

Non-Atomic Arbitrage in Decentralized Finance



Lioba Heimbach, Vabuk Pahari and
Eric Schertenleib

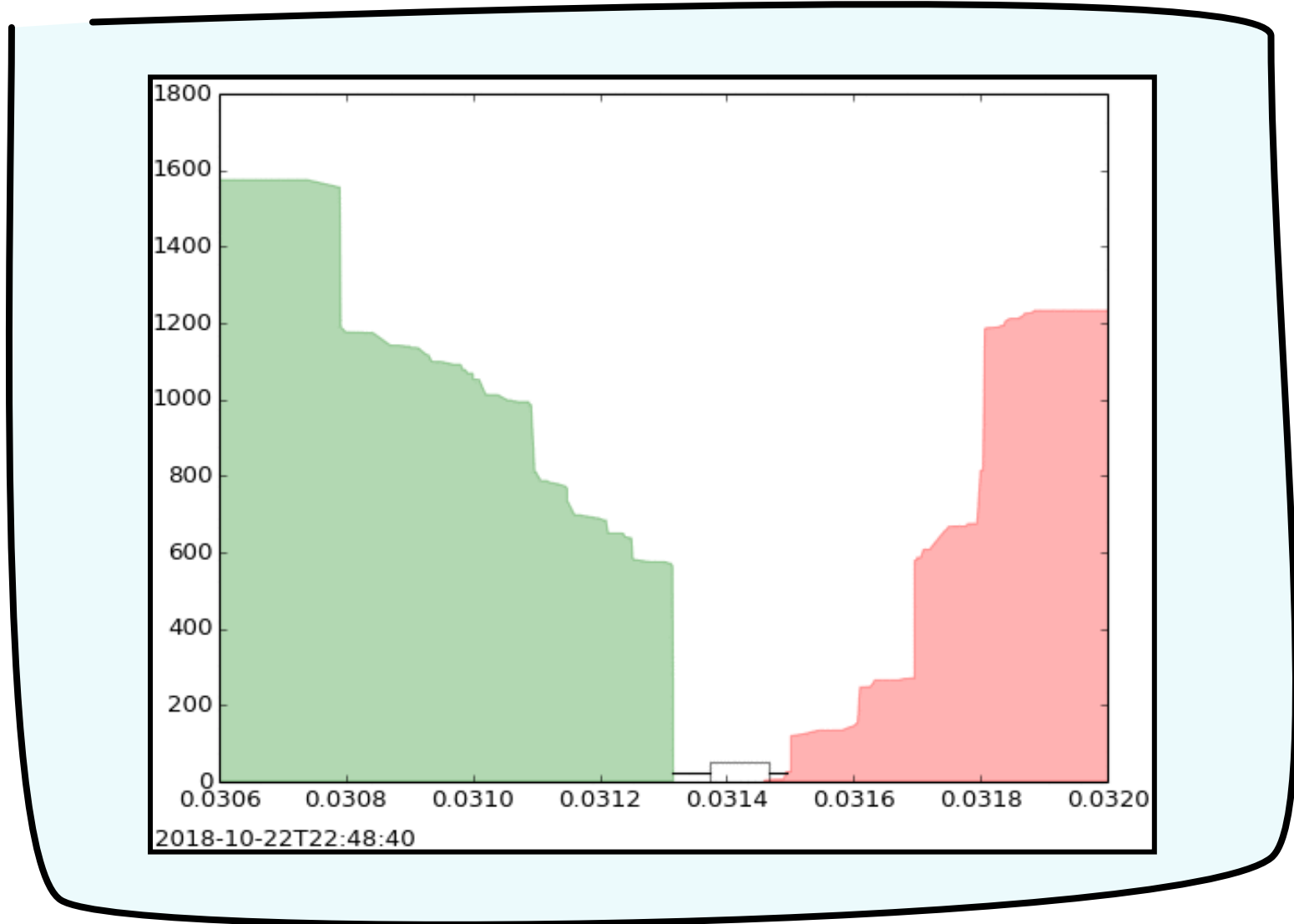
Flashbots Research Seminar

ETH Zurich, MPI-SWS

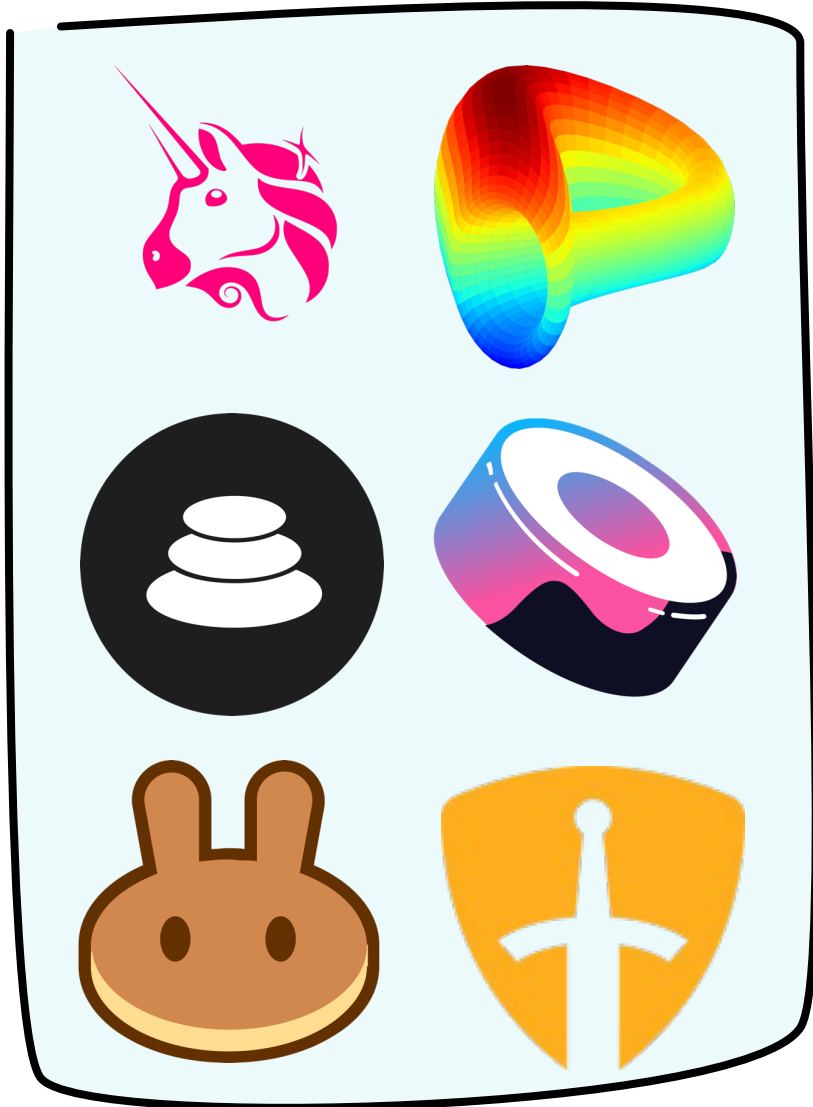
Centralized exchanges (CEXes)



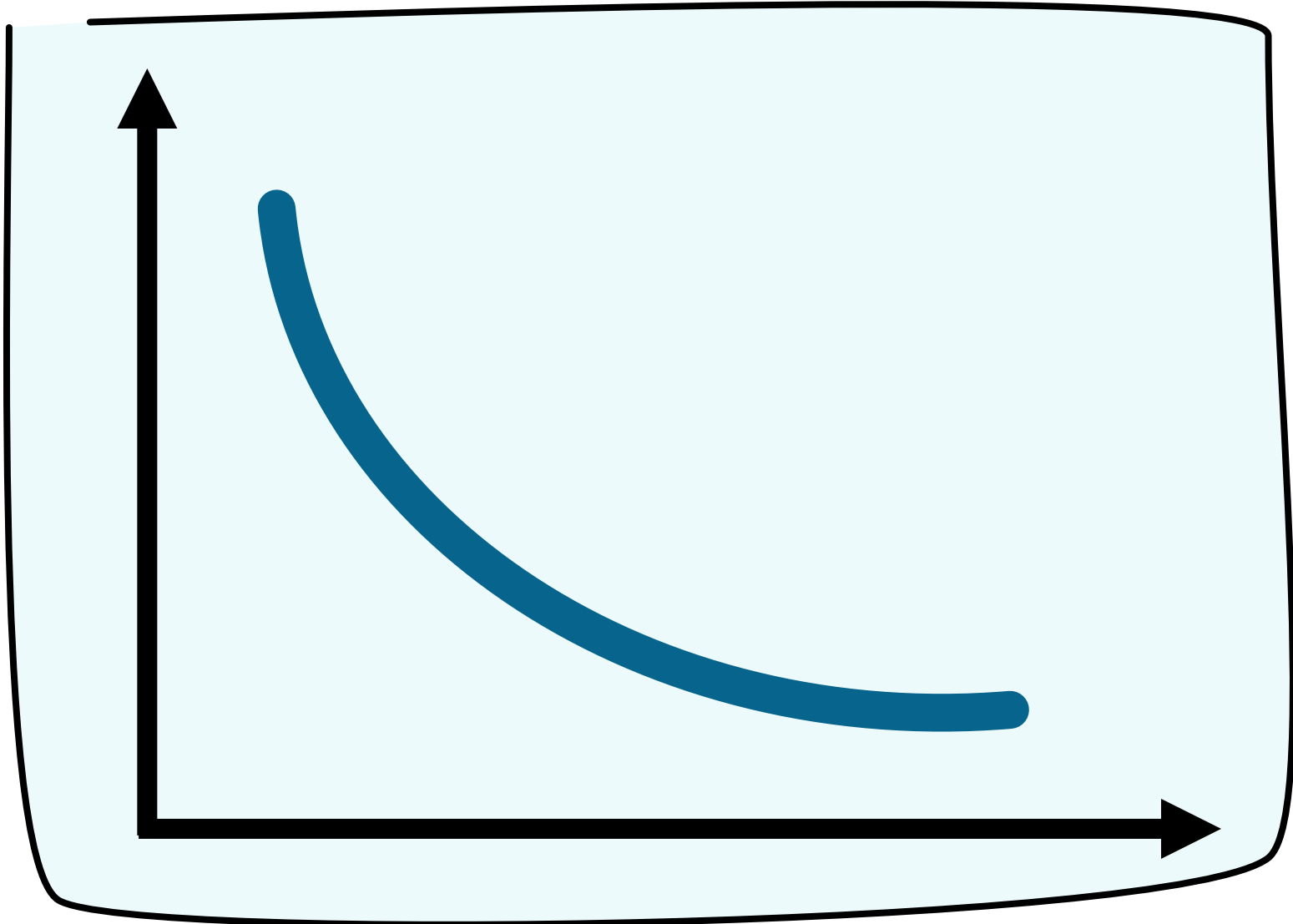
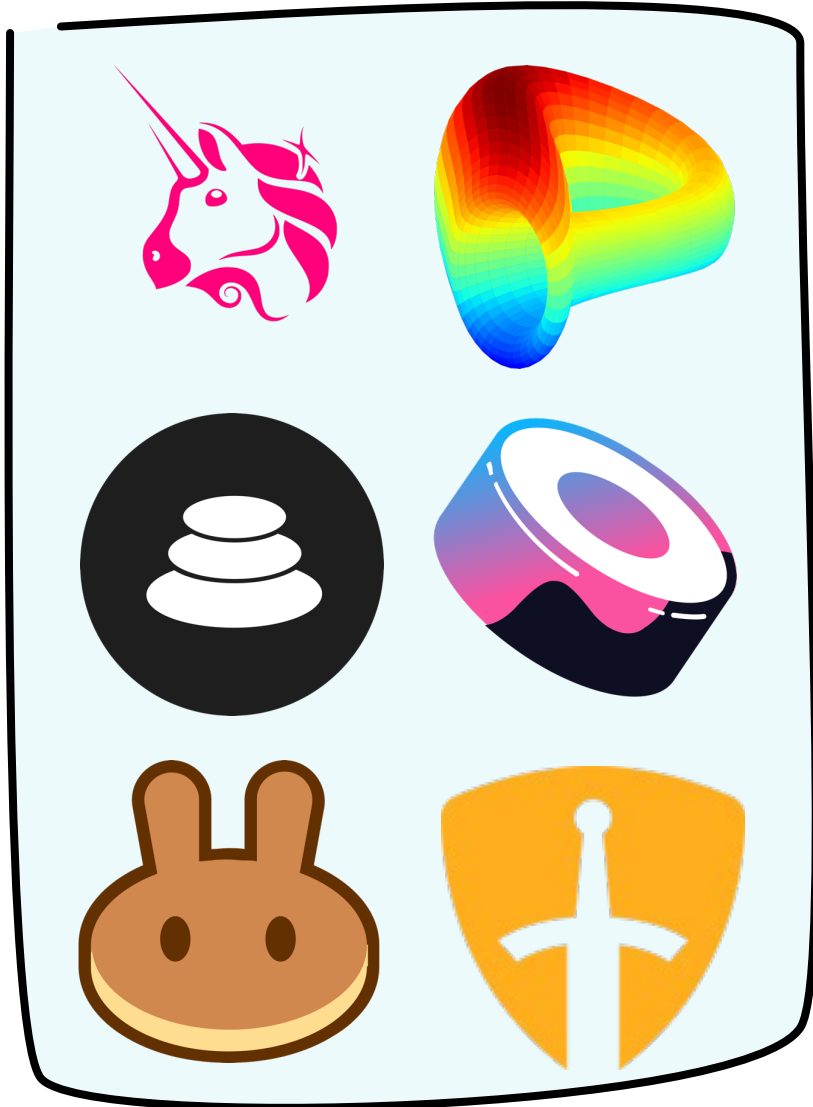
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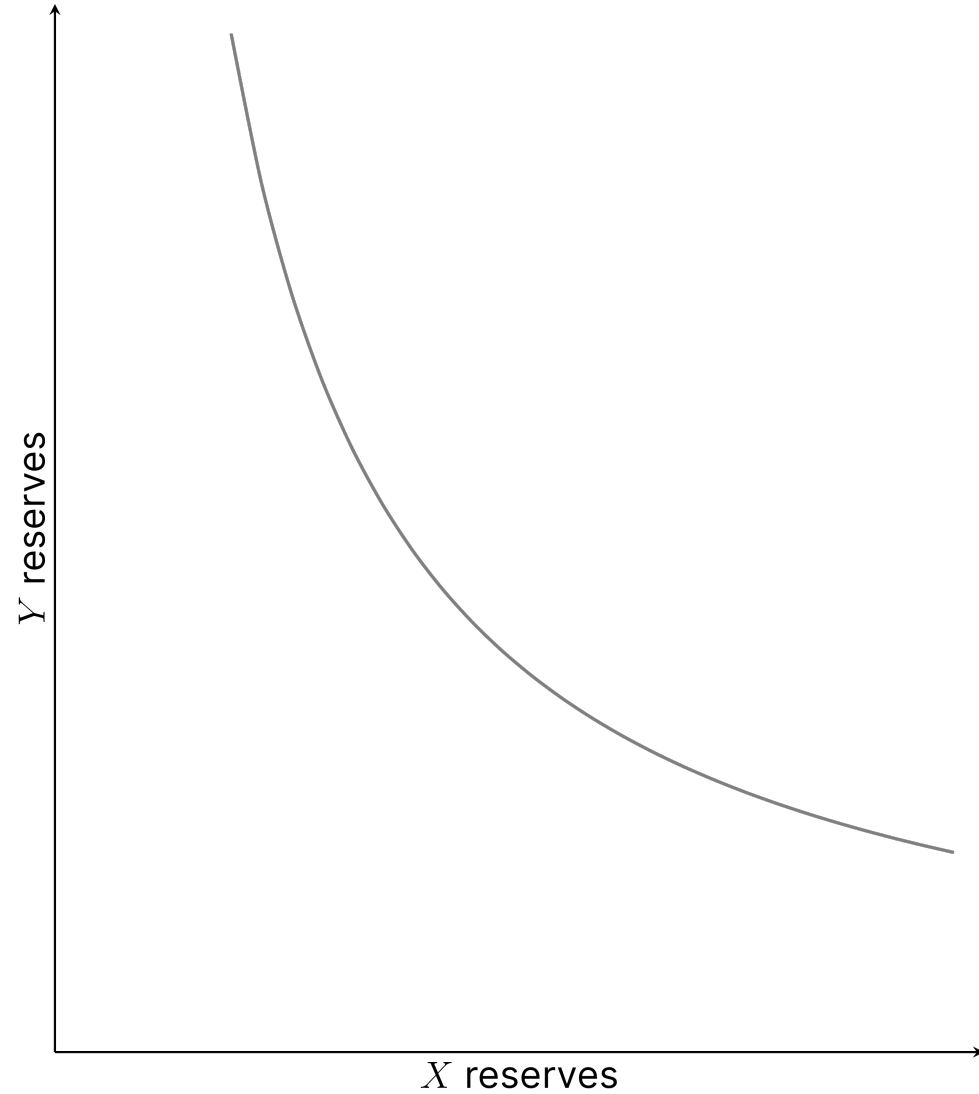
Decentralized exchanges (DEXes)



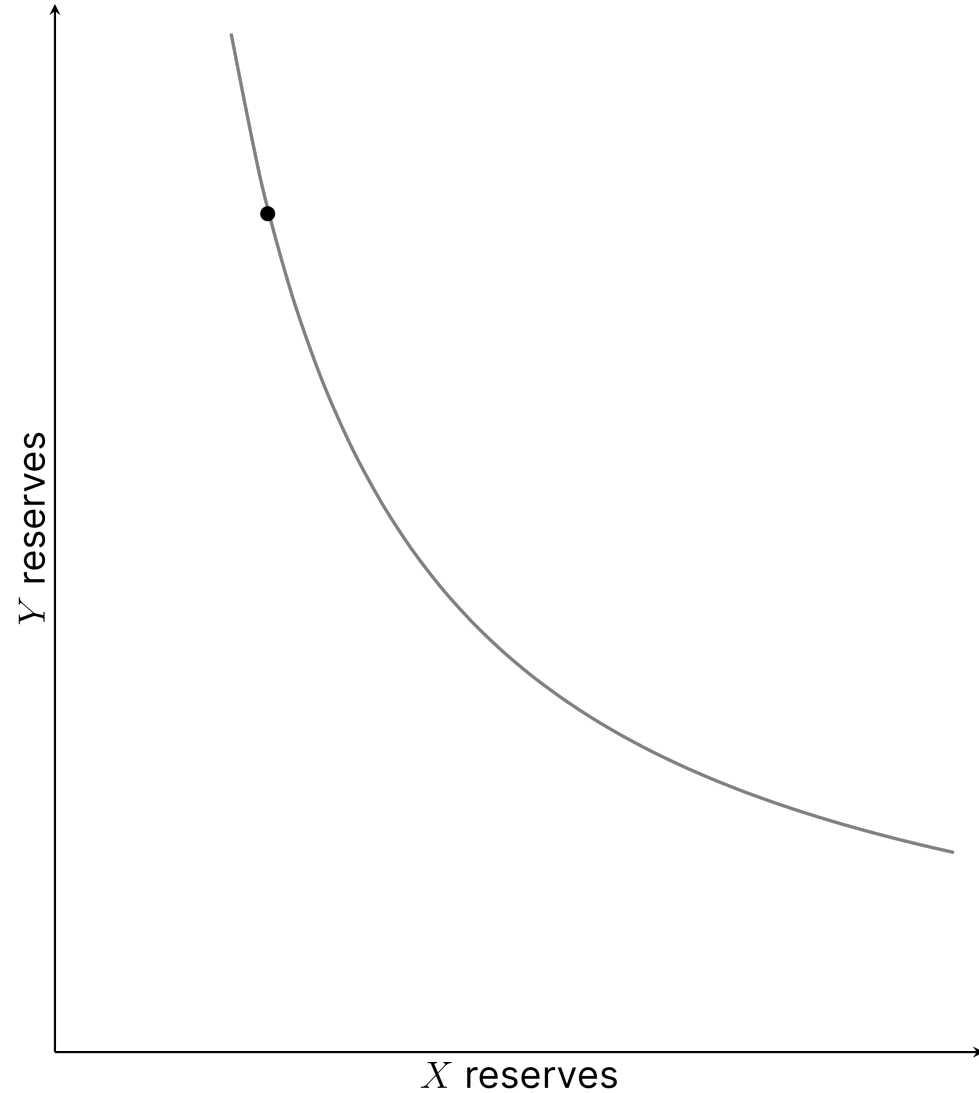
Decentralized exchanges (DEXes)



