Ethereum's Fee Market Reform of EIP 1559

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Current Fee Market Mechanism

Users	Transactions	Miners
• Submit transactions to a common pool that is viewed by miners	• Each transaction requires some predefined gas	• Select which transactions to include
• Users bids = gas prices: how much they are willing to pay for each unit of gas	• Including a transaction poses risks: increases block size and propagation time → risk for stale blocks	• Choose to include only transactions that cover their intrinsic marginal costs

Current Mechanism: Generalized First Price Auction

- A typical transaction requires 21k gas units.
- Block size is 20M gas units (about 950 transactions).

- Users with similar transactions/ but different valuations for their transactions/ urgency to process their transactions.
- Typically: n users to bid for k slots with n >> k.

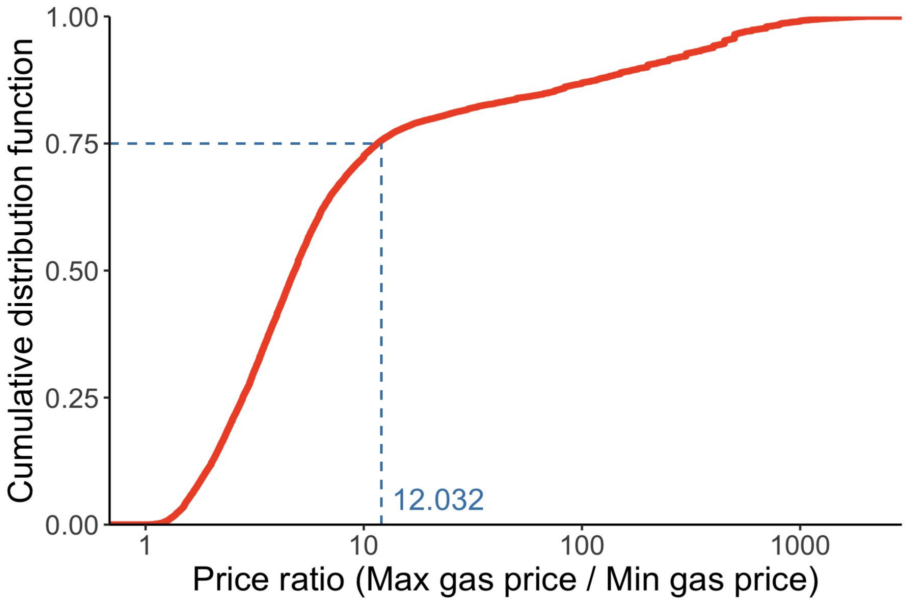
- Generalized First Price Auction

Current Mechanism: Problems

- Extremely volatile transaction fees
- Unnecessary transaction delays
- Unnecessary guesswork for the right fee

Random day: September 27

- Over 25% of blocks report a price ratio above 12!



Current Mechanism: Problems

- Extremely volatile transaction fees
- Unnecessary transaction delays
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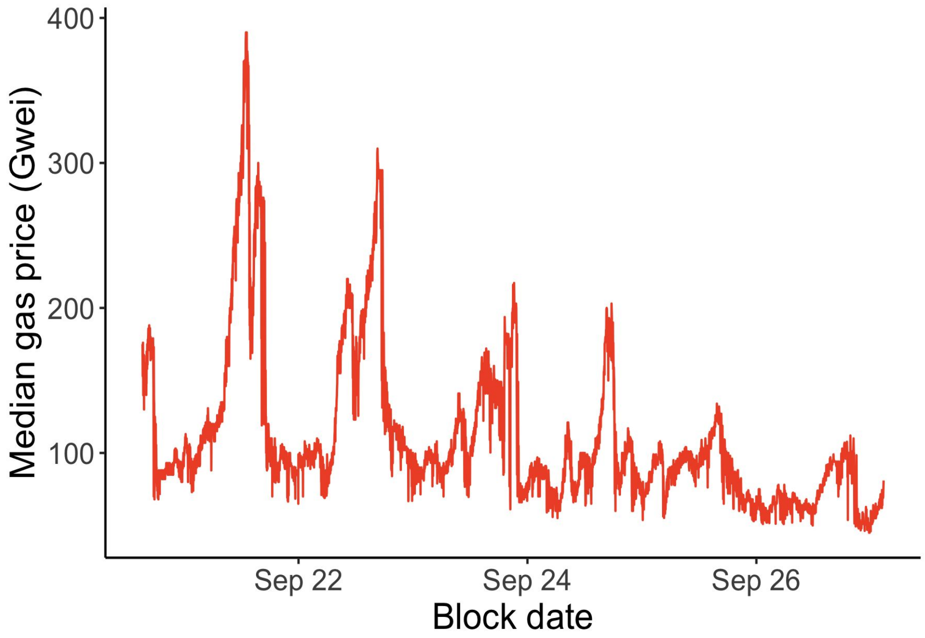
Random week: September 21-27

