Becoming Immutable: How Ethereum is Made

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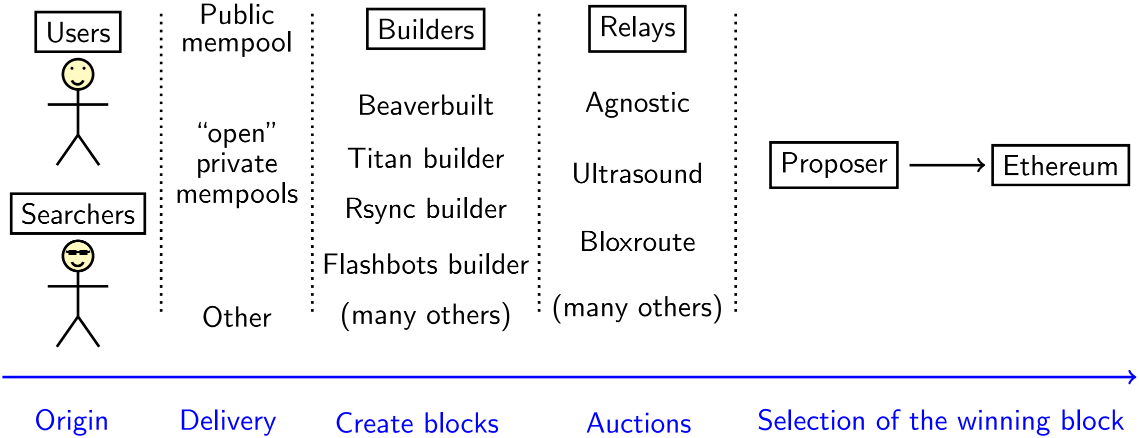
- In what way these intermediaries affect/distort Ethereum's fundamental promise?

Background: The Journey of an Ethereum Transactions



Users

Searchers

Public mempool

“open” private mempools

Other

Builders

Beaverbuilt

Titan builder

Rsync builder

Flashbots builder

(many others)

Relays

Agnostic

Ultrasound

Bloxroute

(many others)

Proposer → Ethereum

Origin

Delivery

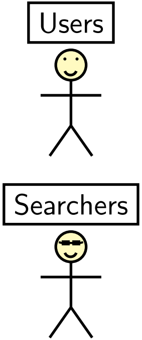
Create blocks

Auctions

Selection of the winning block

(Repeat approximately every 12 seconds)

Origin of transactions

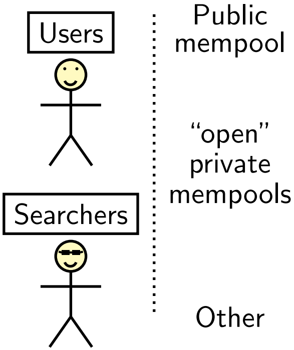


Users

Searchers

- Searchers: arbitrage bots, sandwich bots, liquidation bots, ...
- We classify a tx as a ‘searcher’s tx” if: (1) it is a swap, (2) generated using a smart contract, (3) whose code is not disclosed

Delivery of transactions



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- Other: direct communication with builders

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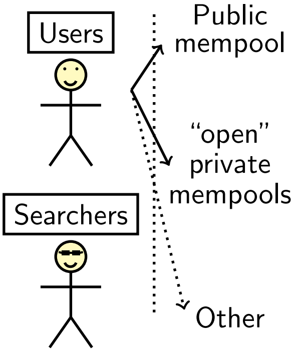

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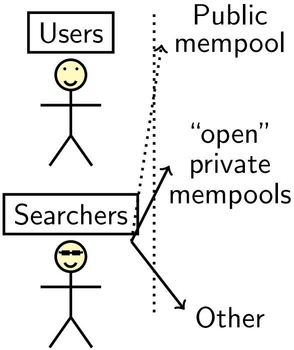