Constant function market makers (CFMMs)

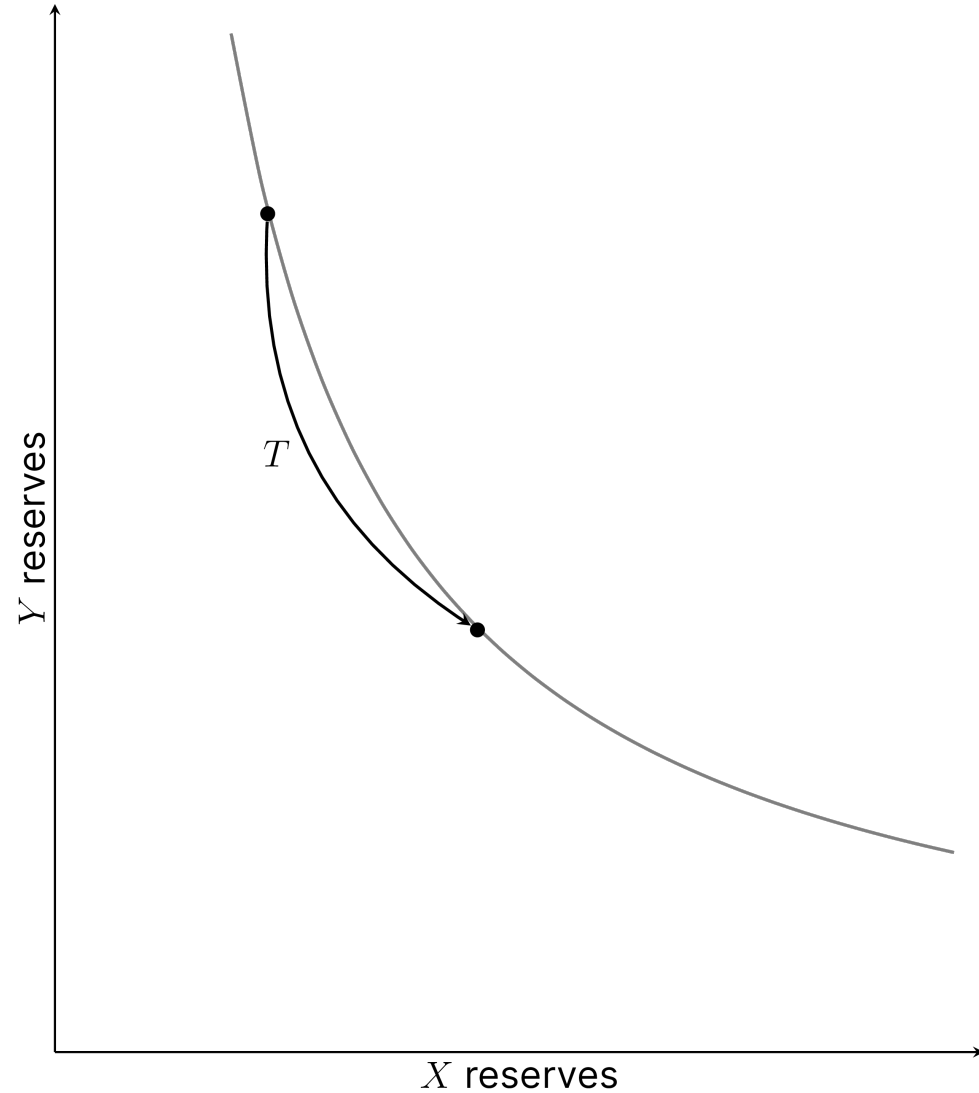


Constant function market makers (CFMMs)



trading along price curve

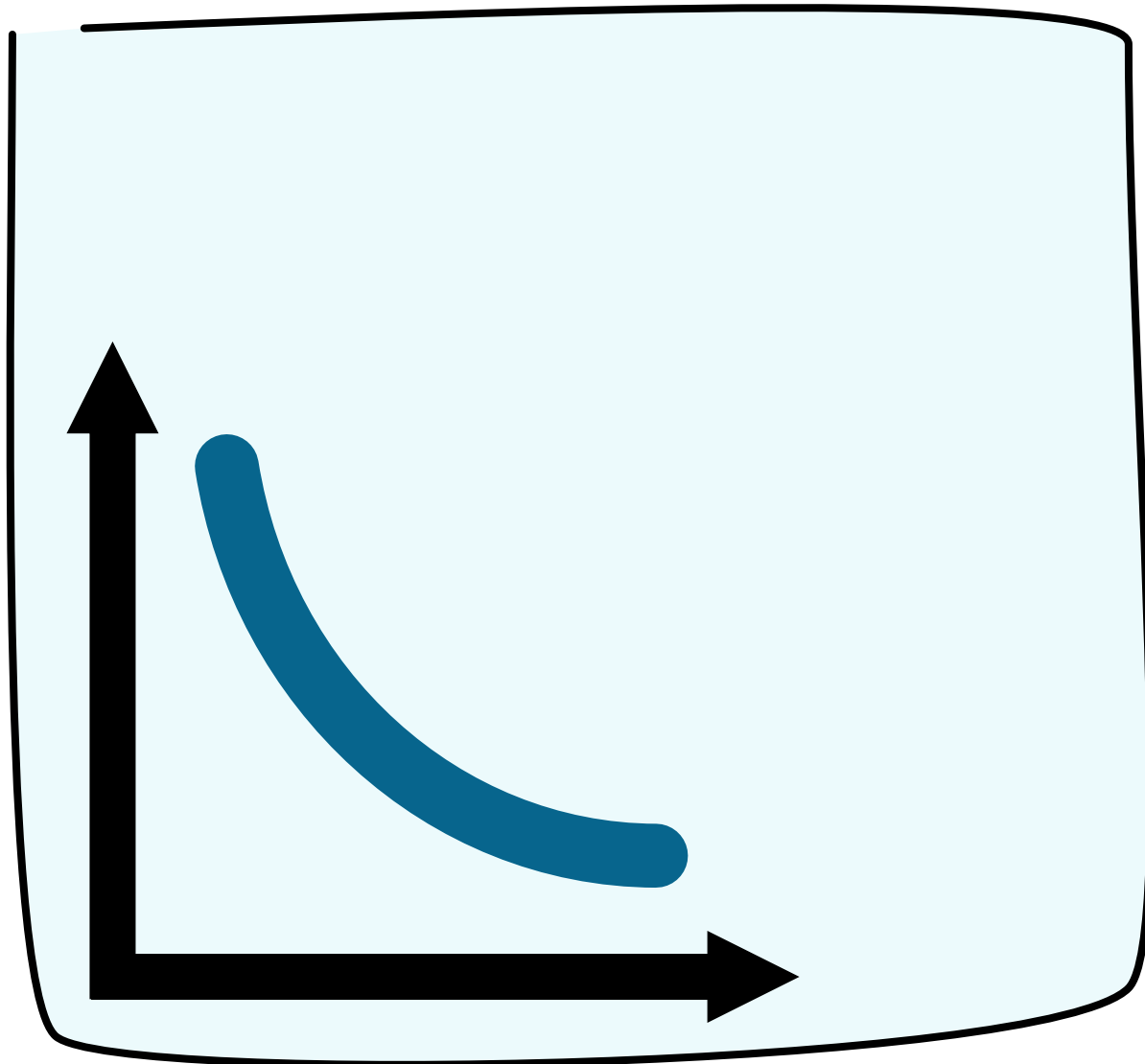
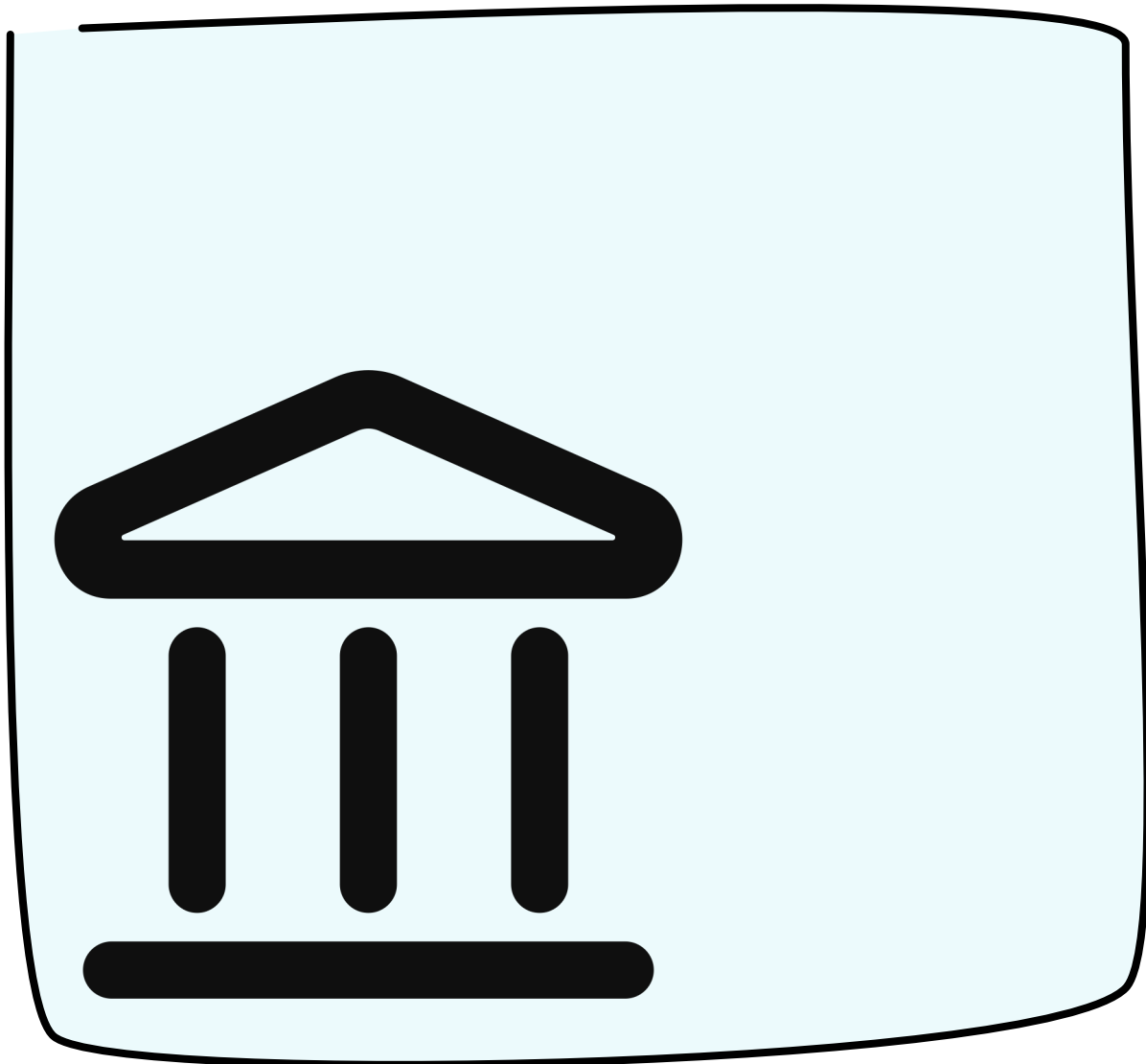
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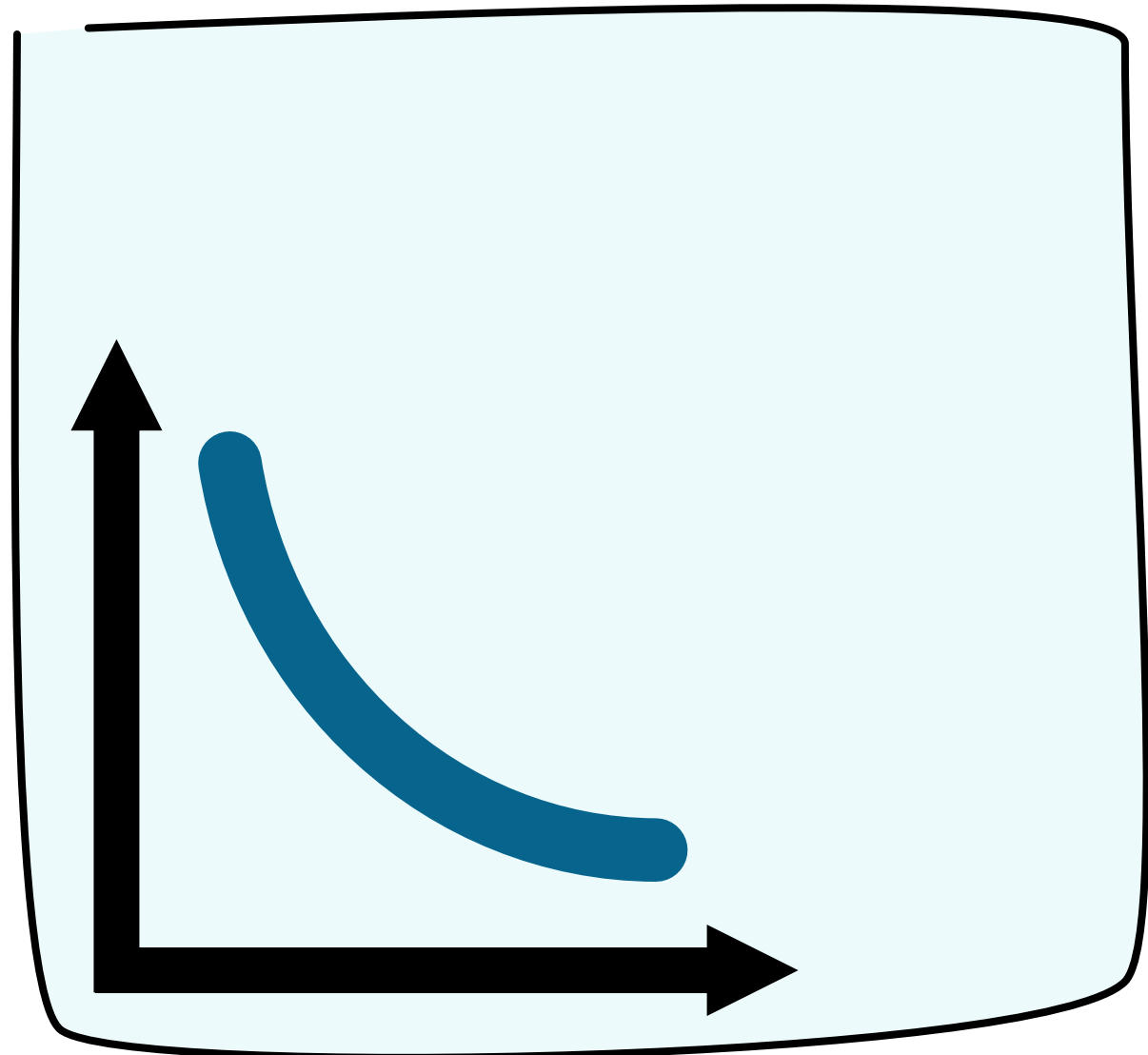
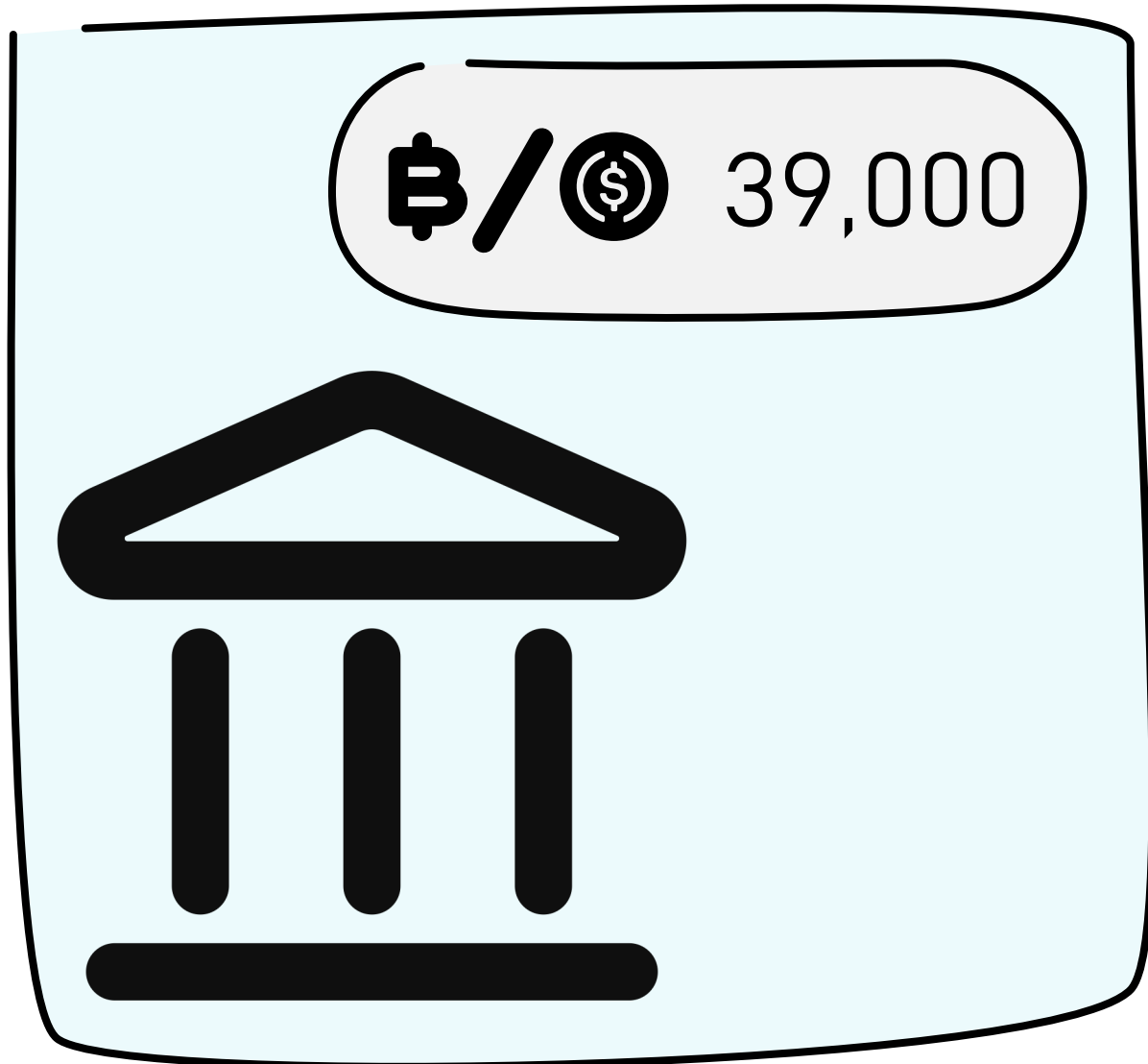
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T : trade $X \rightarrow Y$