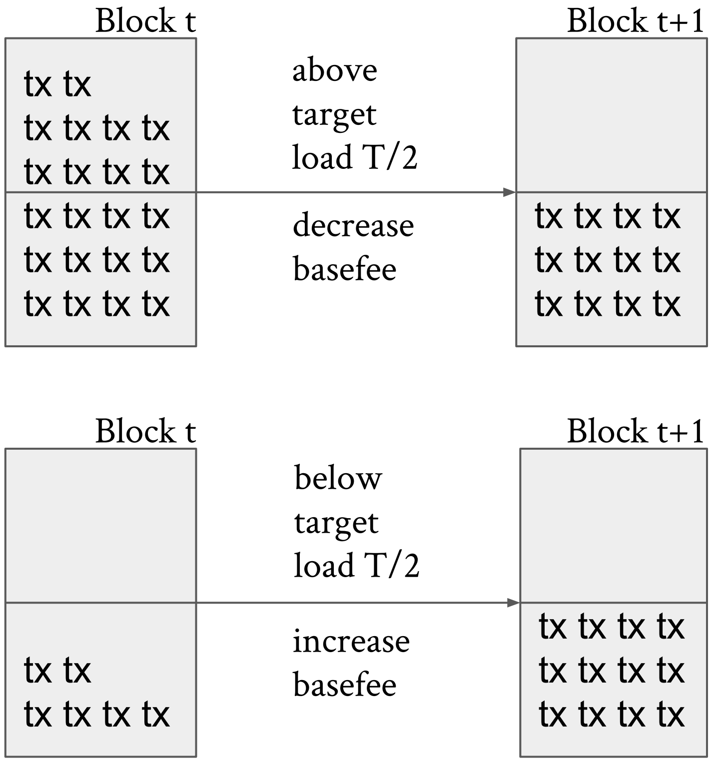
- Median gas prices fluctuate from 400 Gwei to 100 Gwei.



Proposed Reform: EIP 1559

Idea: set a target block load and a dynamic minimum gas price, called basefee which

- increases when blocks are above target ("too full")
- decreases when blocks are below target load ("too empty")



Proposed Reform: EIP 1559

- Set a target block load and a dynamic minimum gas price to achieve this
- Parameters

User bids	Protocol	Miners	Transaction
f = feecap p =premium	T/2 = target load b = basefee	e = minimum marginal cost	✔️ or ❌

- feecap: the highest price the user is willing to pay
- basefee: a dynamic minimum gas price that is burnt
- premium: the maximum tip the miner may receive from the transaction

Proposed Reform: EIP 1559

- Examples

User	Protocol	Miner	Transaction	Why?
f = 10, p = 2	b = 6	e = 2	✔ included	$f>b+e$, $p>e$
f = 10, p = 1	b = 6	e = 2	❌ not included	$f>b+e$ but $p<e$
f = 10, p = 2	b = 9	e = 2	❌ not included	$p>e$ but $f<b+e$

- Condition for inclusion:

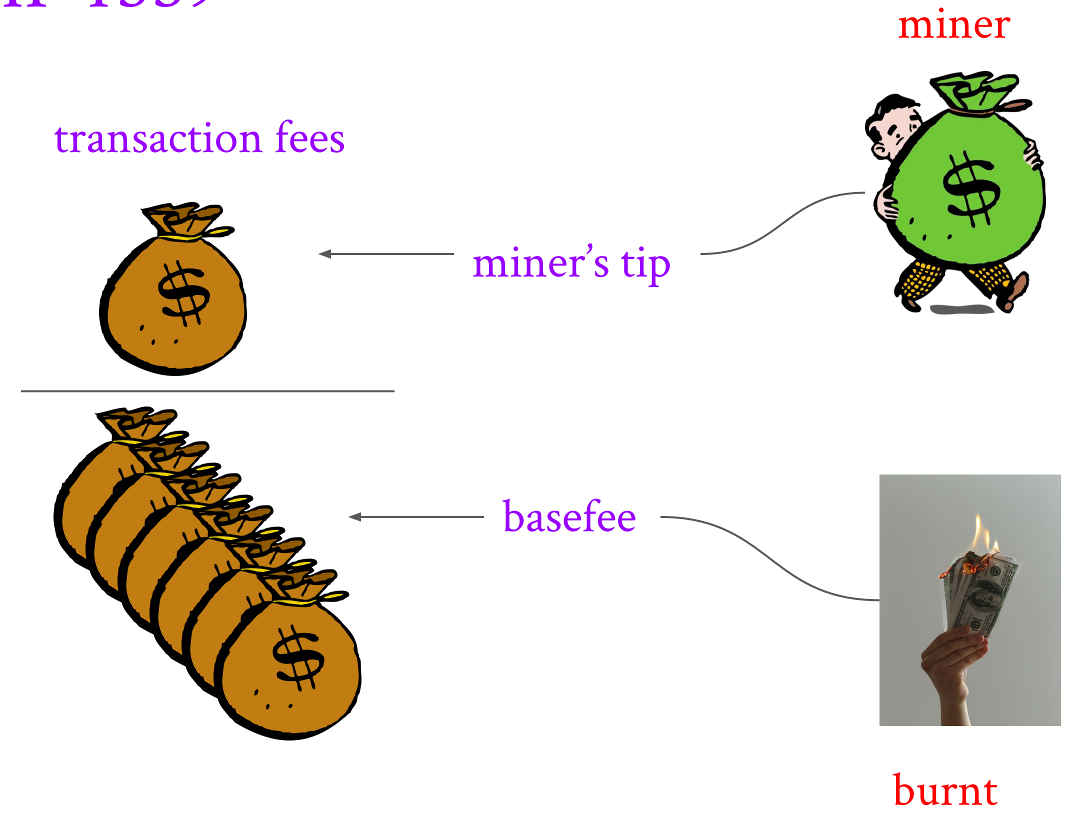
$$\min(f - b_t, p) > e$$

- Left side: miner’s tip

Proposed Reform: EIP 1559

If condition is met, then

- user pays transactions fees at most its feecap
- basefee is burnt
- miner's tip at most the premium set by the user



Goals of EIP 1559

- Price discovery for the transaction fee (quickly match demand fees)
- Price-taking behavior (transparency, efficiency): next-block inclusion
- Not a goal: lower fees (but yes, lower variance of fees)
- Not a goal: always the same fee

Goal of this work

- Test the basefee dynamics theoretically and experimentally under different assumptions

Basefee: Dynamic Adjustment

The basefee, b_{t+1}, at block height t+1 is

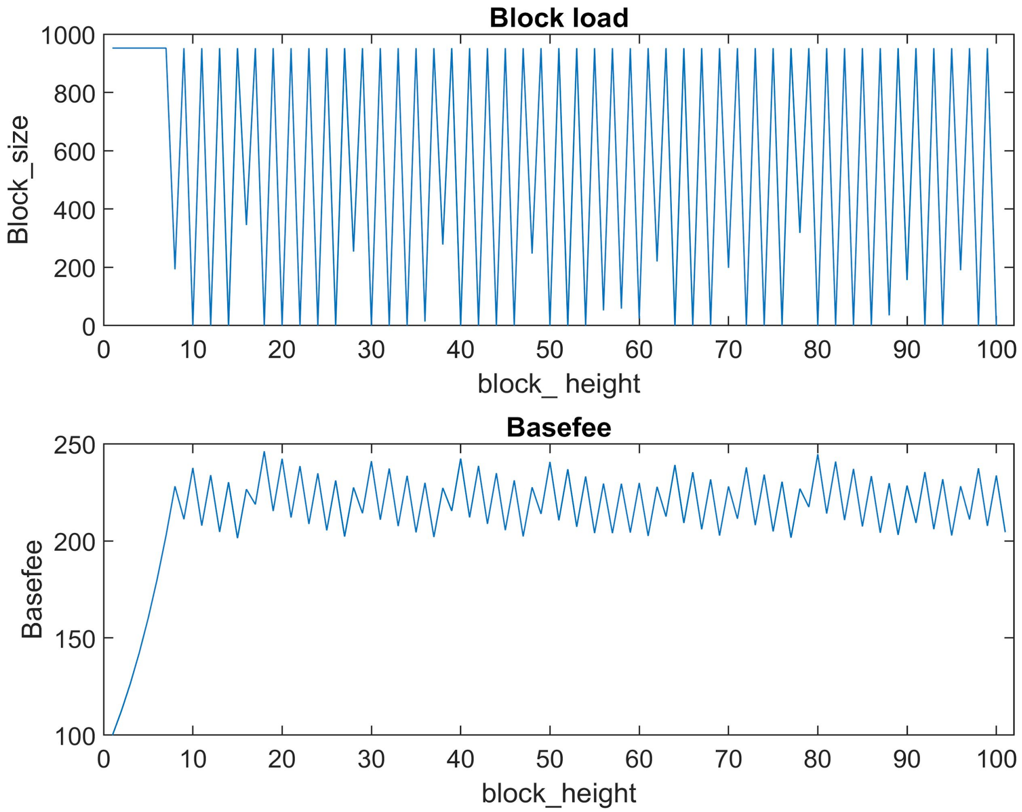
$$b_{t+1} = b_t \left(1 + d \times \frac{g_t|b_t - T/2}{T/2}\right)$$