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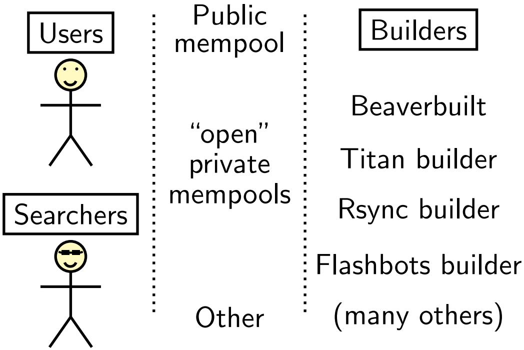
Packaging Transactions into Blocks (Builders)



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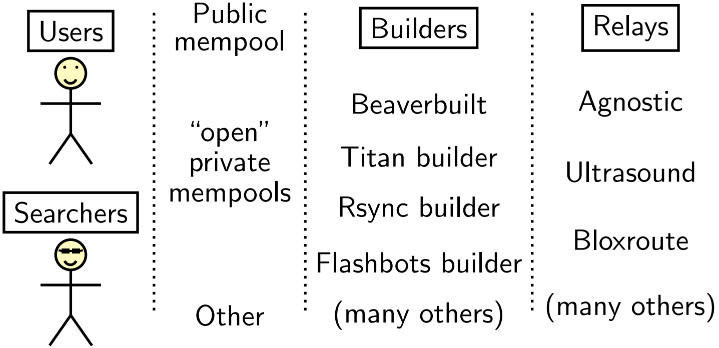
- Public transactions: appear in the public mempool and are available to all builders,
- Private transactions: not public but are included in blocks by multiple builders
- Exclusive transactions: appear only in blocks by a single builder.

Bidding (Relays)



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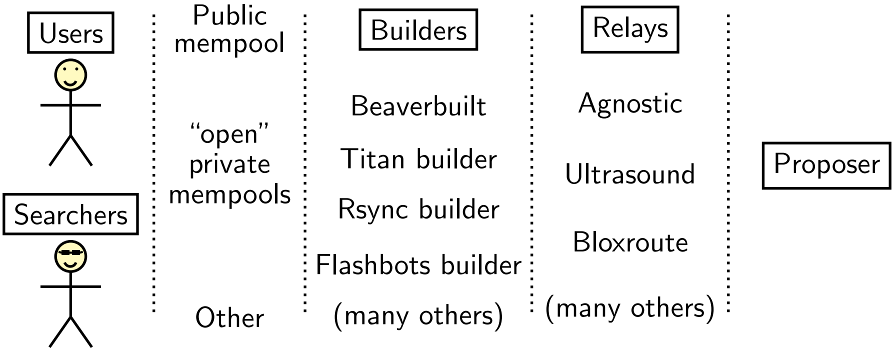
Each relay runs an ascending price auction: block builders submit bids by proposing a block and a payment to the block proposer

The block proposer (or validator)



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Proposer

- The block proposer is known in advance and changes with every slot
- The block proposer queries each relay it is connected with for its highest-paying block
- It chooses the best-paying overall and adds it to the blockchain

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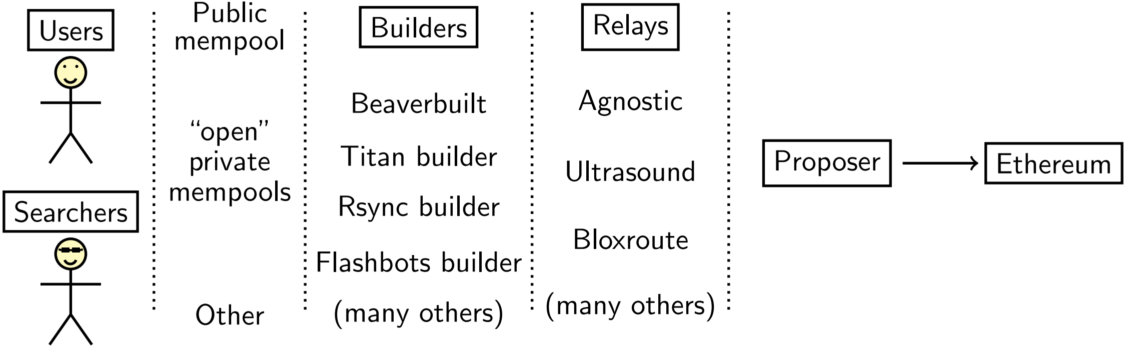