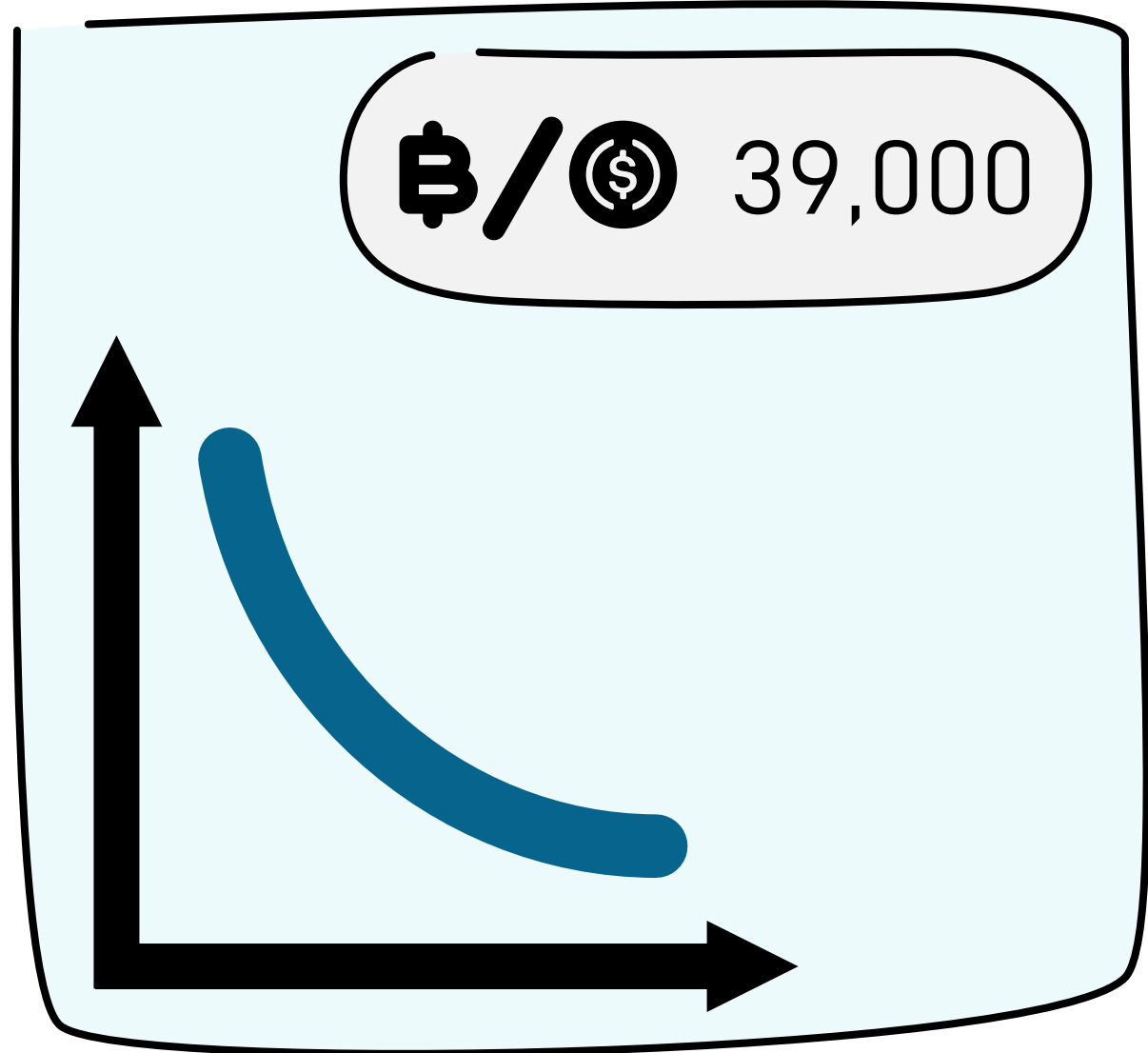
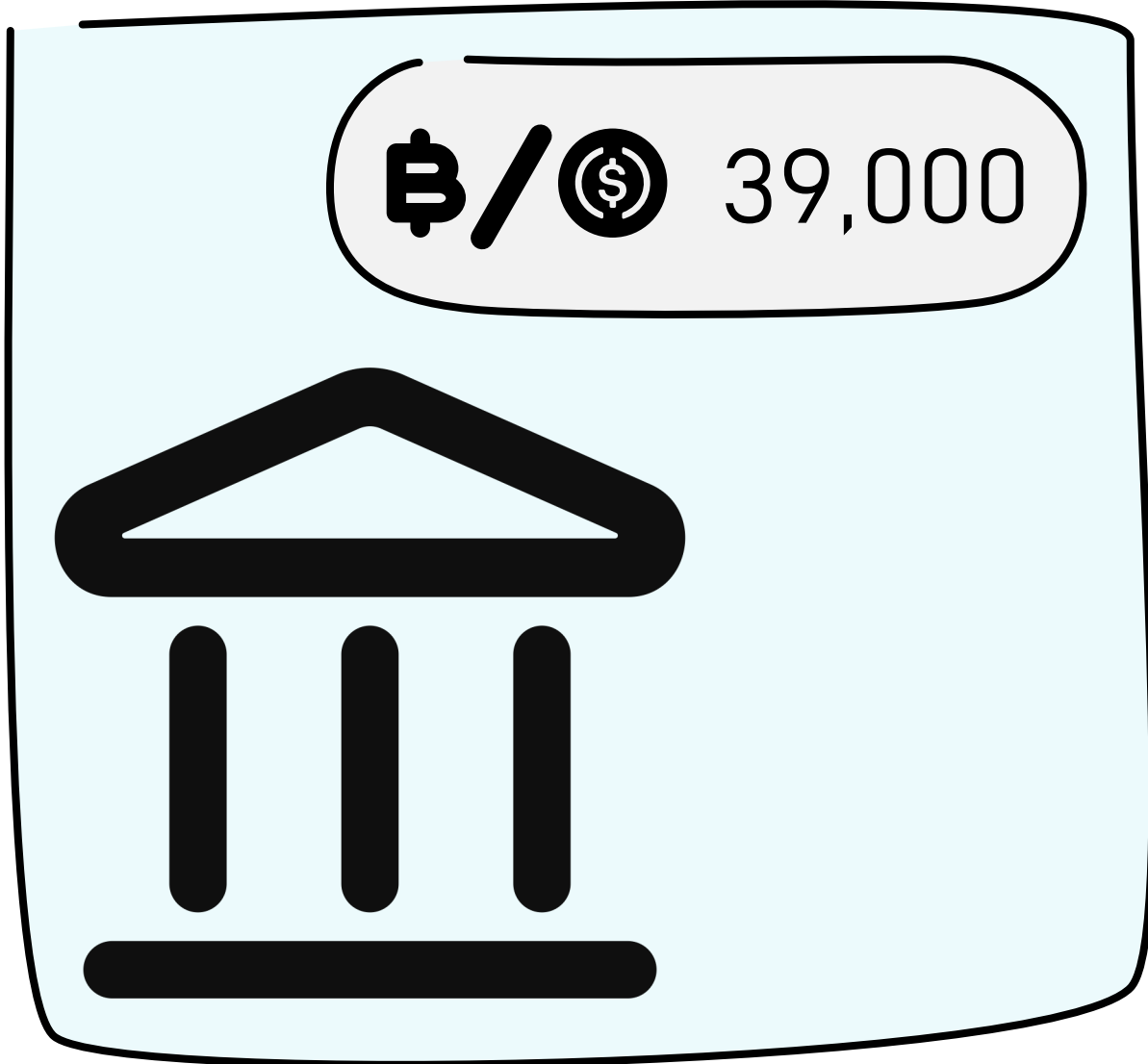
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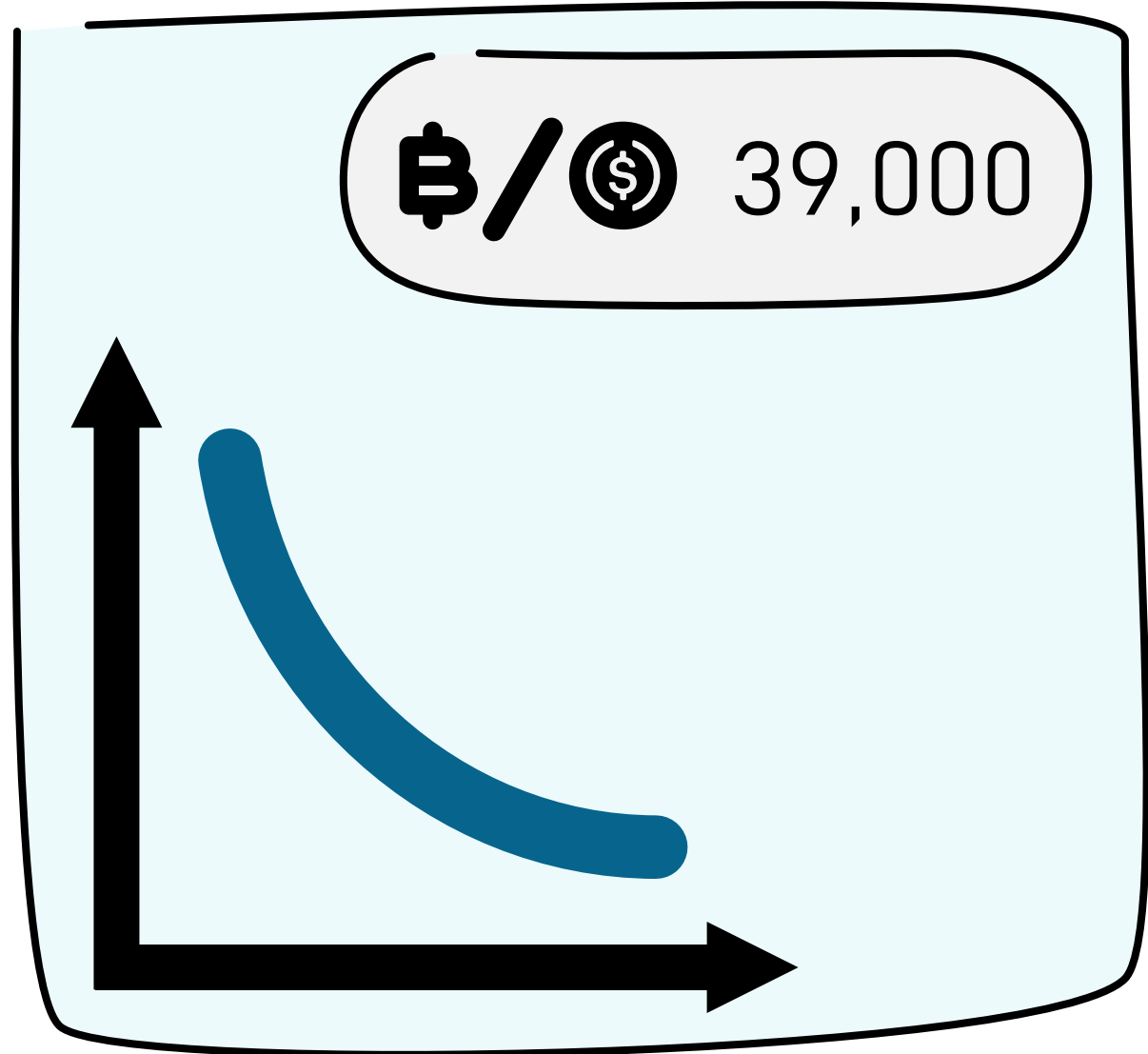
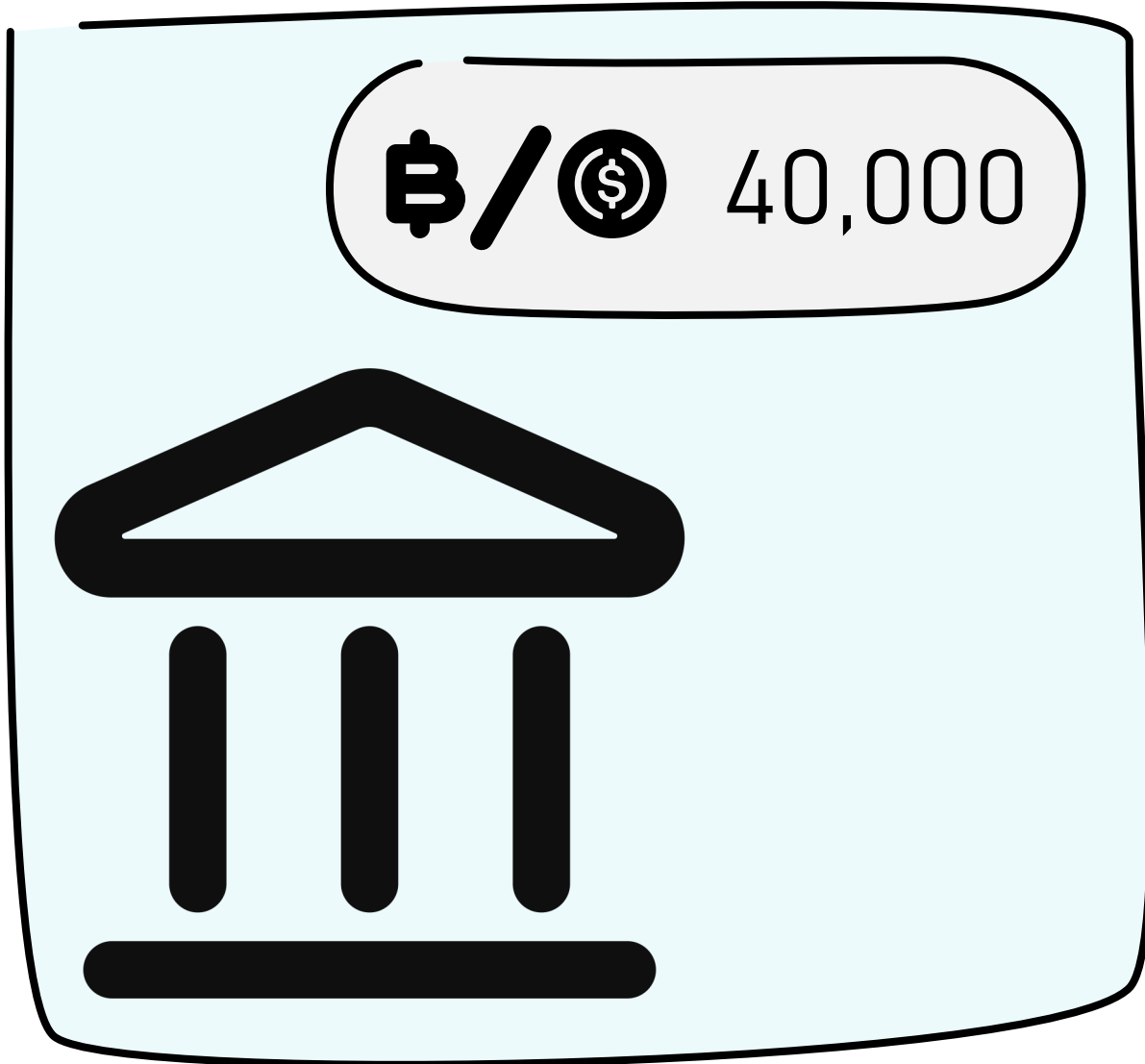
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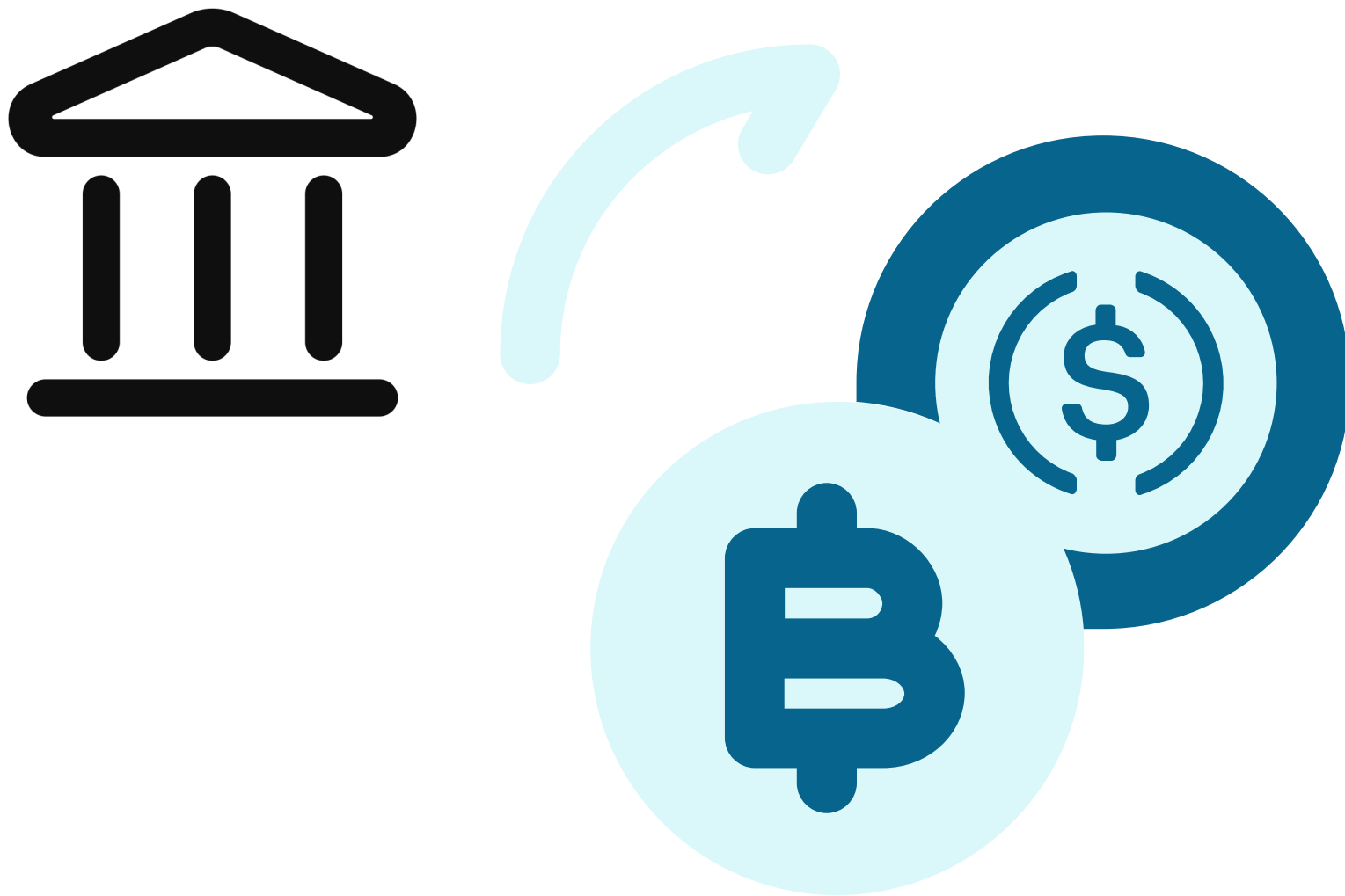
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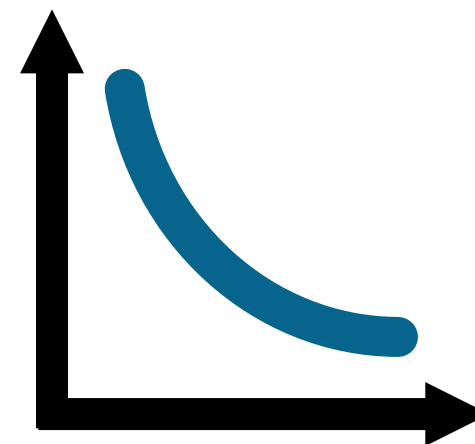
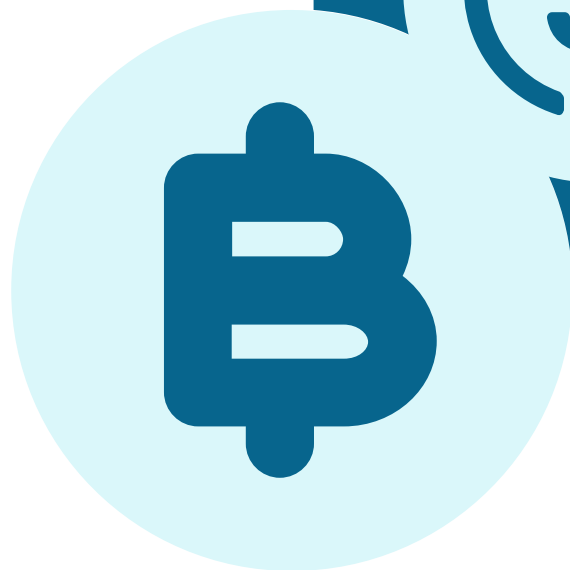
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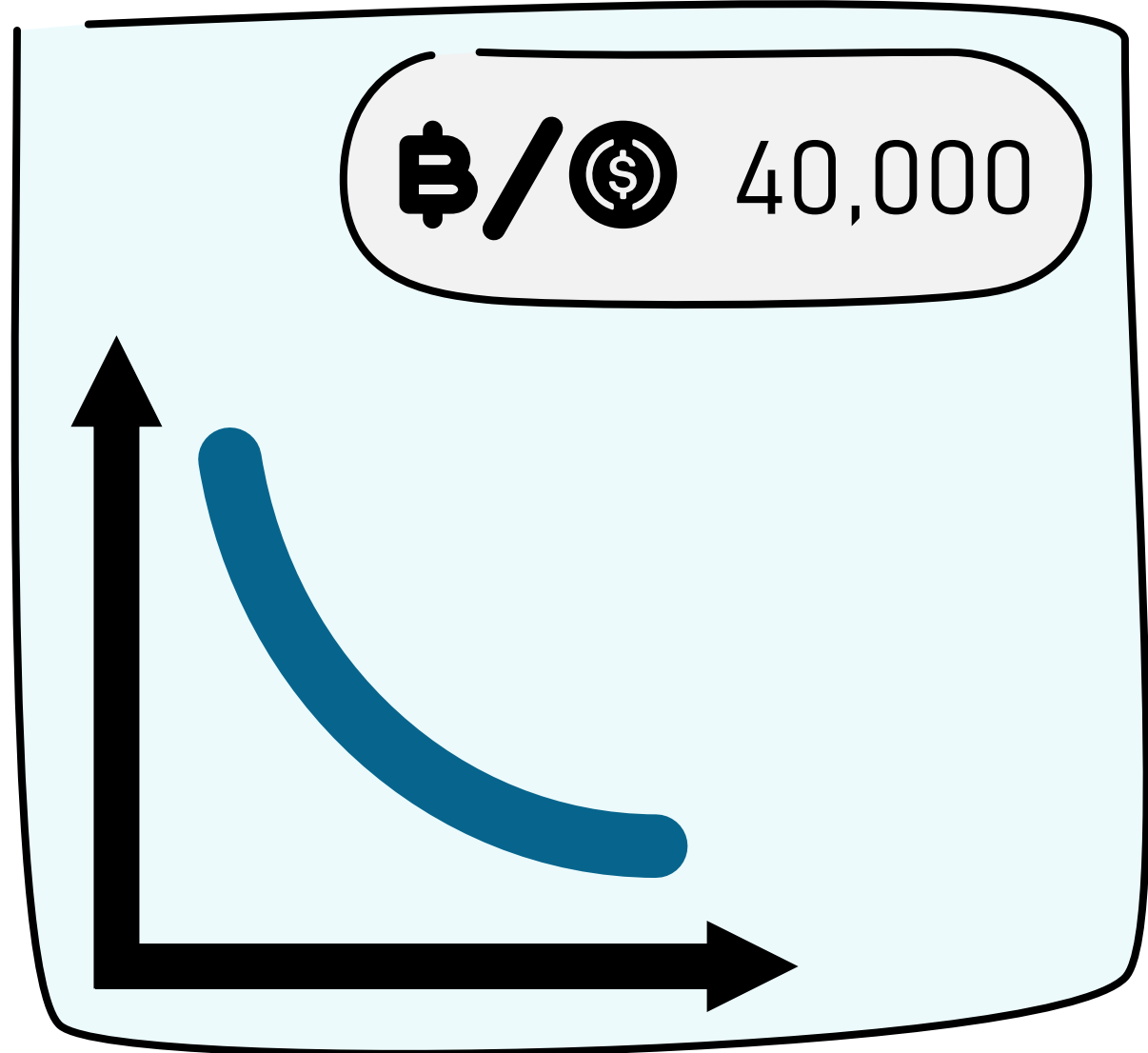
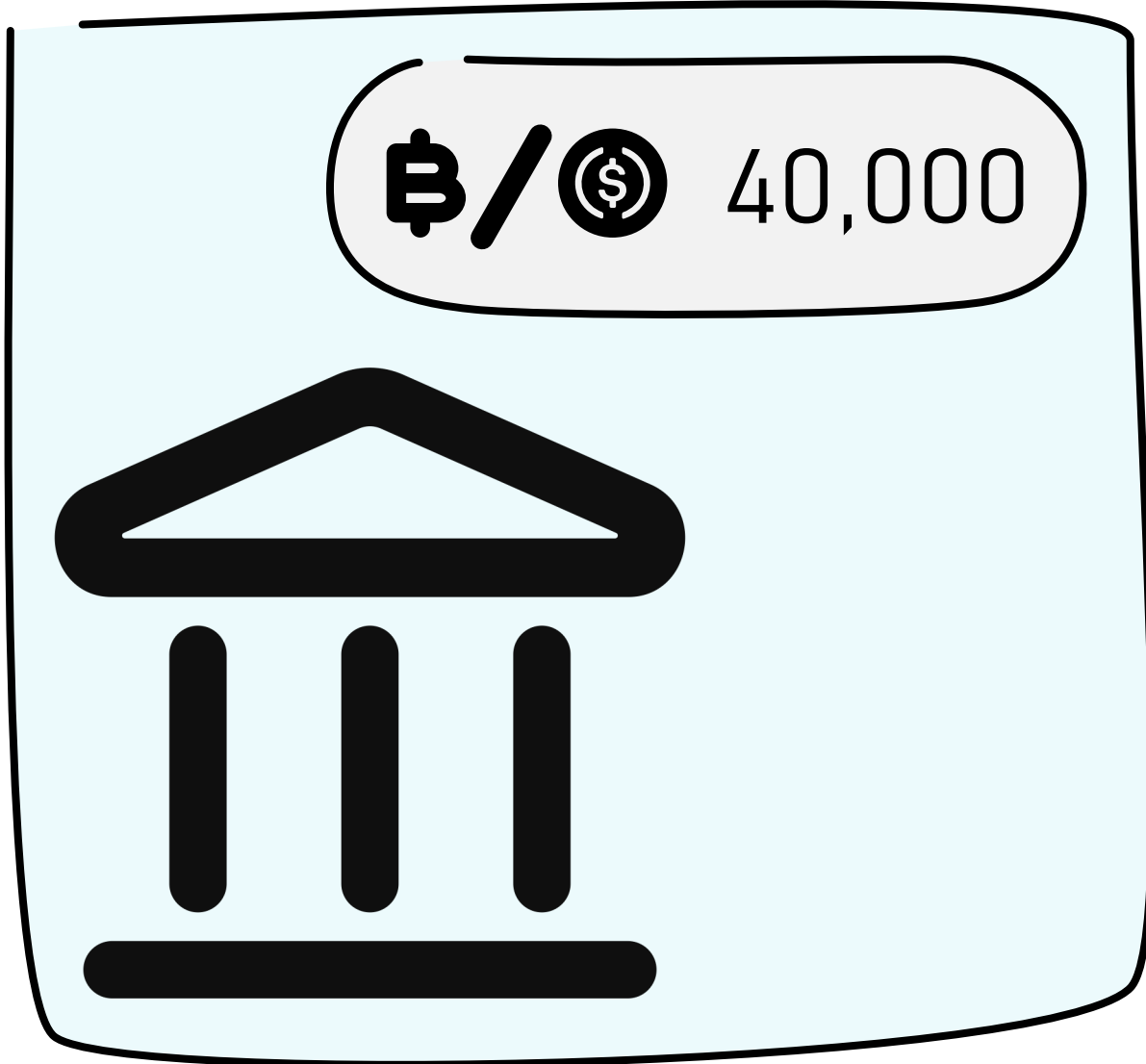
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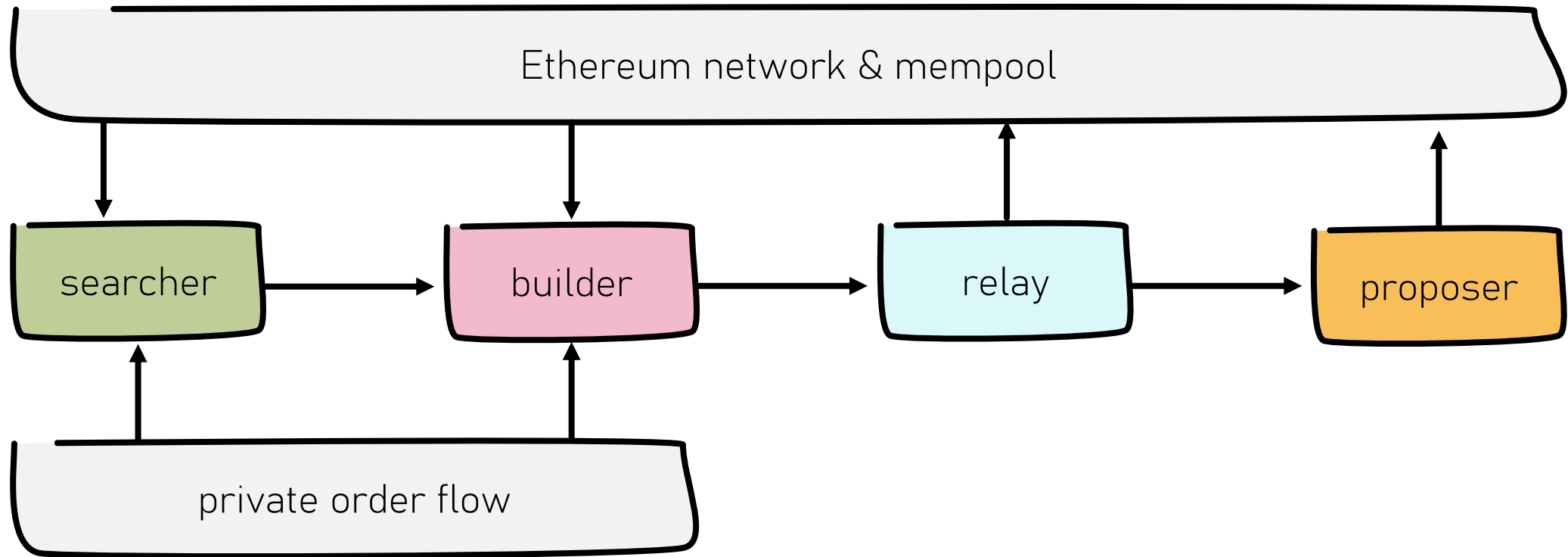
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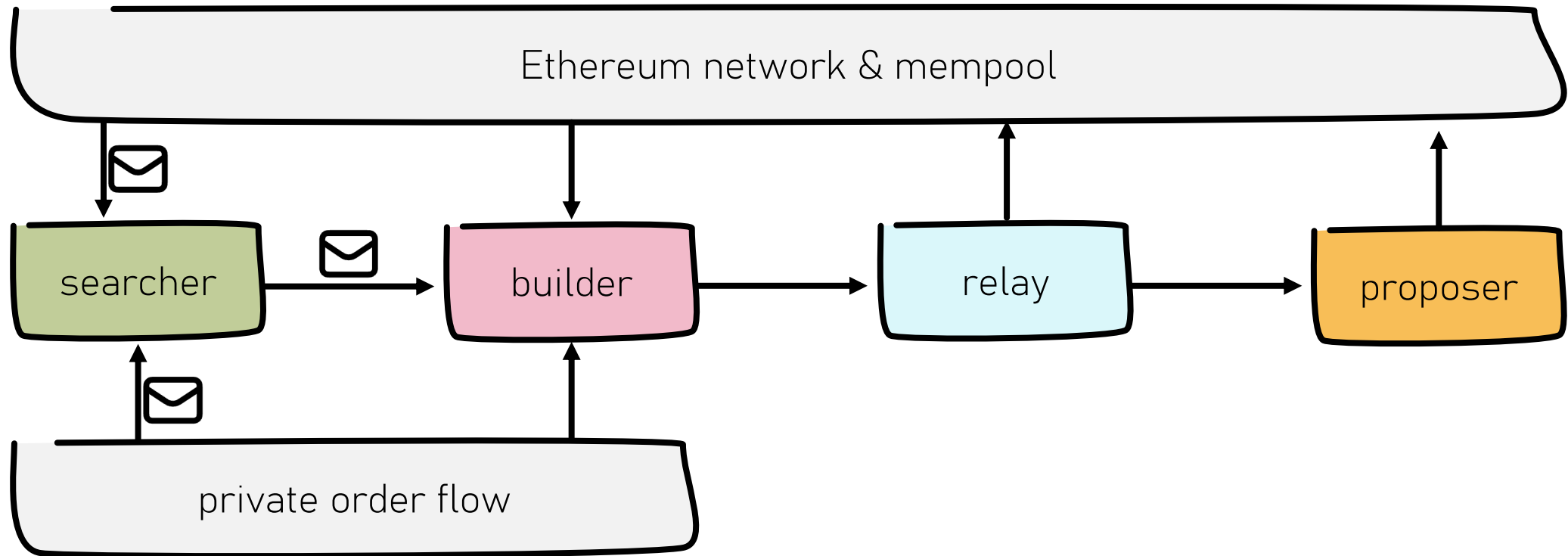
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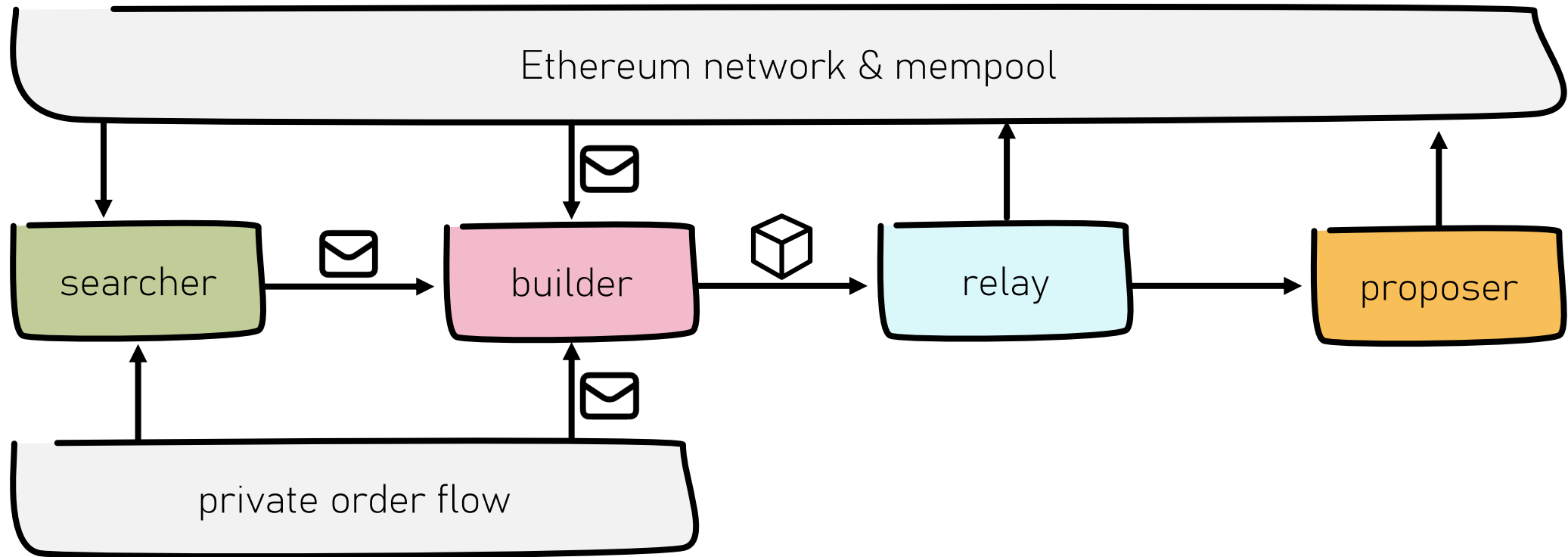
Proposer builder separation (PBS)



