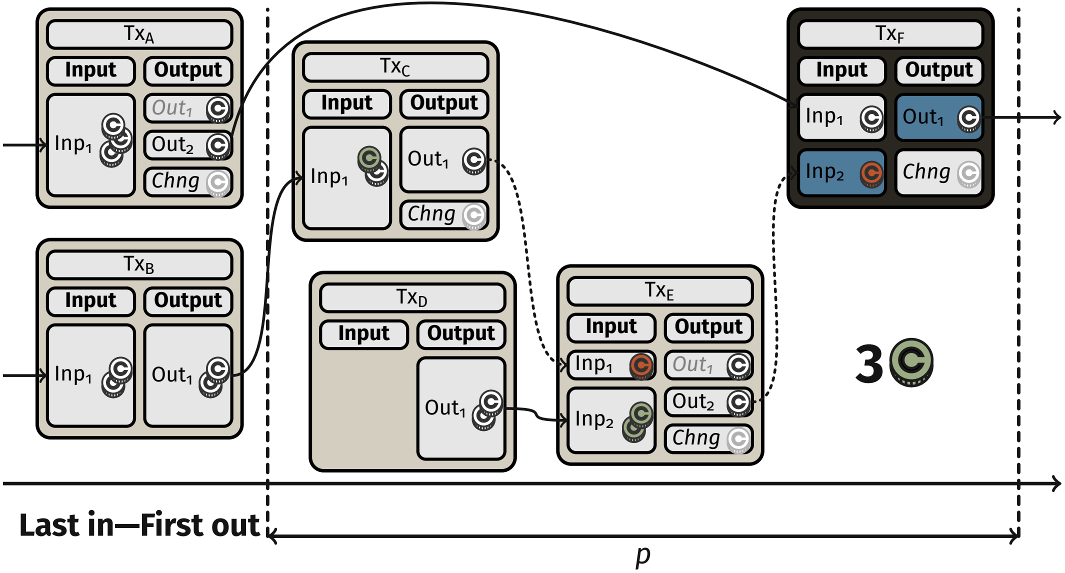

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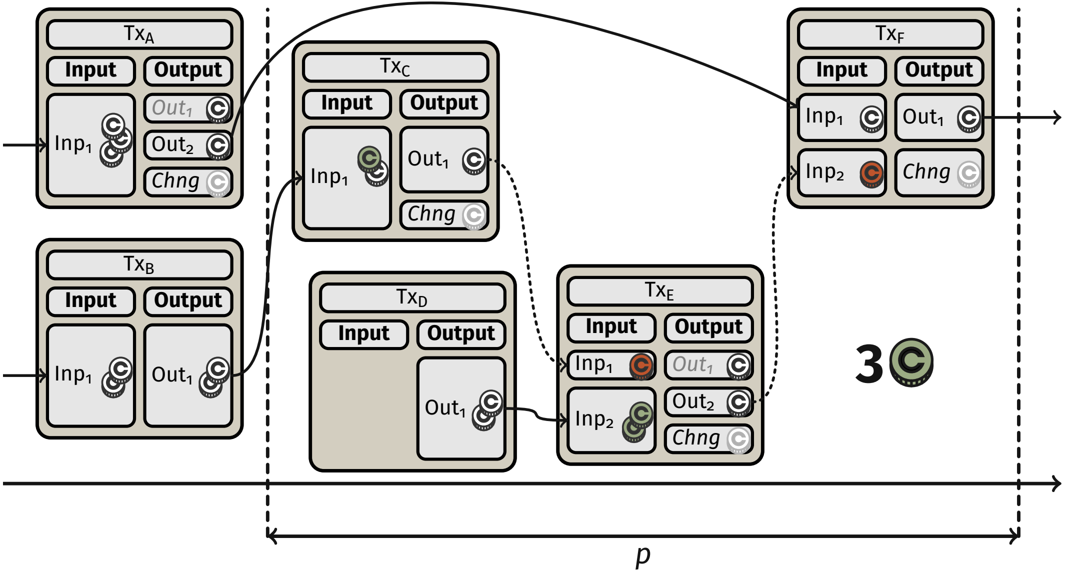

Could we simply use approximations?

Simple ways out to not use all these complicated measures:

- **Coin days destroyed**
- Approximate coin-turnovers[1]
- Ratio: Raw on-chain transaction volume to total coin supply

[1] *[Smith, Reginald D: Bitcoin Average Dormancy: A Measure of Turnover and Trading Activity. 2017.]*

Which one should I use?

Coin days destroyed is almost in all constellations yielding the largest deviations

The trivial measure is almost always significantly lowest

How did we test?

- Bitcoin, daily, 06/2013-06/2019
- Normalization / Standardization
- Mean Absolute Errors / Mean squared Errors
- Raw / First differences
- Model Confidence Set test for significance[2]

[2] *[Hansen et al.: The model confidence set. 2011.]*

Conclusion

1. Operationalization of a new velocity measure accounting for money that "does **not** do what money does".
2. Benchmarking of approximation quality for simple, established proxy-variables.
   - Indication that "coin days destroyed" should be reevaluated.
   - Simple ratio $\frac{\langle P_p, T_p \rangle}{M_p}$ might be preferable.
3. Limitations & Future research:
   - Only on-chain data so far.
   - More sophisticated heuristics for identifying change money.
   - Augment the benchmarking study (different coins, different periodicities)
   - Search for an optimal window-size

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Testing

- $X_t^{\mathrm{norm}} = \frac{X_t - X_t^{\mathrm{min}}}{X_t^{\mathrm{max}} - X_t^{\mathrm{min}}} \in [0, 1]$
- $X_t^{\mathrm{stand}} = \frac{X_t - \mu(X_t)}{\sigma(X_t)}$

Mean Absolute Errors / Mean squared Errors

- $MAE = \sum_t MAE_t = \sum_t \left|\hat{X}_t - X_t\right|$
- $MSE = \sum_t MSE_t = \sum_t \left(\hat{X}_t - X_t\right)^2$

Raw / First differences

- $X_t^{\mathrm{raw}} = X_t$
- $X_t^{\mathrm{diff}} = X_t - X_{t-1}$

Model Confidence Test—Significance of results

We compare models i and j for all $i, j \in M$ where $i \neq j$.
Loss functions are MAE and MSE.

Thus (exemplified for MSE)

$$d_{ijp} = \left(V_p^{\mathrm{msr}} - V_{ip}^{\mathrm{app}}\right)^2 - \left(V_p^{\mathrm{msr}} - V_{jp}^{\mathrm{app}}\right)^2.$$

The relative performance of model i compared to all other models then is

$$d_{i.} = \frac{1}{m-1} \sum_{j \in M \setminus i} d_{ij},$$

with $i = 1, \ldots, m$. The null hypothesis states

$$H_{0M} : E(d_{i.}) = 0, \ \forall i \in M.$$