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  - For each block received, each relay discloses its hash, the name of the builder, a timestamp, and the associated bid, but not its content.
- **Private mempools / RPC endpoints** are becoming increasingly important:
  - MEV Blocker, MEV Share, Blink, Merkle share users' transactions with multiple builders;
  - no public documentation on how Metamask Smart Transactions work.

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Open research question: it requires to compare the content of non-winning blocks with that of the winning one.

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- Novel dataset but unbalanced:
  - Missing 11 auction cycles
  - Very few blocks from Beaverbuilt (9.4% in our data vs 40.2% total)

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  - We identify them as builder-integrated searchers performing CEX-DEX arbitrage, and call them “Rsync-bot” and “Titan-bot”.
- We find that 85% of the value of winning blocks is from exclusive transactions (10% from private but not exclusive transactions, the rest from transactions that go through the mempool).

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Sharing policy of a private RPC operator?

A possible explanation: a private RPC shares transactions exclusively with one builder and falls back to the public mempool only after that builder loses several slots in a row.

Result 2: Execution Quality is Heterogeneus across Candidate Blocks

The execution of the same swap transaction (fail/succeed and price received if successful) varies across proposed blocks, and the distribution is very skewed:

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blockchain is far from deterministic when we include the transaction inclusion process

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- They appear "integrated" with two builders: we call them *Titan-bot* and *Rsync-bot*.
- We can derive an implied CEX price and compare it to Binance.
- On the WETH/USDC and WETH/USDT markets, the bots trade at 2.8 bp *better* than the contemporaneous Binance price.

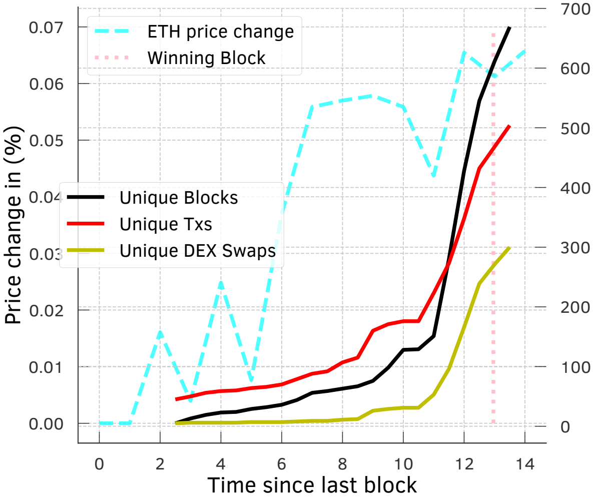
Outline

1. Auction cycle for Block 21322649 (nice graphs)
2. All data (regressions)
3. Relevant literature & Conclusions

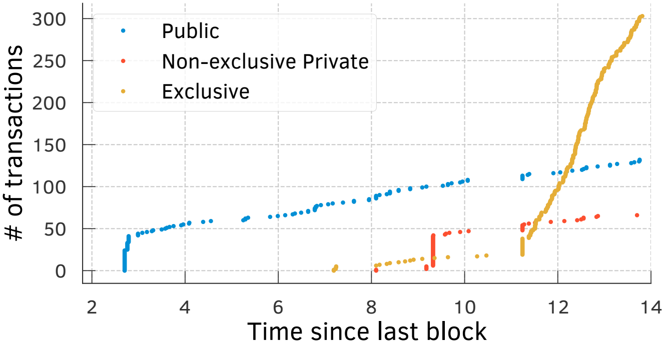
The auction cycle for block 21322649

Why this auction cycle?