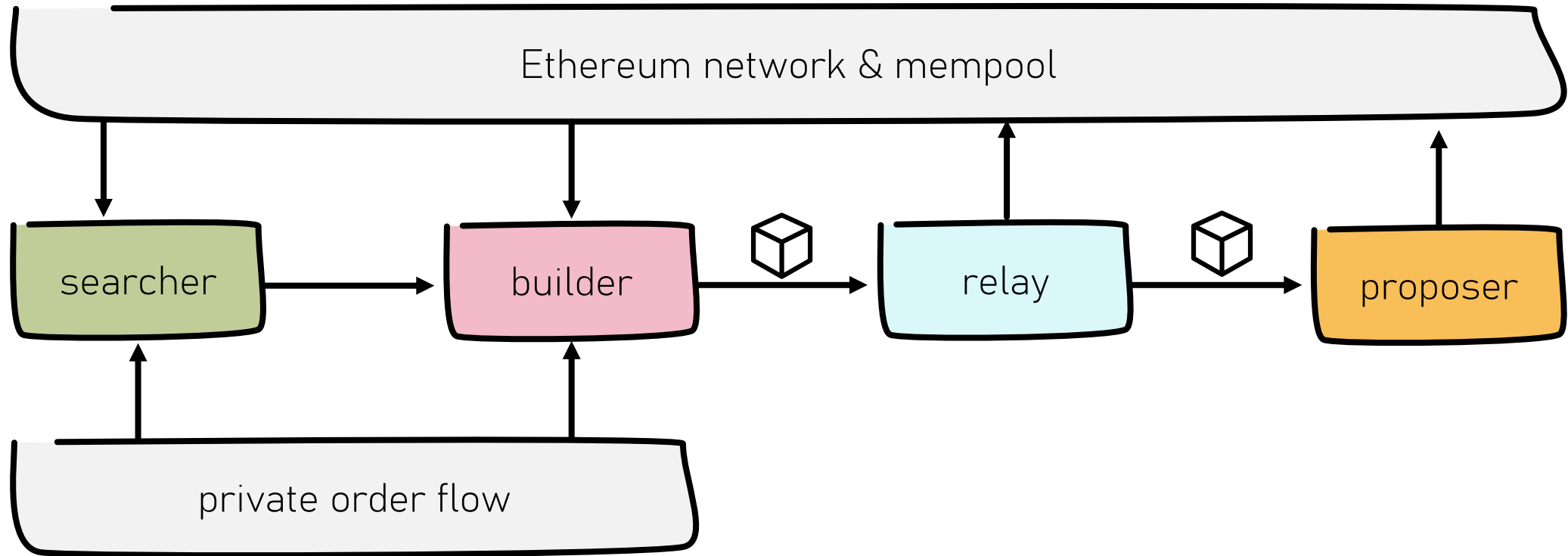
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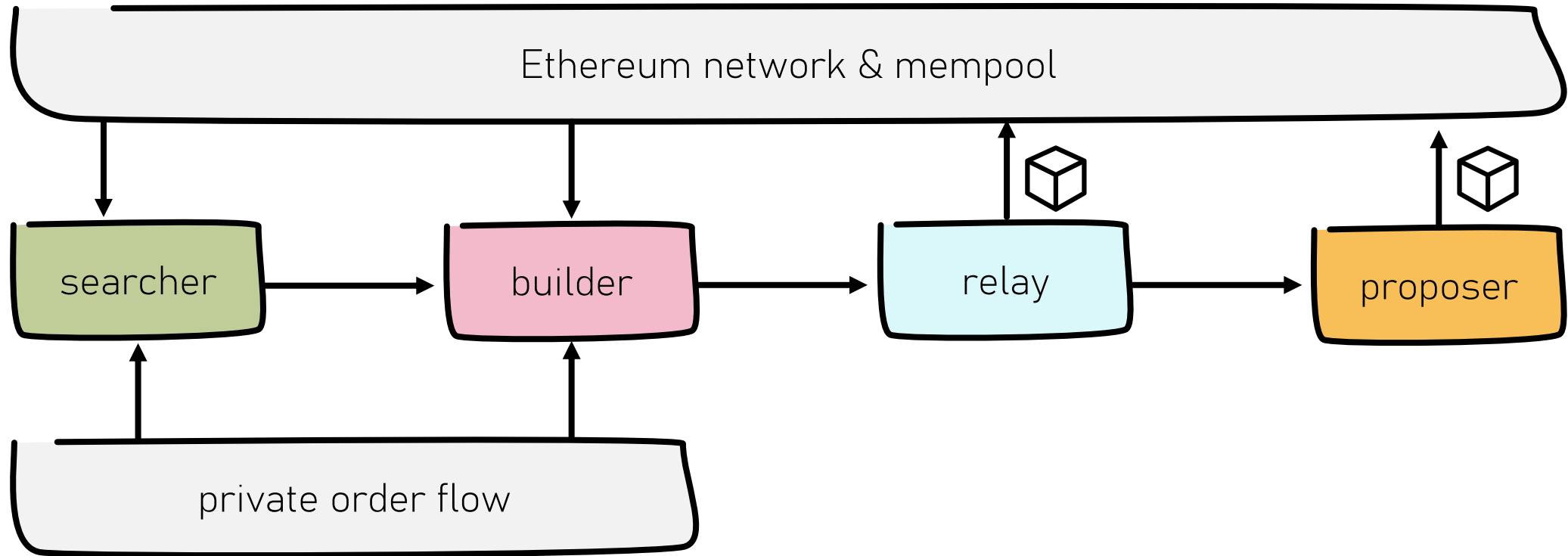
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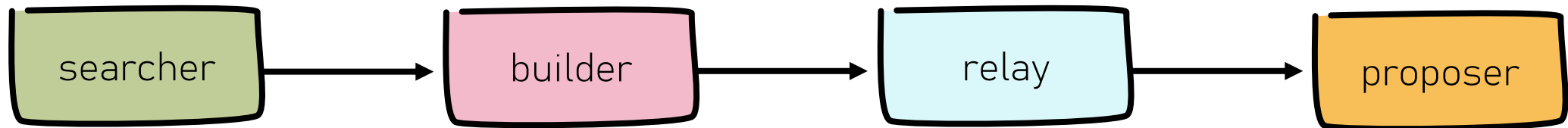
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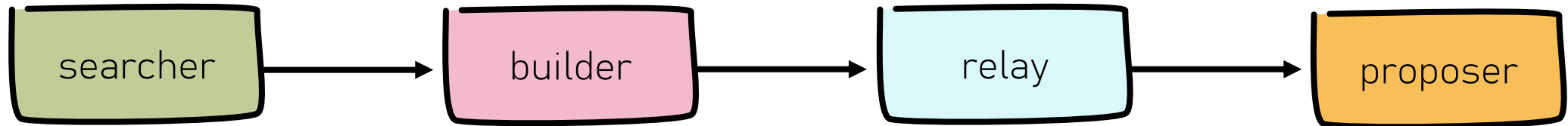