- d = adjustment parameter or step size (think d = 12.5%)
- T/2 = target block size (think T = 952)
- $g_t \mid b_t$ = number of included transactions in block B_t, t>0 given that the basefee is b_t.

This a stochastic process with the Markov property.

Edge Cases

- Proofs of convergence difficult due to edge cases
- E.g.: all users have similar valuation, and basefee jumps (by a step of d) from below to above and vice versa.
- Here: 3000 arrivals per block with equally spaced valuations in 200-230.



Basefee: Dynamics

- Pointwise convergence: not possible
- Convergence in expectation? If block size is unlimited, then

$$\mathbb{E}[g_t \mid b_t] = \mathbb{E}\left[\sum_{i=1}^{N} X_i \;\middle|\; b_t\right] = \mathbb{E}[N]\mathbb{E}[X \mid b_t] = \lambda\cdot(1-F(b_t+\epsilon)),$$

where λ is the Poisson arrival rate of transactions and F is the distribution of valuations.

Basefee: Dynamics

- Pointwise convergence: not possible
- Convergence in expectation? If we ignore the limit in block size for a while, then the sequence of conditional expectations is

$$\mathbb{E}[b_{t+1} \mid b_t] = b_t + b_t \left(\frac{d}{T/2} \left[\lambda \left(1 - F(b_t + \epsilon) \right) - T/2 \right] \right)$$

which yields a single fixed point candidate

$$b^* = F^{-1}(1 - T/2\lambda) - \epsilon$$

Theorem

- Consider the deterministic process $b_{t+1} = b_t \times (1 + r_t)$ with

$$b_{t+1} = b_t + b_t \times \frac{d}{T/2} \left(\min \{ T, \lambda(1 - F(b_t + \epsilon)) \} - T/2 \right)$$

- Then

$$b_{t+1} \to [(1-d)b^*, (1+d)b^*]$$

Proof

- One-dimensional deterministic dynamical system
- Sign analysis on the rate of change

$$r_t = d \times \left(\frac{\min\{T, \lambda(1 - F(b_t + \epsilon))\} - T/2}{T/2} \right)$$

with $r_t > 0$ for $b_t < b^*$ and $r_t < 0$ for $b_t > b^*$.

- Bounded oscillations: starting at a $b_t > b^*$

$$b_{t+1} > b_t(1 - d) > b^*(1 - d)$$

and analogously when starting at a $b_t < b^*$.

Relaxing the assumptions

- Block size = T, then

$$\mathbb{E}[g_t \mid b_t] = \mathbb{E}\Big[\min\Big\{T, \sum_{i=1}^{N} X_i\Big\} \,\Big|\, b_t\Big] \leq \min\Big\{T, \mathbb{E}\Big[\sum_{i=1}^{N} X_i \,\Big|\, b_t\Big]\Big\}$$
$$= \min\{T, \lambda(1 - F(b_t + \epsilon))\}.$$