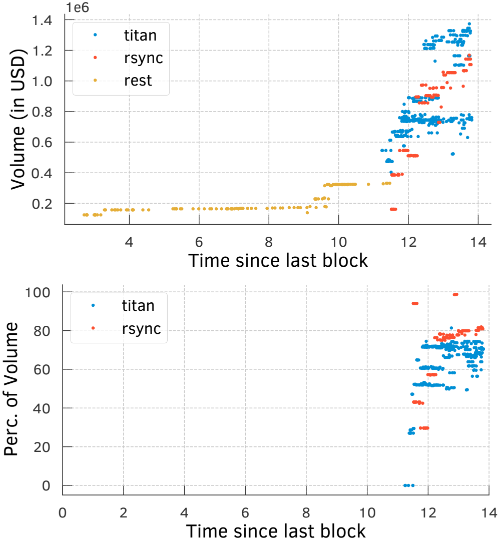
- Intense competition between Rsync and Titan builders *across all relays*.
    - Rsync wins in the end.
- Rsync-bot and Titan-bot compete on the same DEX pools and are responsible for 94%–97% of the total value of the blocks built by their respective builders.



Number of Unique transactions, blocks and swaps vs ETH price change on Binance, during the auction cycle for Block 21322649

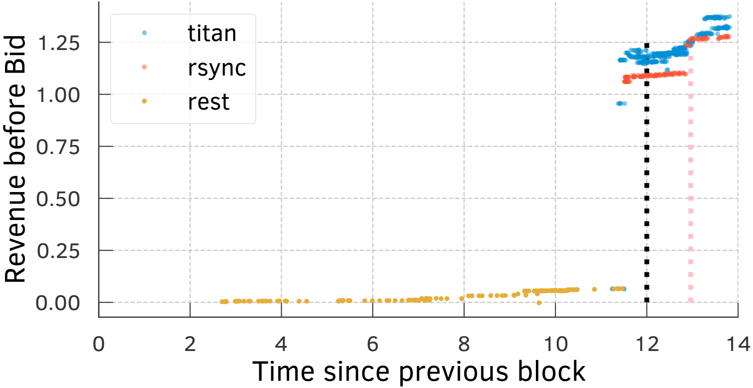


Number of Unique Public, Private, and Exclusive transactions



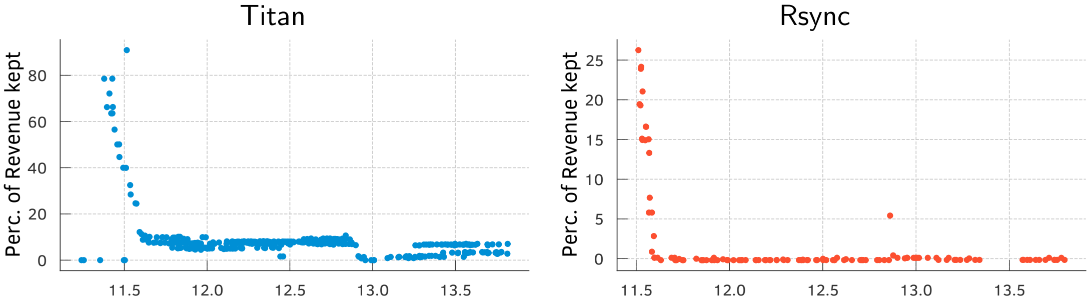
Swap volume per block and percentage attributable to Rsync-bot and Titan-bot

Value of blocks in our data (i.e., sum of all the payments to the builder)



Rsync and Titan build all the high-value blocks (in our sample)

Percentage of block value retained (vs bid)



The fraction of the value retained rapidly converges to 0% for both builders
→ Rsync is more aggressive

Competition between Rsync-bot and Titan-bot

Rsync-bot

- 42 unique transactions (5 included on chain)
- five DEX pools: USDC/WETH, USDT/WETH, MOGCOIN/WETH (2 pools), and WBTC/cbBTC