Non-atomic arbitrage flow



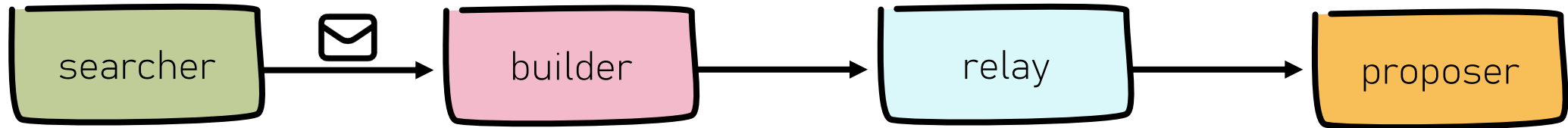
Non-atomic arbitrage flow

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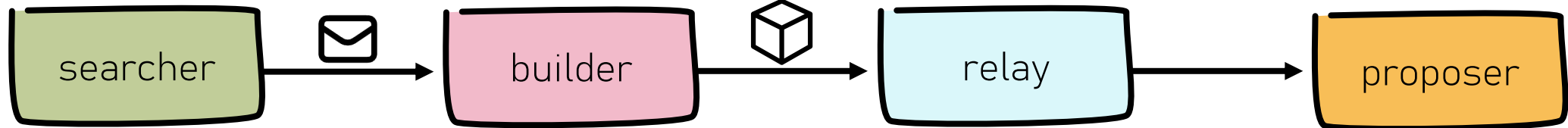


② searcher sends non-atomic arbitrage tx T_A to builder

Non-atomic arbitrage flow

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③ builder builds high value block and includes tx T_A from searcher

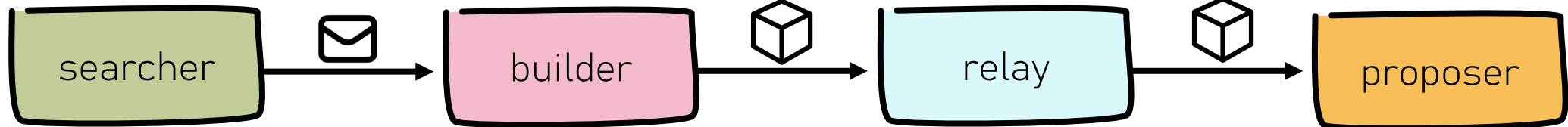


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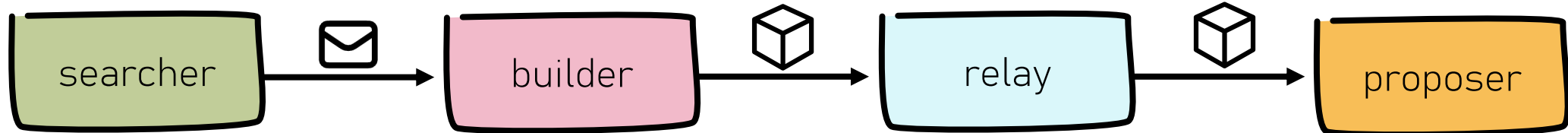
④ if requested, relay sends highest value block to proposer

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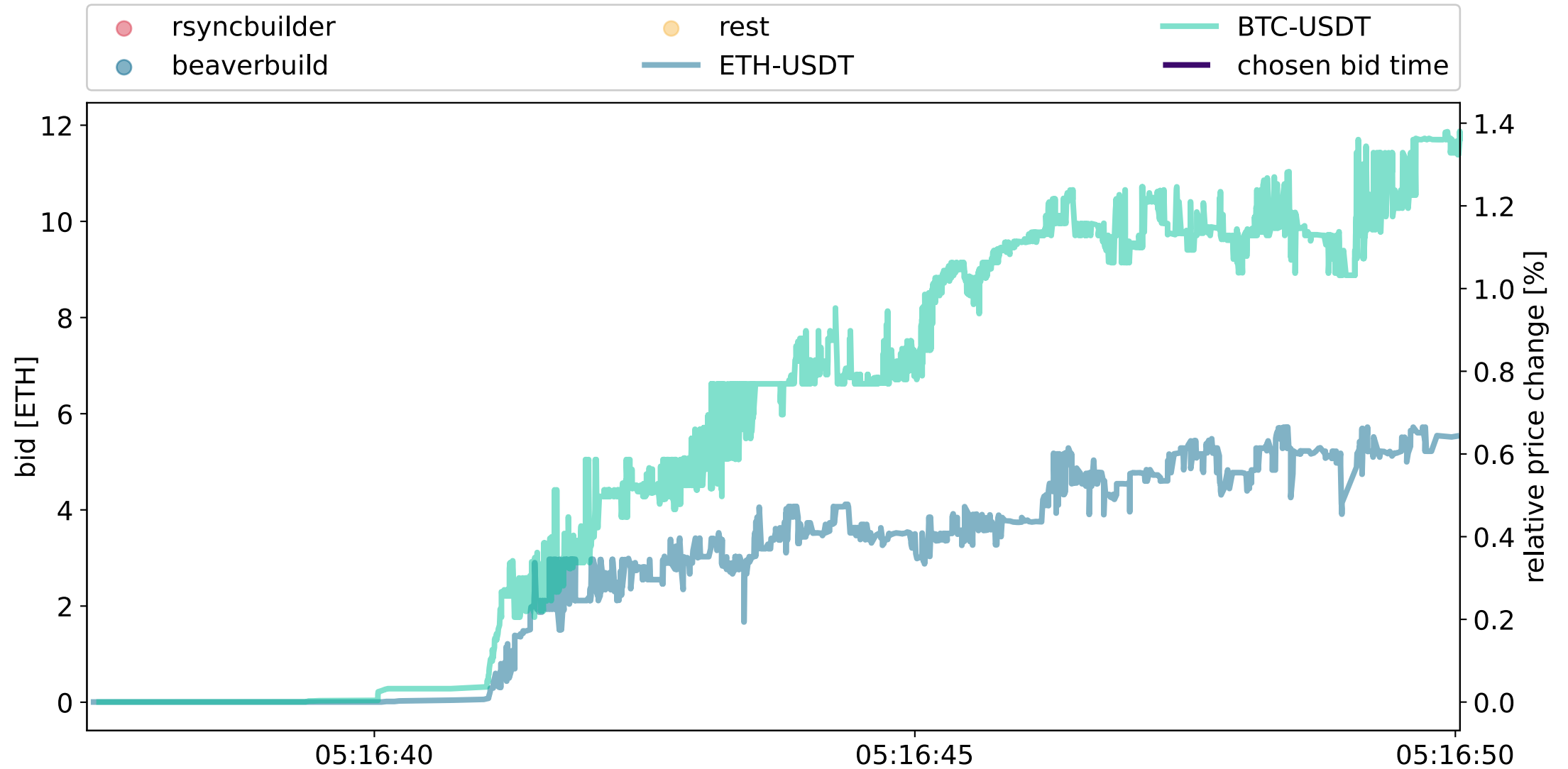
⑤ proposer picks highest bidding block with tx T_A and proposes the block



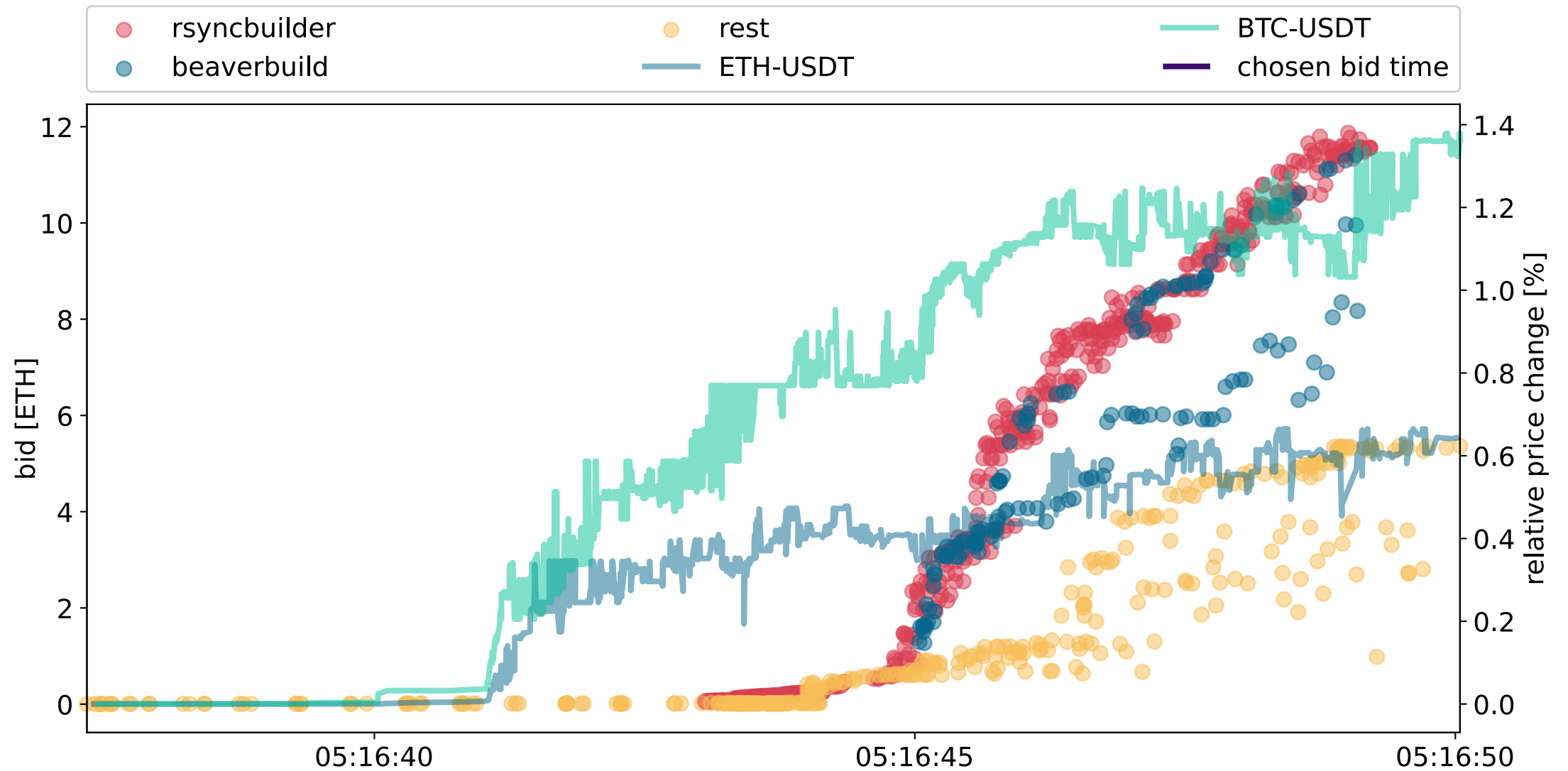
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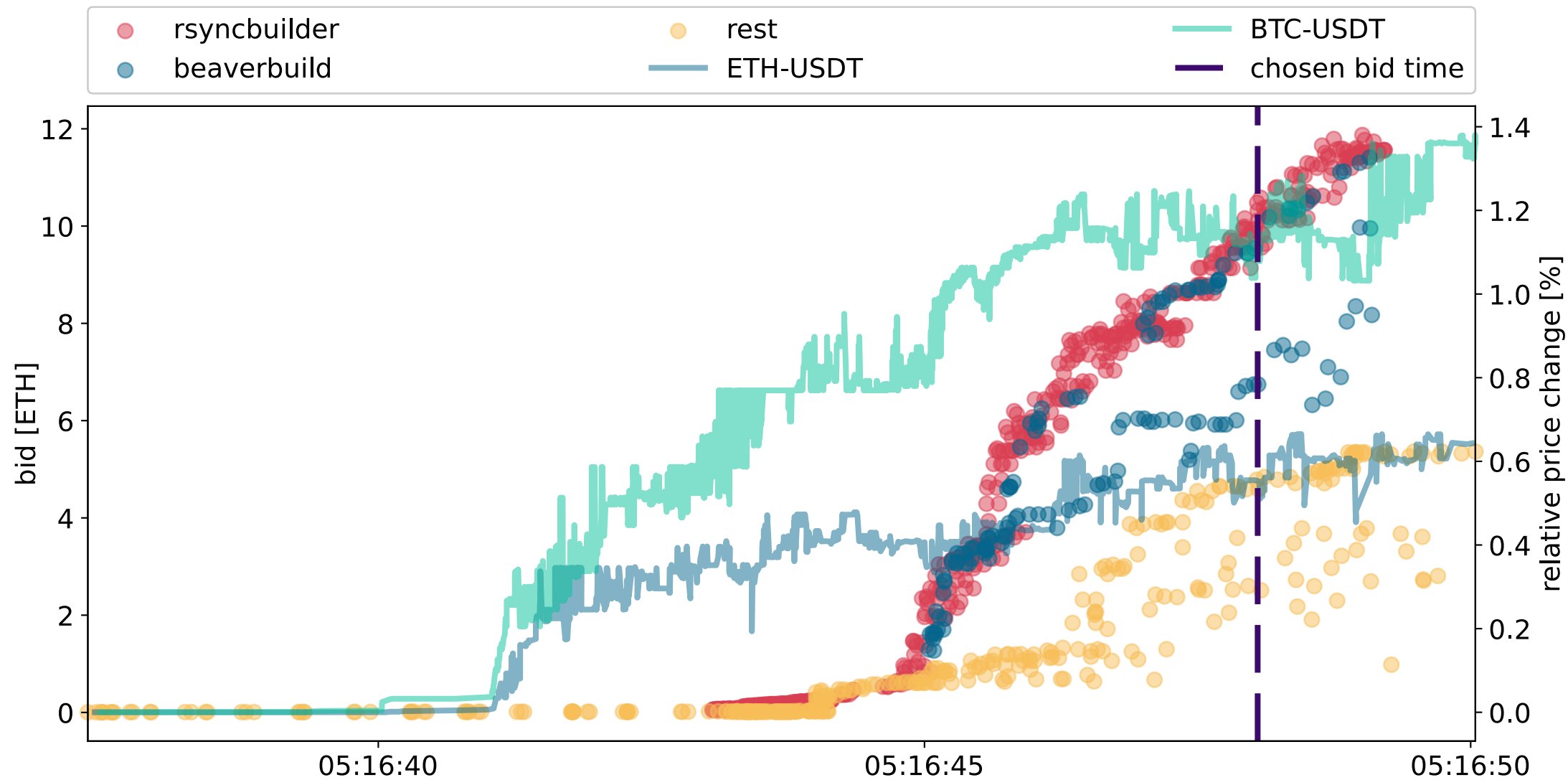
Block 18,360,789 on 16 October 2023



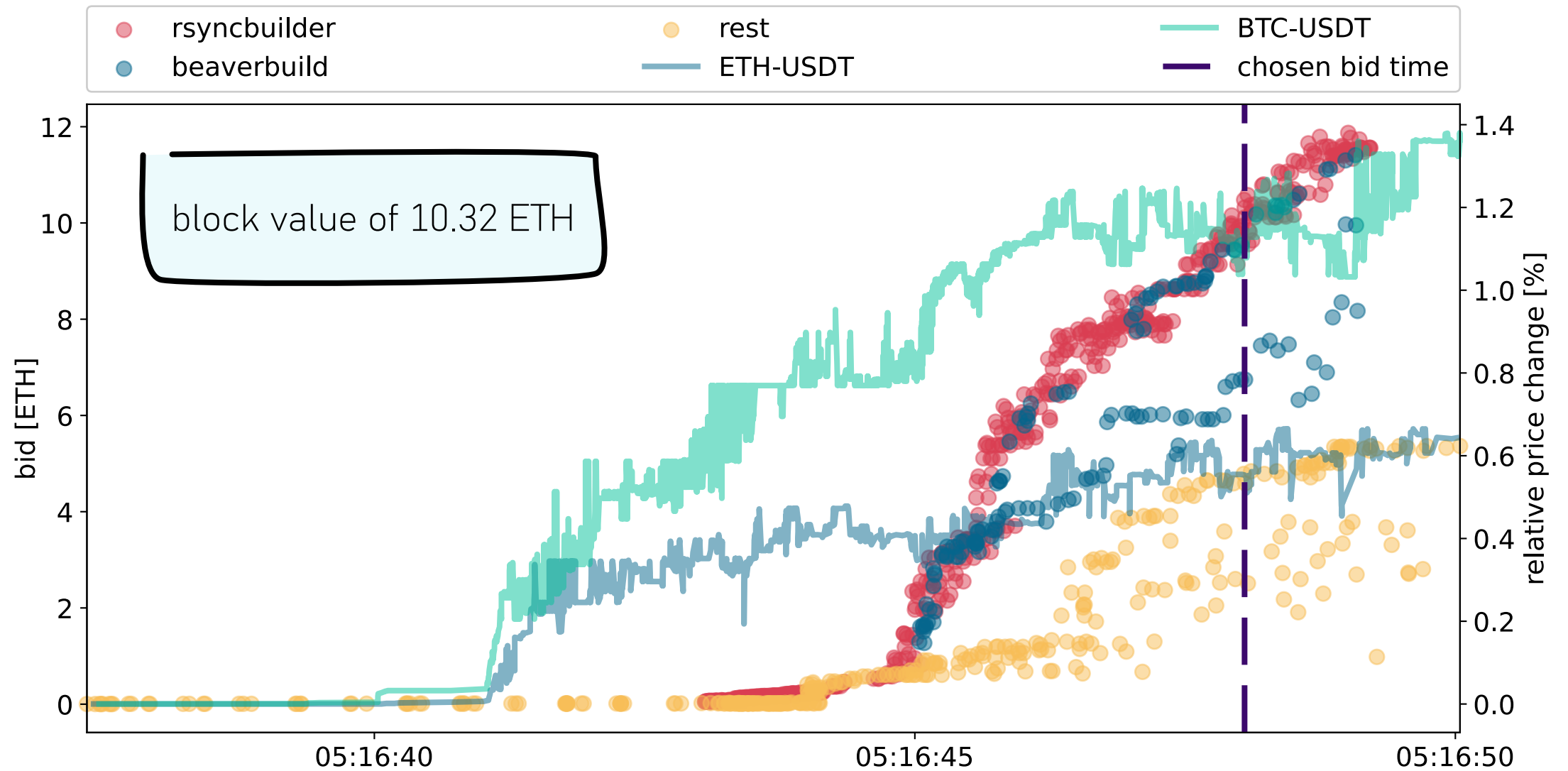
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Block 18,360,789 on 16 October 2023

tx index	searcher	pool	tokenIn	tokenOut	amount [US\$]
0	rsyncsearcher3	0x88e6a...f5640	USDC	ETH	2148195.308
1	rsyncsearcher3	0x99ac8...abc35	USDC	BTC	659507.701
2	rsyncsearcher3	0x4585f...a20c0	ETH	BTC	554524.411
3	rsyncsearcher3	0x9db9e...8425b	USDT	BTC	186858.044
4	rsyncsearcher3	0x11b81...697f6	USDT	ETH	523225.597
5	rsyncsearcher3	0x4e68c...dfa36	USDT	ETH	524150.487
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22	rsyncsearcher3	0x824a3...c0673	ETH	BLUR	11451.829
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28	rsyncsearcher3	0x290a6...f5b42	ETH	MATIC	14629.722
31	searcher5	0xcd828...a9fbf	FXS	ETH	6247.832
33	rsyncsearcher3	0x919fa...daf79	ETH	CRV	4954.943
35	rsyncsearcher3	0x34704...08d60	USDT	UNI	1106.016
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26 non-atomic arbitrage swaps
with a volume of 6,023,565 \$

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non-atomic arbitrage by merely
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price difference closed

Identifying non-atomic arbitrage

Identifying non-atomic arbitrage

Assumption

Non-atomic arbitrage transactions have a high value. Thus, searchers performing these non-atomic arbitrages are likely to protect their transaction and pay suspicious amounts to have their “simple” swap included.