- Hence

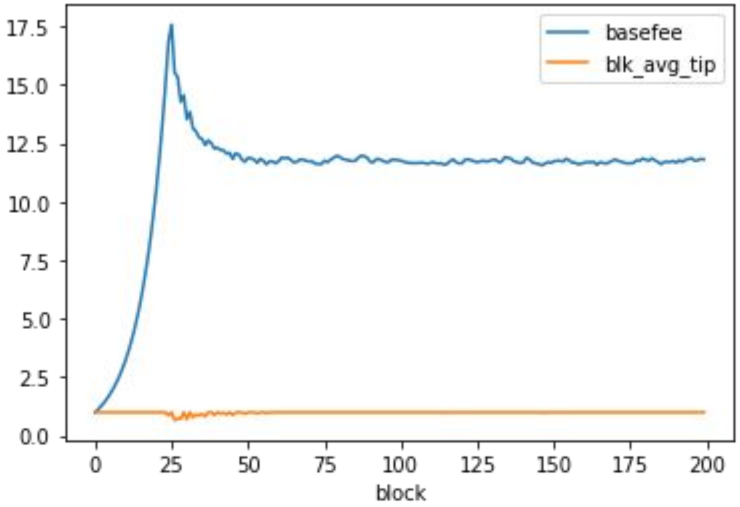
$$\mathbb{E}[b_{t+1} \mid b_t] \leq b_t \left(1 + \tfrac{d}{T/2}\left[\min\{T, \lambda\,(1 - F(b_t + \epsilon))\} - T/2\right]\right)$$

and the same proof applies in an upper bound sense.

Non-Strategic Users

- Poisson arrivals of constant rate suggest that price discovery occurs fast and the basefee stabilizes there

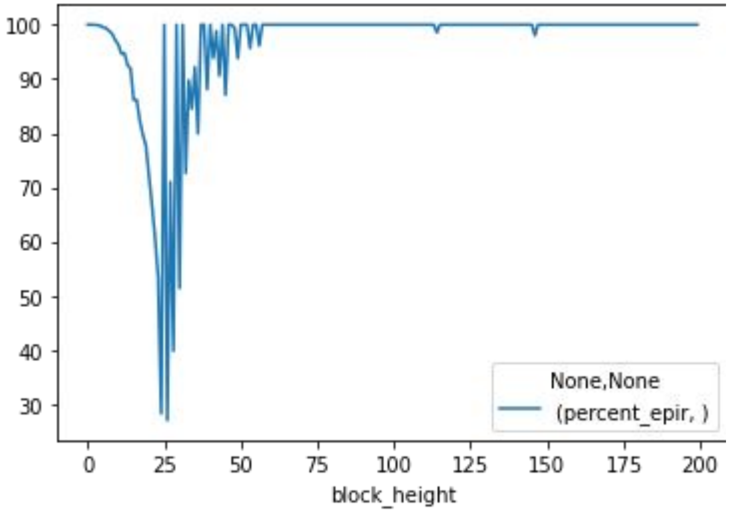
- Users bid their valuation as feecap and miner's cost as premium.



payoff = value - waiting cost (per block) - transaction fee

Non-Strategic Users: Ex-post Rationality

- Some users receive negative utility but only before the basefee reaches its stationary level

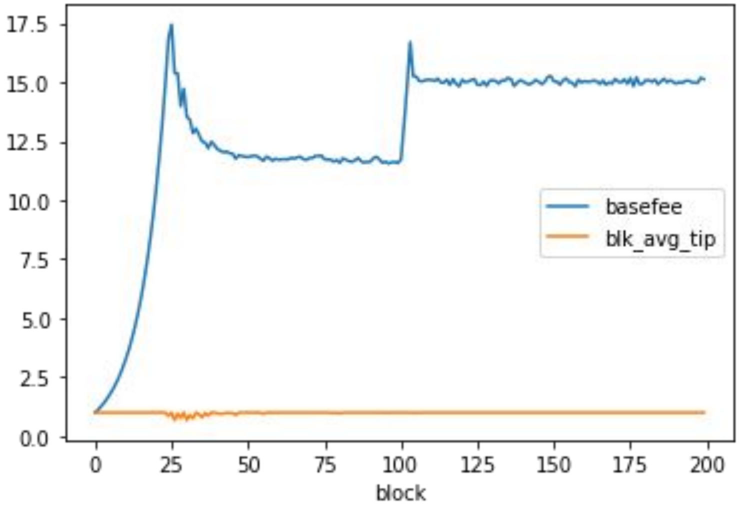


payoff = value - waiting cost (per block) - transaction fee

Non-Strategic Users: Demand Shocks

- Poisson arrivals with demand shocks suggest that price discovery occurs fast and the basefee stabilizes there

- What is the speed of convergence?