Titan-bot

- 181 unique transactions (none included on chain)
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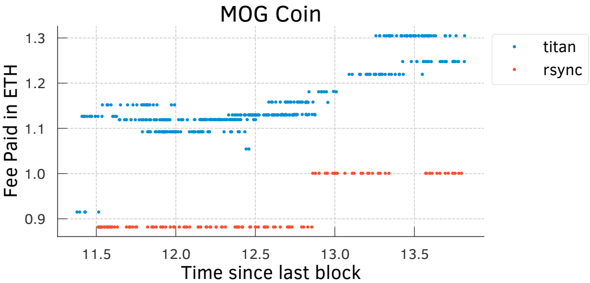
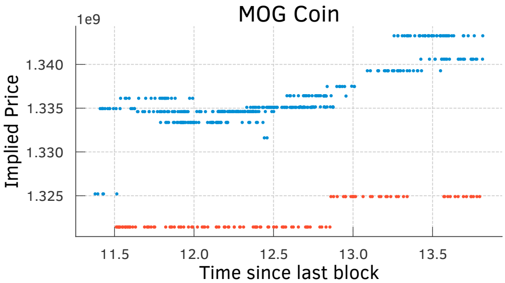
Competition between bots: Both sell MOGCoin for WETH and sell WETH for USDC/USDT

Risk-adjusted implied CEX prices

- We observe the amount swapped on the DEX v; the price of execution on the DEX p_{DEX}; and the fee attached to each transaction $=$ willingness to pay for inclusion $=$ **risk adjusted** profits π
- Depending on the direction of the trade, we have $\pi = v \cdot (p_{\text{CEX}} - p_{\text{DEX}})$ or $\pi = v \cdot (p_{\text{DEX}} - p_{\text{CEX}})$
- We can then back up a risk-adjusted implied CEX price and compare it to Binance (if it exists)

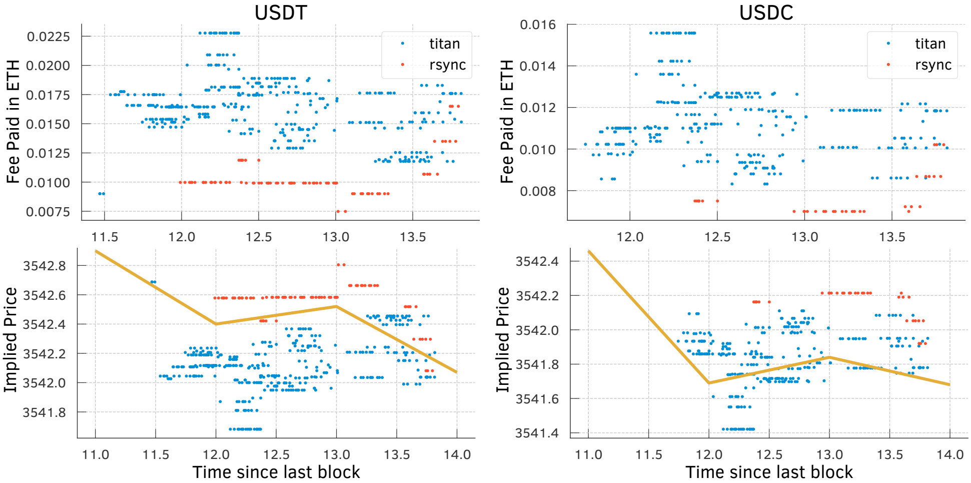
Competition on the MOGCoin/WETH Uni V3 pool.





Large expected profits, Titan seem more efficient in the DEX leg of the trade

Competition on the WETH/USDC and WETH/USDT Uni v3 pools.