Heuristics



Heuristic 1
simple transaction

Heuristics



Heuristic 1
simple transaction



Heuristic 2
private transaction

Heuristics



Heuristic 1
simple transaction



Heuristic 2
private transaction



Heuristic 3
coinbase or priority

Heuristics



Heuristic 1
simple transaction



Heuristic 2
private transaction



Heuristic 3
coinbase or priority

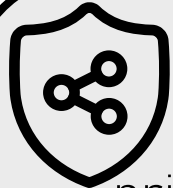


Heuristic 4
first in block

Heuristics



Heuristic 1
simple transaction



Heuristic 2
private transaction



Heuristic 3
coinbase or priority

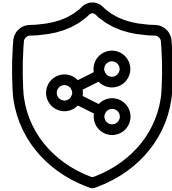
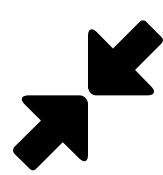


Heuristic 4
first in block



Heuristic 5
top tokens

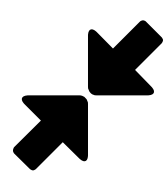
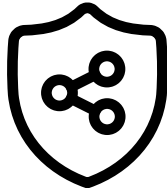



Heuristics



	total swaps	simple heuristic 1	private heuristic 2	coinbase transfer or priority heuristic 3	first swap in pool heuristic 4	top tokens fee heuristic 5	all
beaversearchers	1,188,696	0.982	0.815	0.917	0.826	0.822	0.580
rsyncsearchers	346,570	1.000	0.997	0.954	0.924	0.931	0.884
mantasearcher	60,813	0.999	0.941	0.977	0.921	0.955	0.879
overall	77,019,583	0.651	0.317	0.601	0.280	0.151	0.028