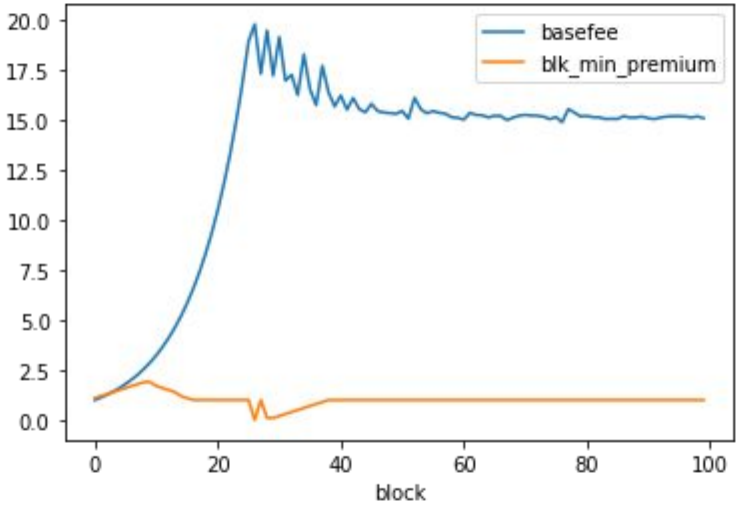


payoff = value - waiting cost (per block) - transaction fee

Strategic Users

- Non-strategic Users (fixed bids according to their parameters)

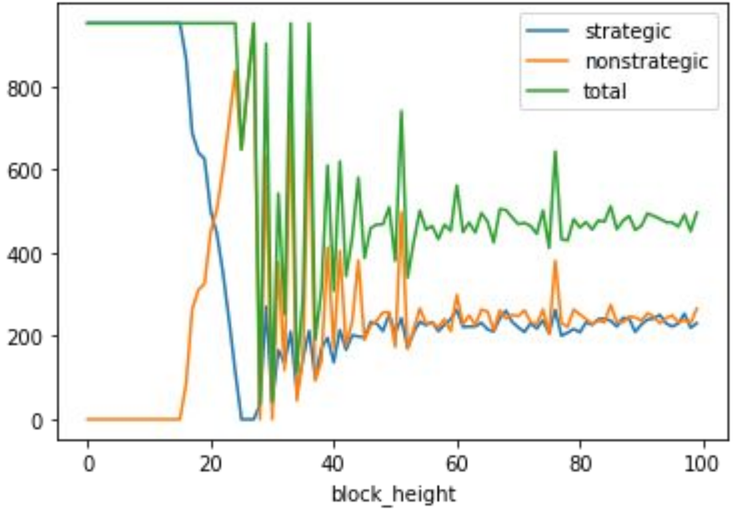
  Strategic Users (bid their valuation as feecap and min premium + increment seen in previous block)



early on: strategic users bid against each other instead of their true value

Strategic Users: Inclusion Rates

- First blocks only strategic users
- When the basefee stabilizes strategic and non-strategic users are included in the same ratio

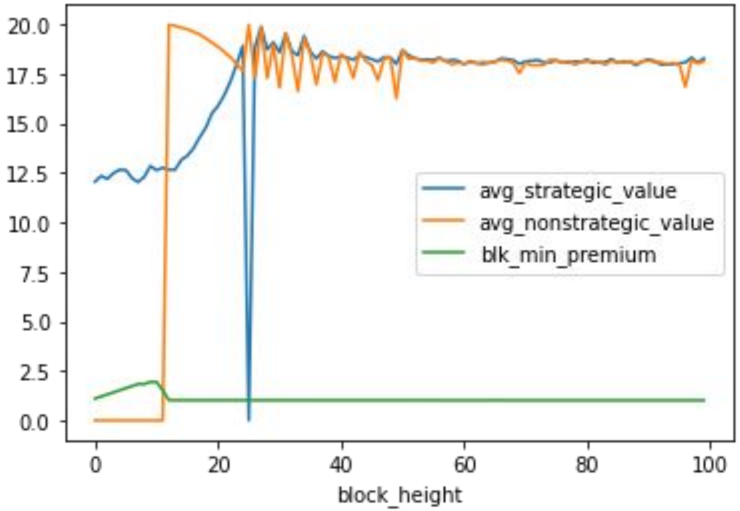


- Figure: numbers of included

but: when basefee settles, strategic behaviour does not help

Strategic Users: Valuations

- First blocks: strategic premium determines inclusion
- Stationary blocks: basefee and valuation determine inclusion



- Figure: values of included

but: when basefee settles, strategic behaviour does not help

Open Questions - Current Work

- Study the mode of convergence (if any) of the dynamic update rule
- Continue to study different scenarios (already promising results)
- Transition period
- (Floating) Escalator
- …

All code and notebooks open-sourced in the abm1559 library (Github)

Thank you