Fee for inclusion and implied DEX price **compared to Binance price**

The auction cycle for block 21322649: summary of results

Determinants of who wins the block:

- Titan-bot seems more efficient (i.e., trades at better prices on the CEX), especially on the most valuable arbitrage opportunity.
- But Rsync builders bids more aggressively (and wins)

All data

Probability of successful execution (only swaps, with transactions FE)

	All Swaps	Same Dir. as Bots	Opp. Dir. as Bots
Time Since Last Block	-0.0038***	-0.0217***	-0.0012***
	(0.0001)	(0.001)	(0.000)
Tx Index	0.0001***	0.0006***	5.74e-06
	(0.0000)	(3.18e-05)	(9.23e-06)
Is Titan Builder	-0.0078***	-0.1341***	-0.0144***
	(0.0008)	(0.005)	(0.001)
Is Rsync Builder	-0.0148***	-0.1592***	-0.0021
	(0.0006)	(0.006)	(0.002)
Has Titan-bot tx	0.0024***	-0.0423***	0.0286***
	(0.0005)	(0.004)	(0.001)
Has Rsync-bot tx	0.0075***	-0.0301***	0.0095***
	(0.0005)	(0.004)	(0.001)
Observations	318742	17224	26705
R-squared	0.744	0.556	0.493
Tx fixed effect	yes	yes	yes

Execution quality for swaps (higher values are better for the user)

	All Swaps	Same Dir. as Bots	Opp. Dir. as Bots
Time since Last Block	-0.0022***	-0.0430***	0.0163***
	(0.0005)	(0.002)	(0.002)
Tx Index	0.0003***	0.0001***	0.0007***
	(0.0000)	(4.01e-05)	(4.28e-05)
Is titan builder	-0.0053**	-0.1206***	0.0923***
	(0.0024)	(0.006)	(0.007)
Is rsync builder	0.0198***	-0.0924***	0.2758***
	(0.0031)	(0.008)	(0.009)
Has titan-bot tx	0.0048**	0.0068*	-0.0640***
	(0.0019)	(0.005)	(0.006)
Has rsync-bot tx	-0.0235***	-0.0038	-0.0402***
	(0.0019)	(0.005)	(0.006)
Observations	342528	15404	25718
R-squared	0.002	0.142	0.073
Tx fixed effect	yes	yes	yes

Implied CEX price: correlation with Binance (only WETH/USTD and WETH/USDC)

	Coefficient	Standard Error
Binance Price (0 sec.)	0.7945^{***}	0.108
Binance Price (+1 sec.)	-0.1491	0.129
Binance Price (-1 sec.)	0.2513^{**}	0.108
Binance Price (-2 sec.)	0.0972	0.063
Constant	21.5424	23.070
Observations	89	
R-squared	0.998	

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Price improvement over contemporaneous binance price

Time since Last Block	-0.009	-0.001
	0.001	0.001
Is Titan Bot	-0.0069**	-0.007**
	0.003	0.003
Volume × (Volume lower than 50)		-0.0007
		0.004
Volume × (Volume between 50 and 100)		0.0003
		0.004
Volume × (Volume between 100 and 150)		0.0066
		0.004
Volume × (Volume greater than 150)		0.0231***
		0.008
Constant	0.028	0.0287**
	0.018	0.013
Observations	89	89
R-squared	0.080	0.195

Relevant literature & Conclusions

Relevant literature

- Value of blocks vs bids: Yang, Nayak, and Zhang (2024),
- Competition between arbitrageurs pre-PBS: Capponi, Jia, and Yu (2024) (see also Capponi, Jia, and Wang, 2023)
- Quantifying arbitrage volume and arbitrage profits: Heimbach, Pahari, and Schertenleib (2024), Canidio and Fritch (2023), Fritch and Canidio (2024)
- Use "failed" transactions to identify HFT races and profits: Aquilina, Budish, O'Neill (2022)
- Builder-searcher integration: Pai and Resnick (2024),
- Builders' competition: many

Check out our other paper (with the same data): "How Exclusive are Ethereum Transactions? Evidence from non-winning blocks"

Conclusions

- The set of transactions included on-chain looks very different from the set of transactions submitted for inclusion,
- A surprisingly large number of users' transactions are delayed because they are exclusive (or not shared with all builders)
- Some indication that an OFA provider shares users' transactions exclusively with a single builder, and then releases them in the public mempool after 1 or 2 auction cycles if this builder does not win
- Novel insights relative to searchers' competition, in particular to the CEX leg of CEX-DEX arbitrage