Heuristics



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Non-atomic arbitrage

landscape

drivers

vertical integration

impact

Non-atomic arbitrage

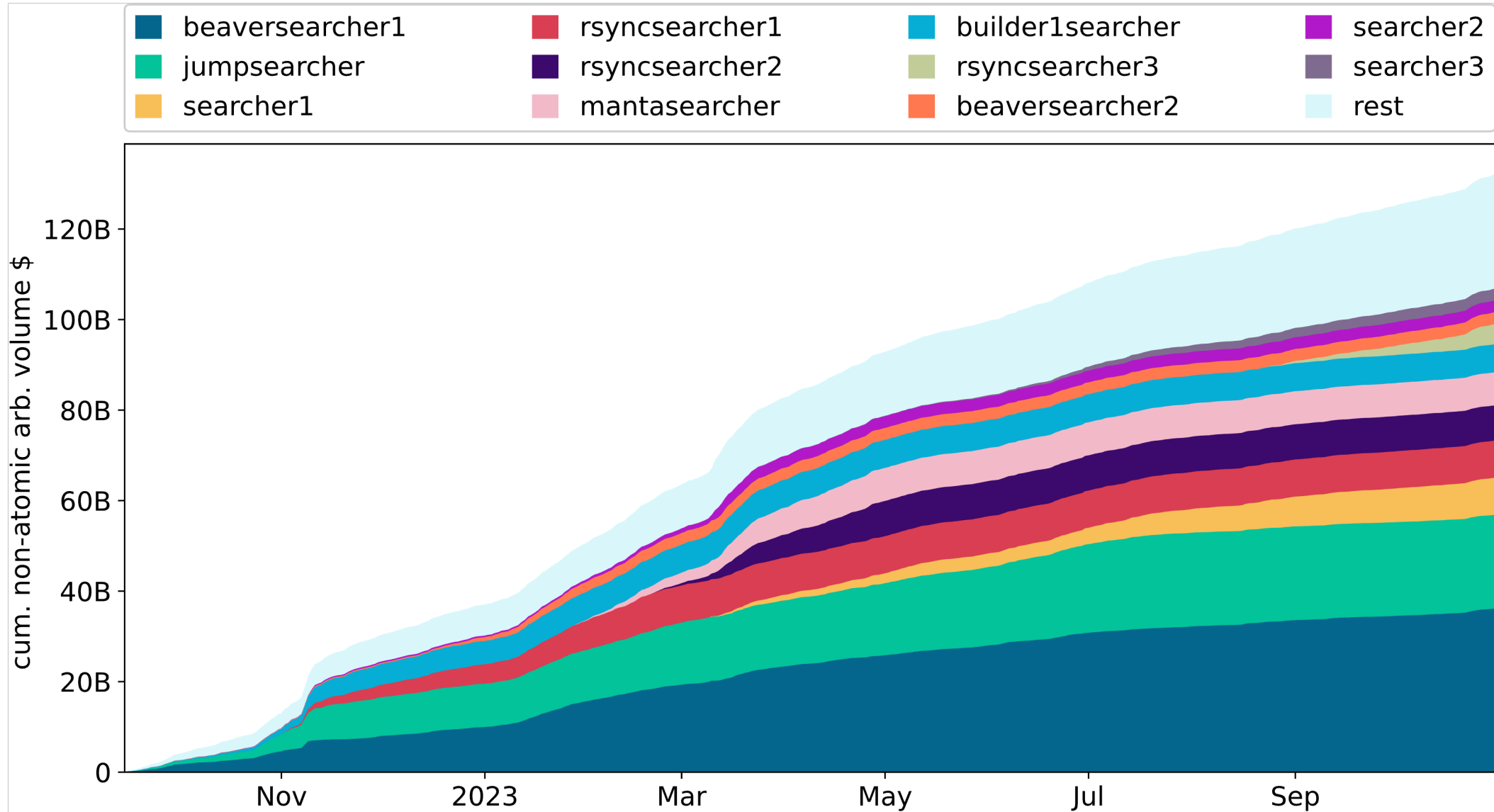
landscape

drivers

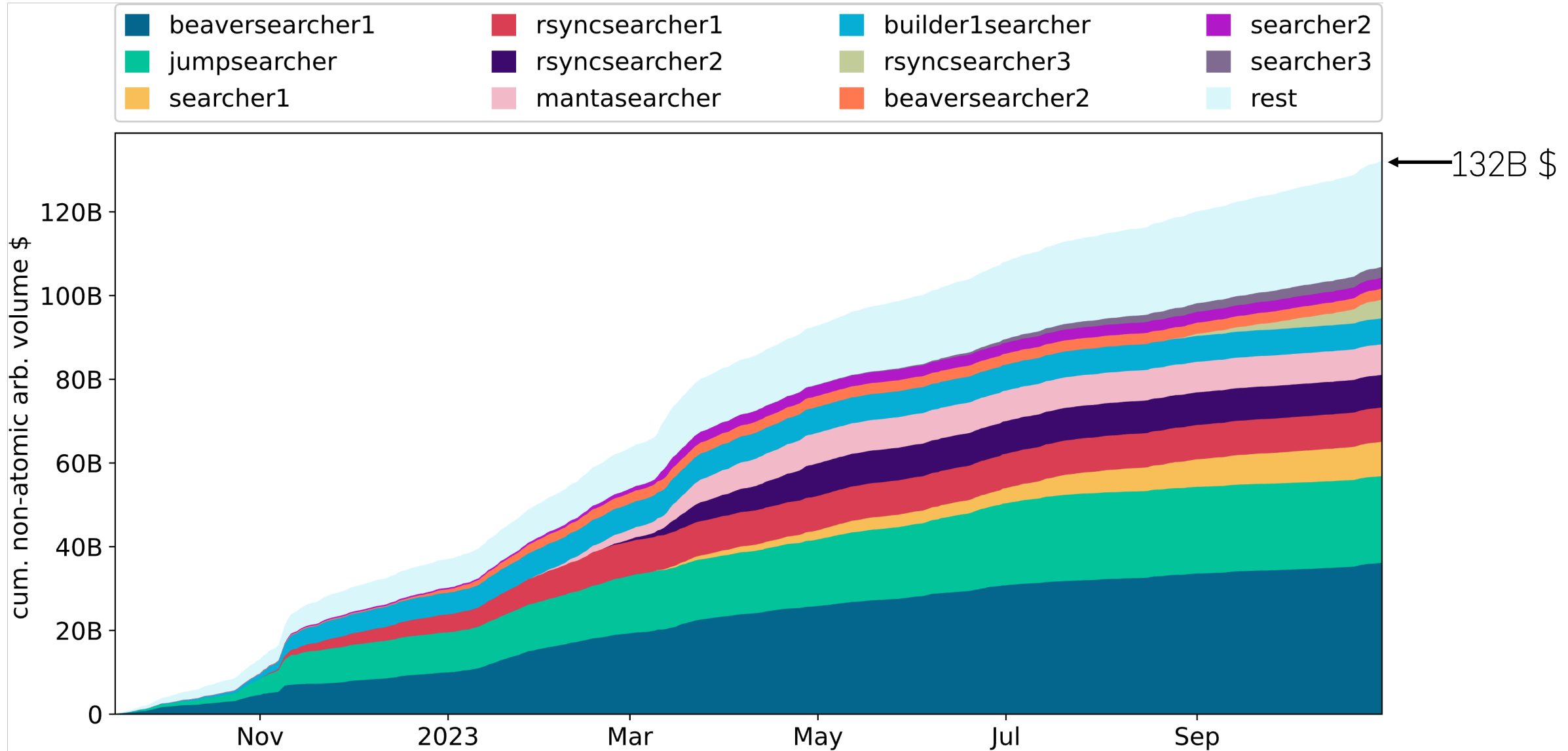
vertical integration

impact

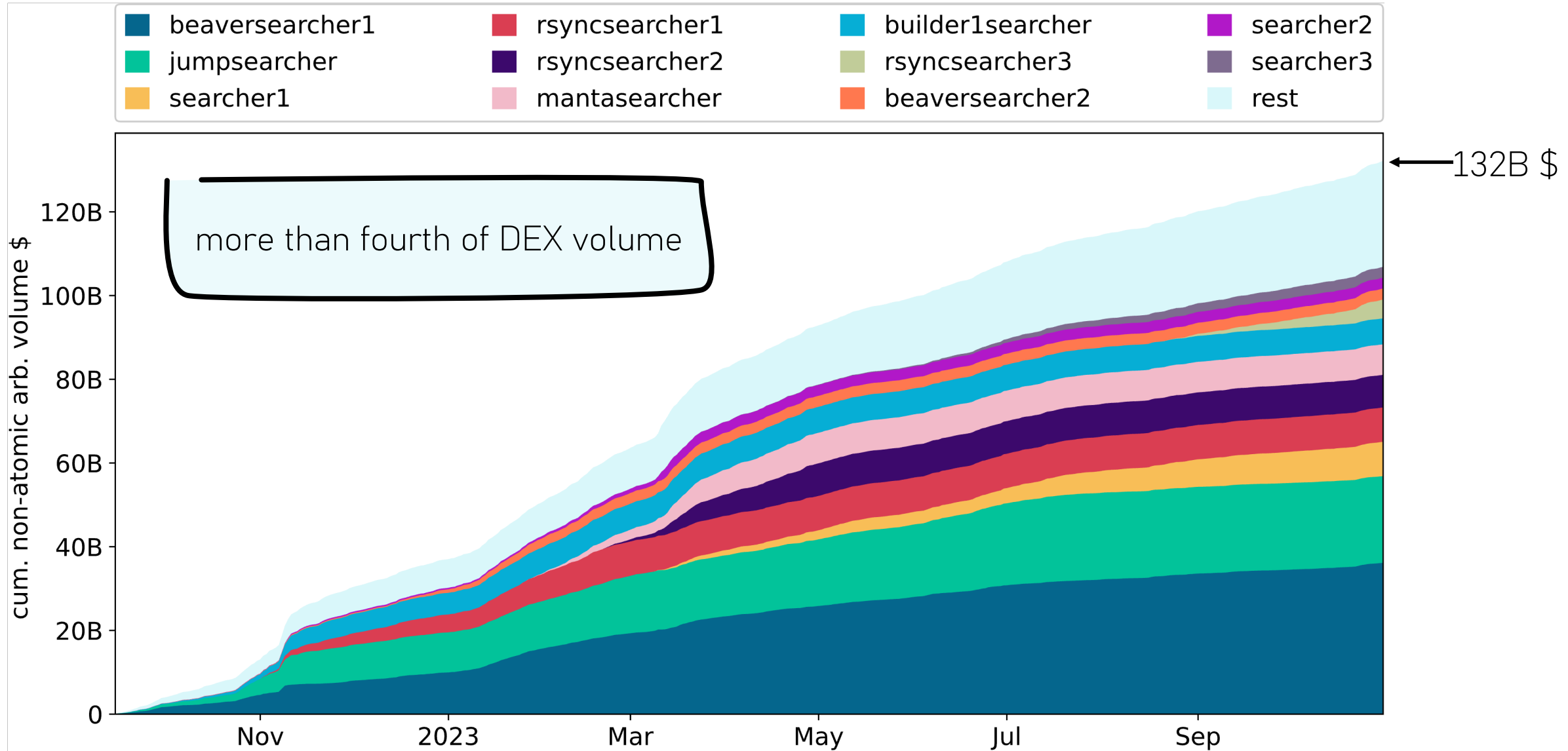
Cumulative non-atomic arbitrage volume



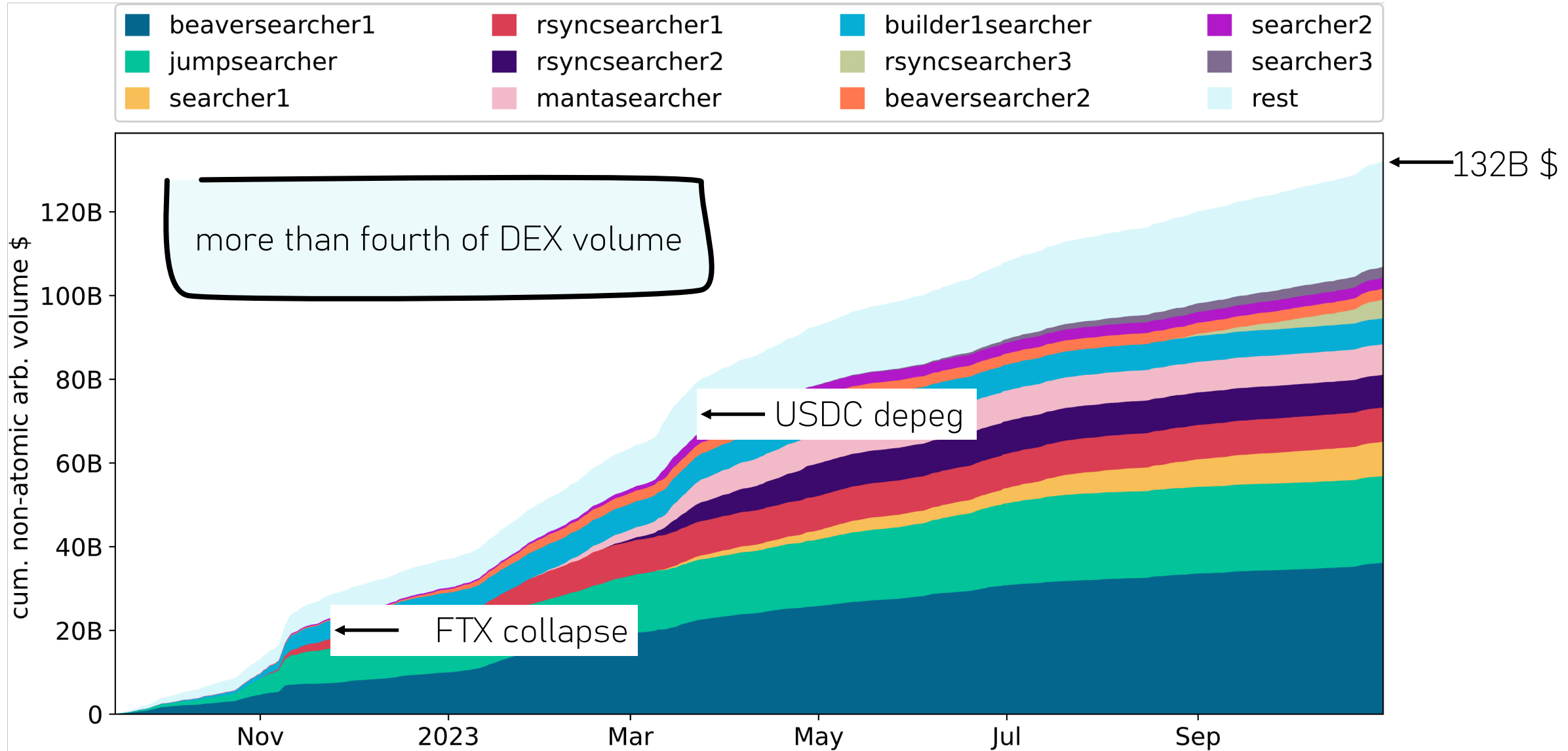
Cumulative non-atomic arbitrage volume



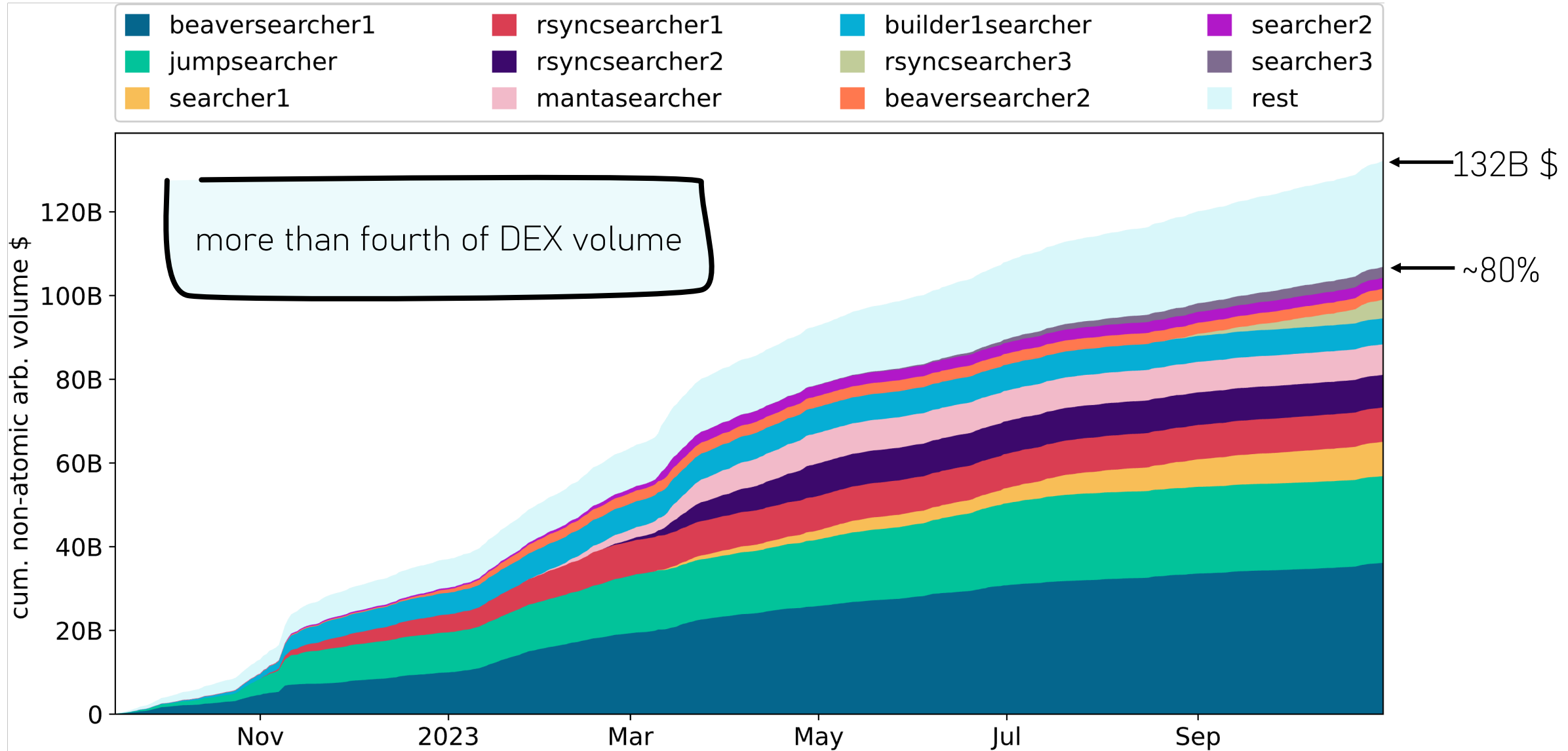
Cumulative non-atomic arbitrage volume



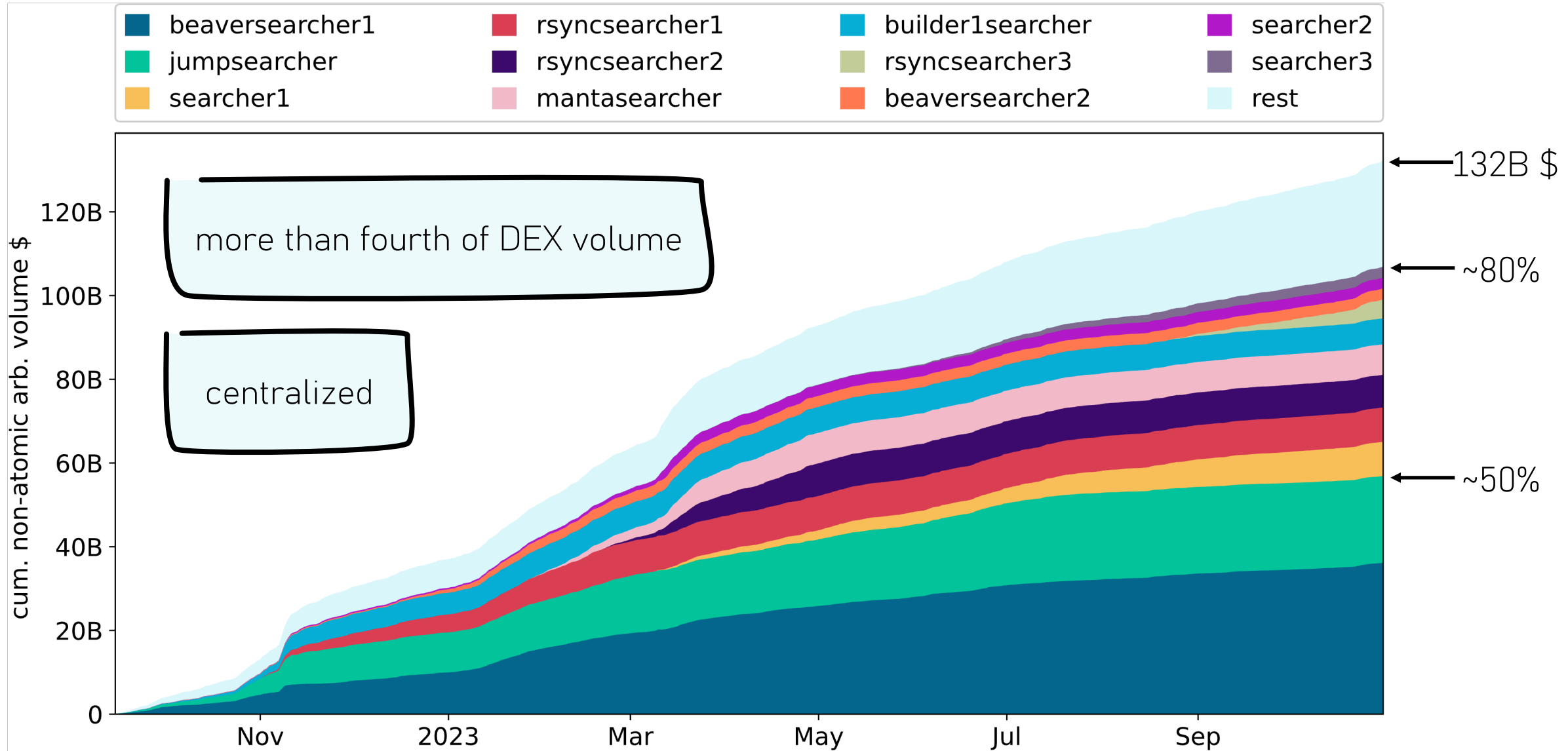
Cumulative non-atomic arbitrage volume



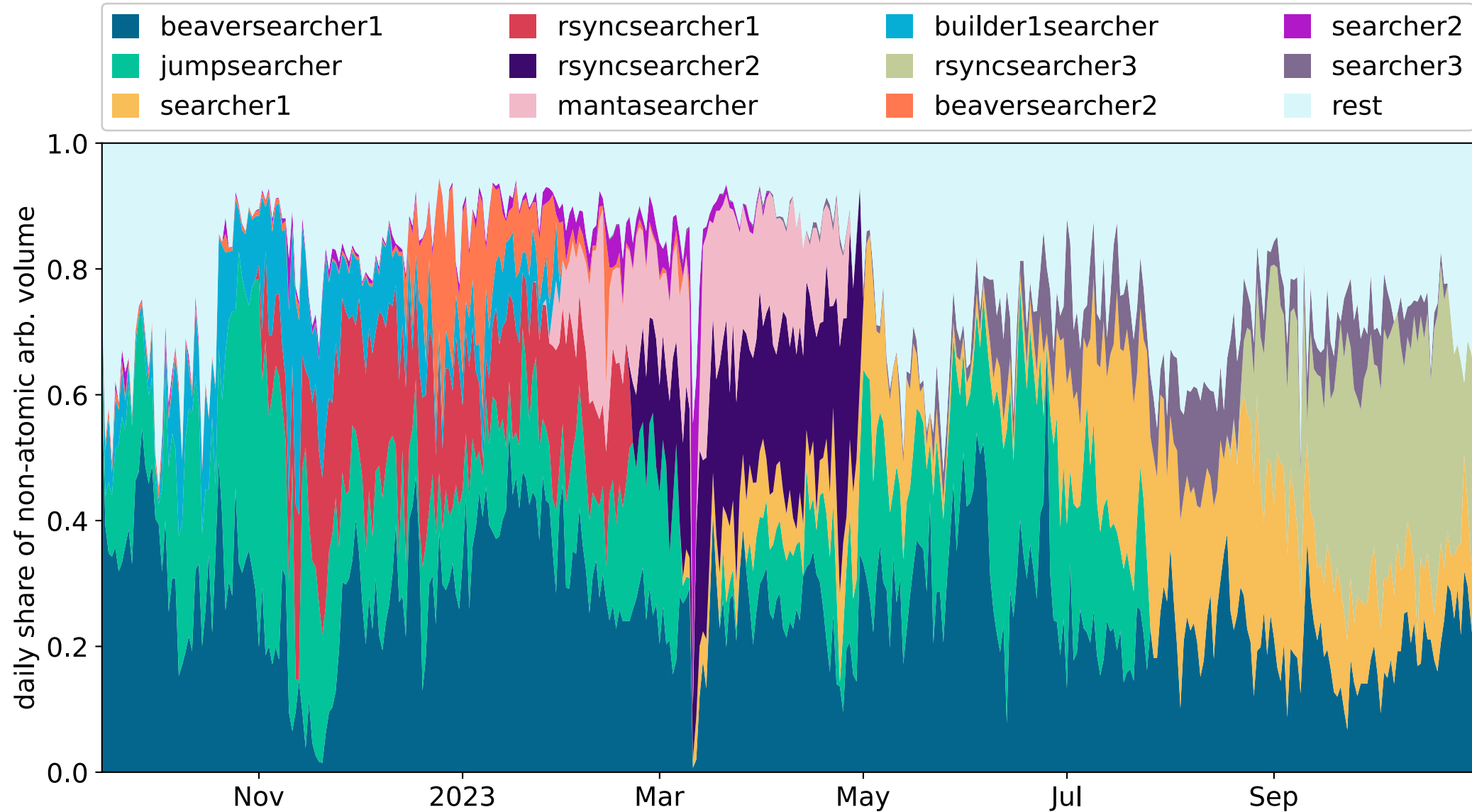
Cumulative non-atomic arbitrage volume



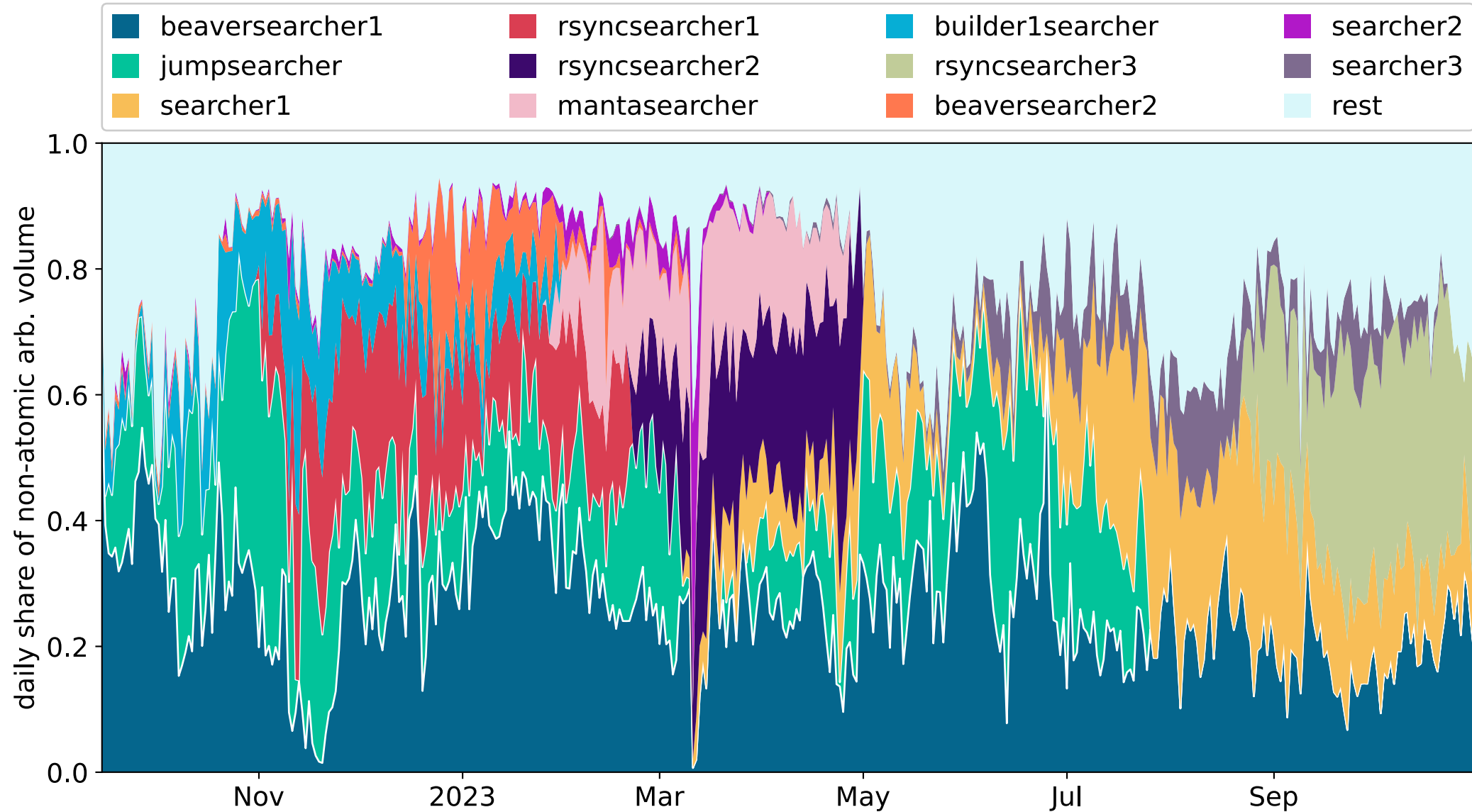
Cumulative non-atomic arbitrage volume



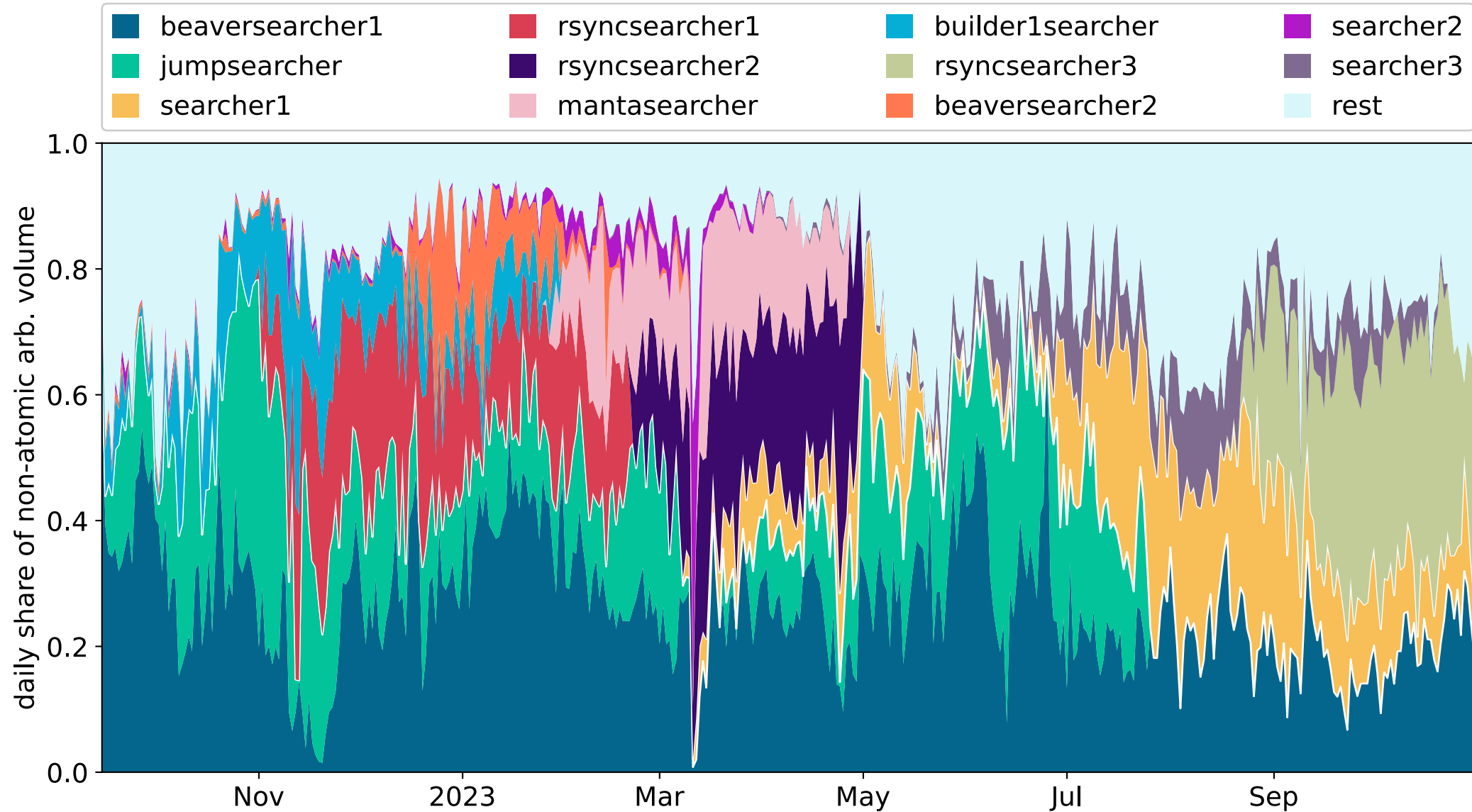
Share non-atomic arbitrage volume



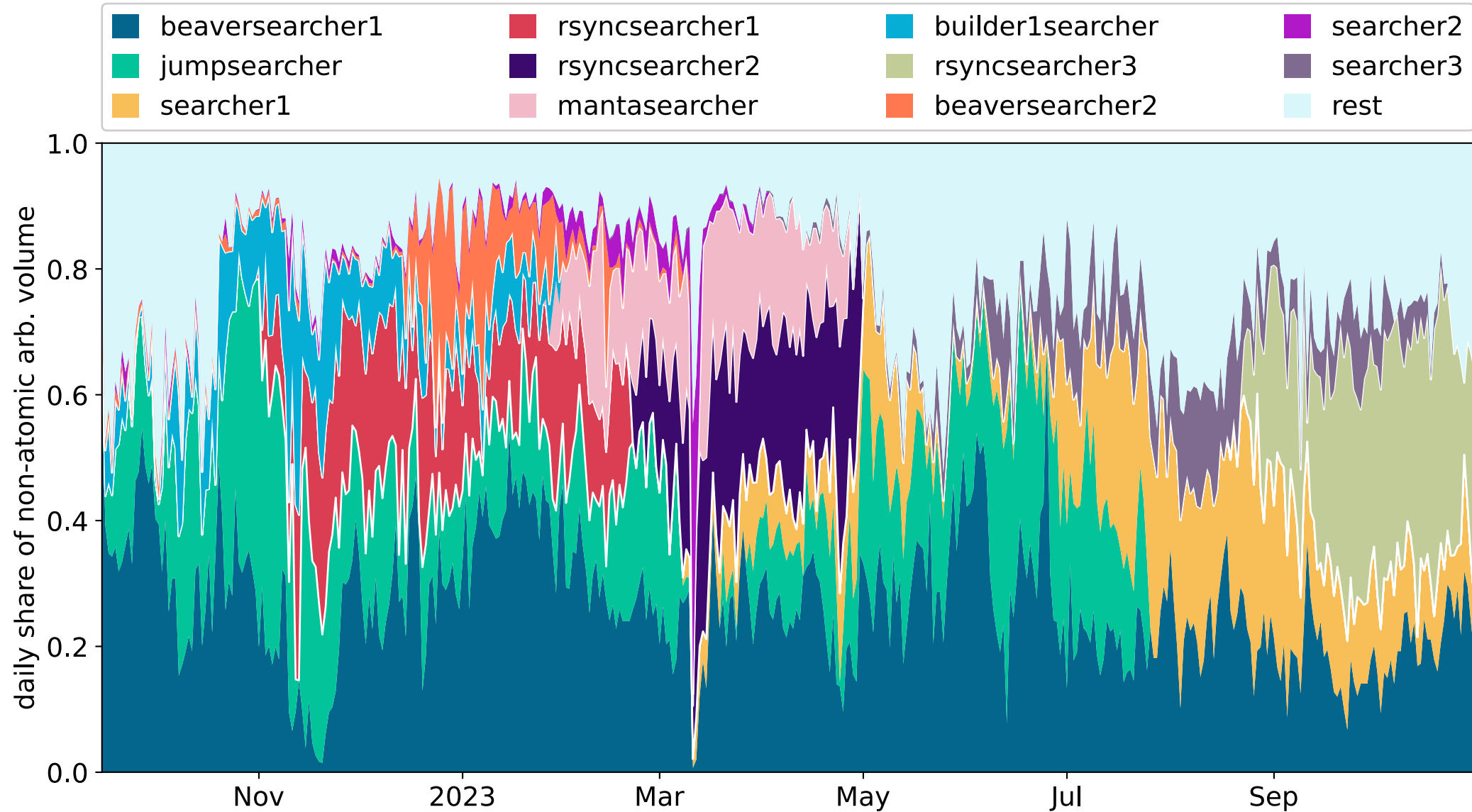
Share non-atomic arbitrage volume



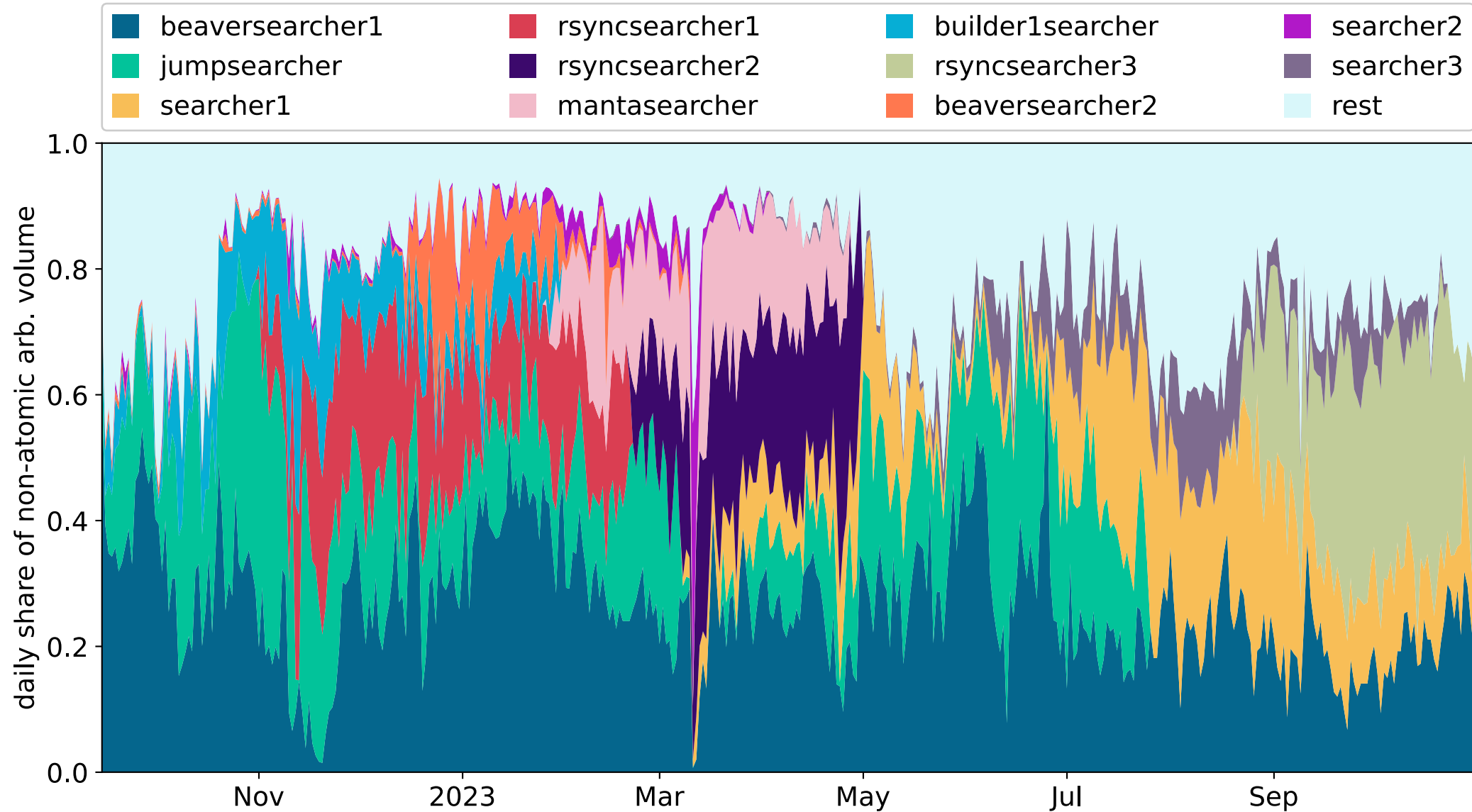
Share non-atomic arbitrage volume



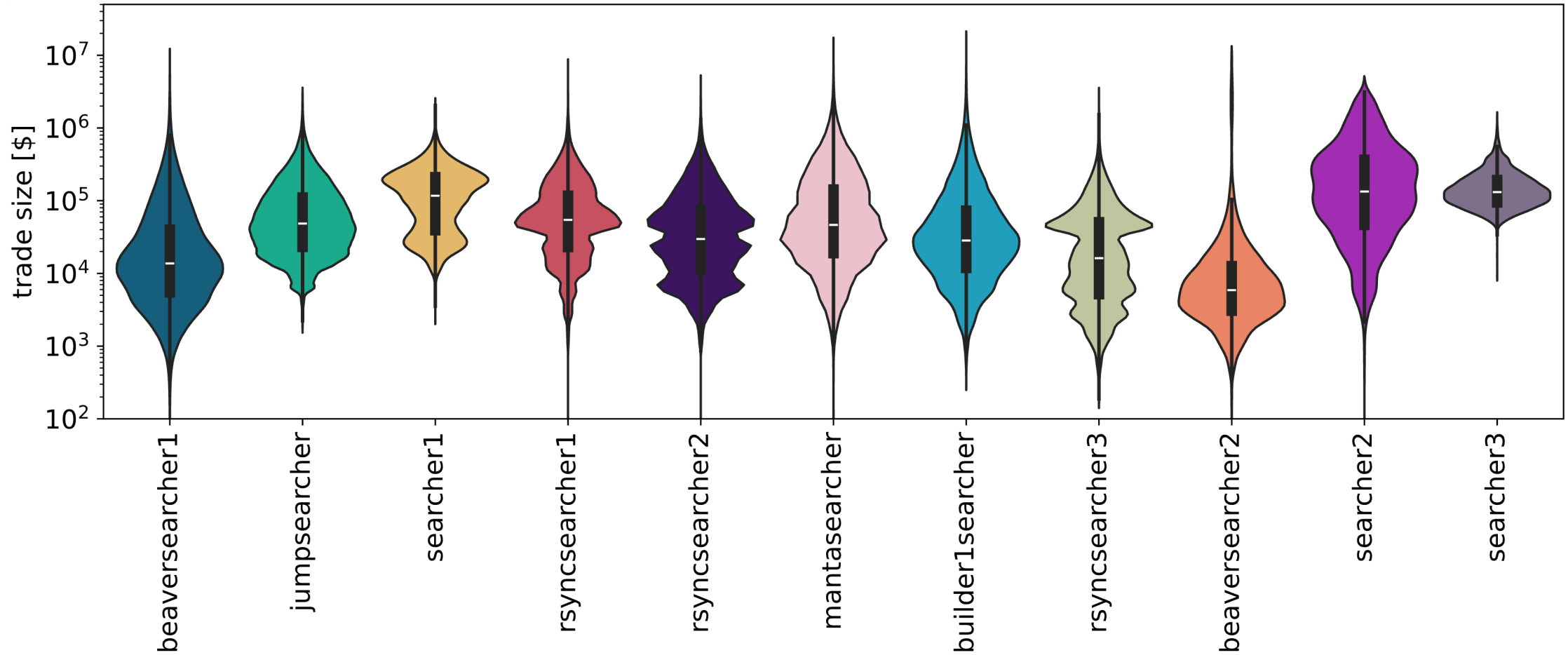
Share non-atomic arbitrage volume



Share non-atomic arbitrage volume

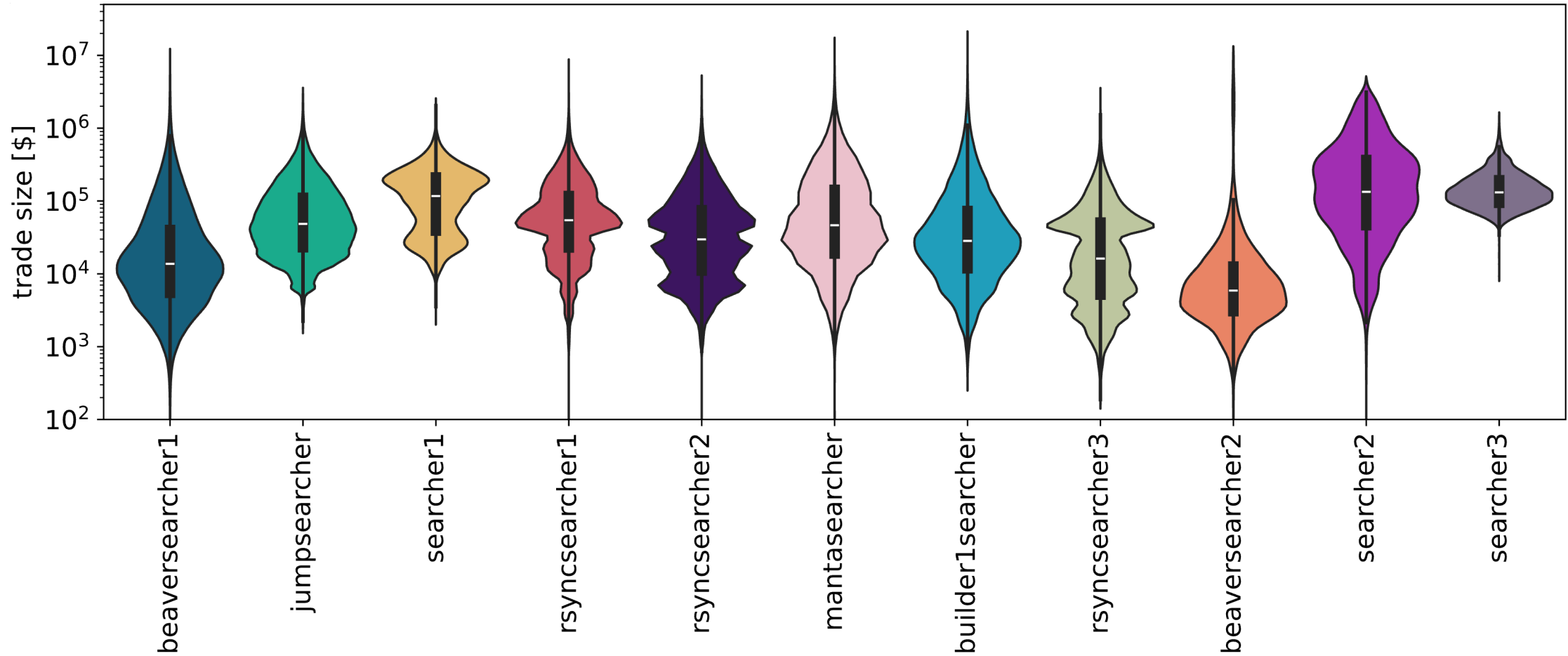


Trade size distribution

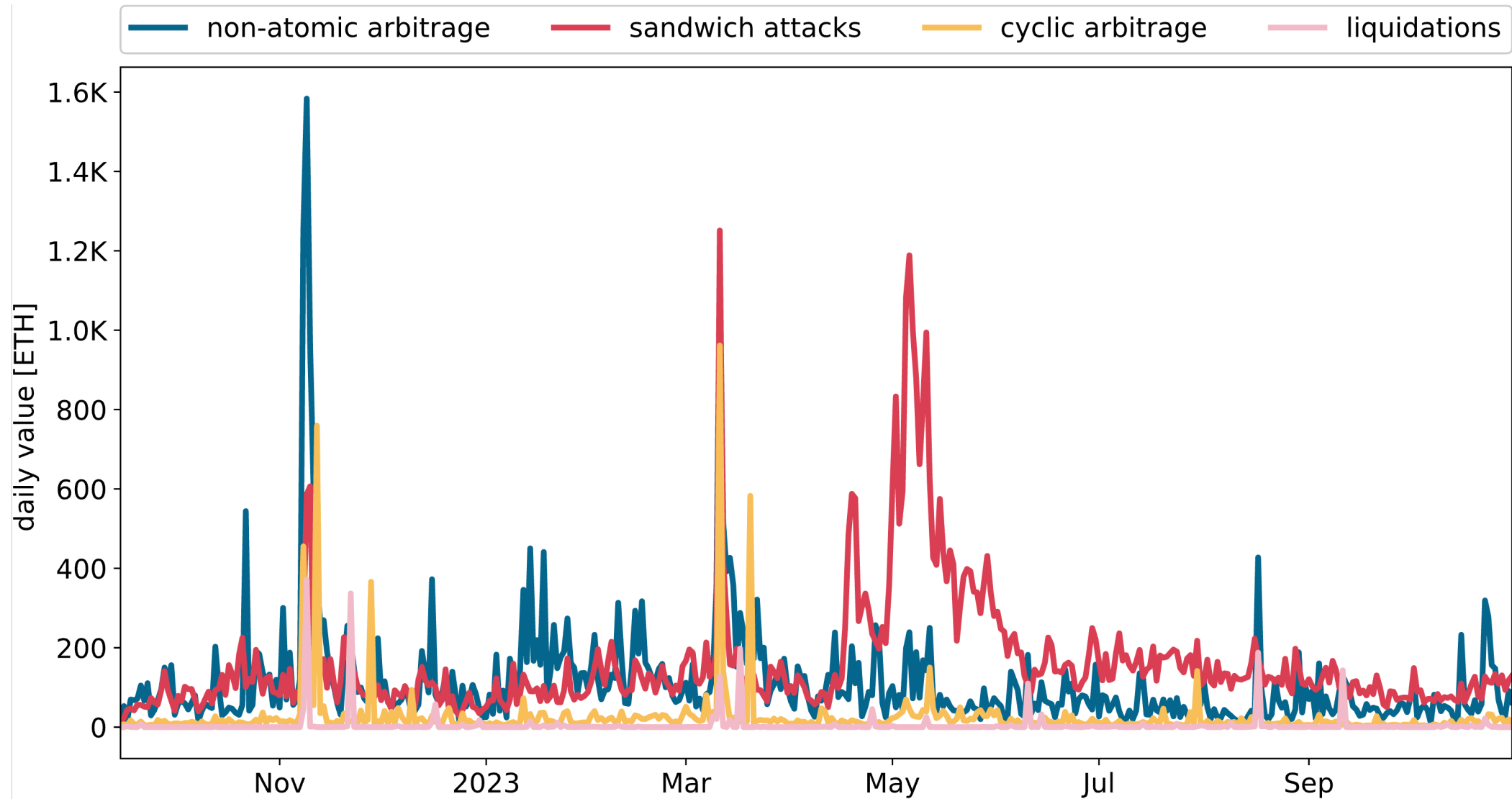


Trade size distribution

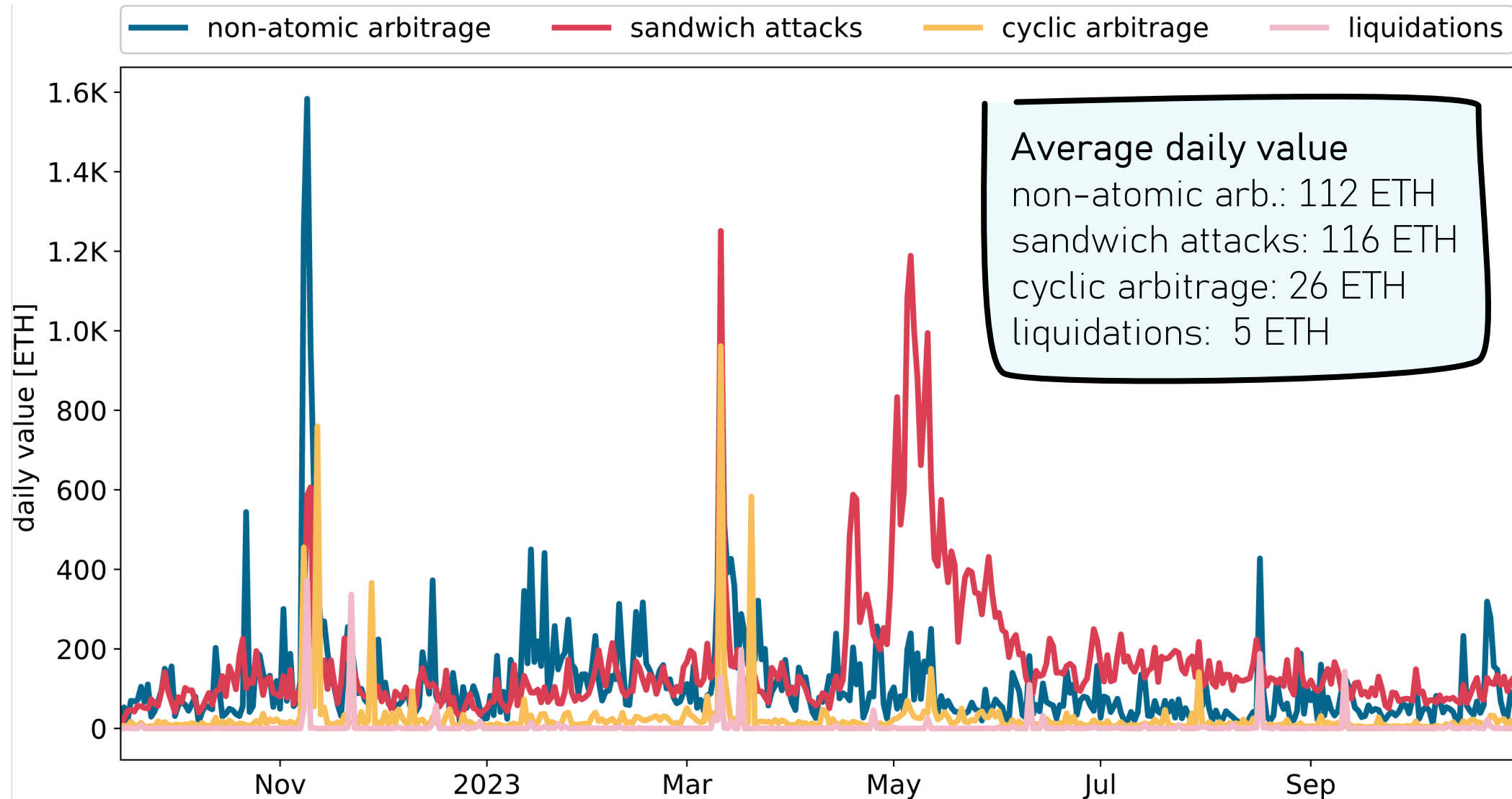
average trade size 73,891\$



MEV comparison



MEV comparison



Non-atomic arbitrage

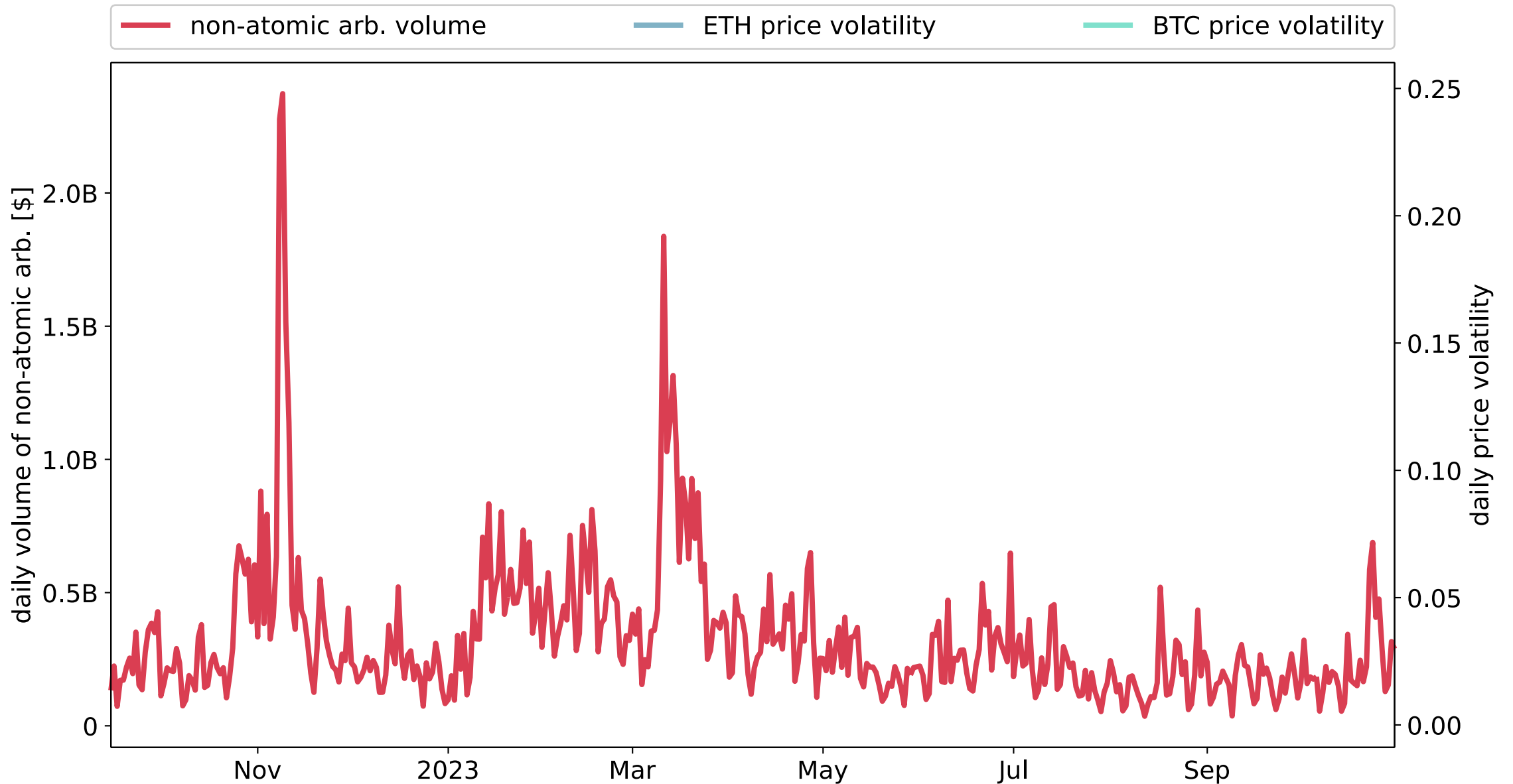
landscape

drivers

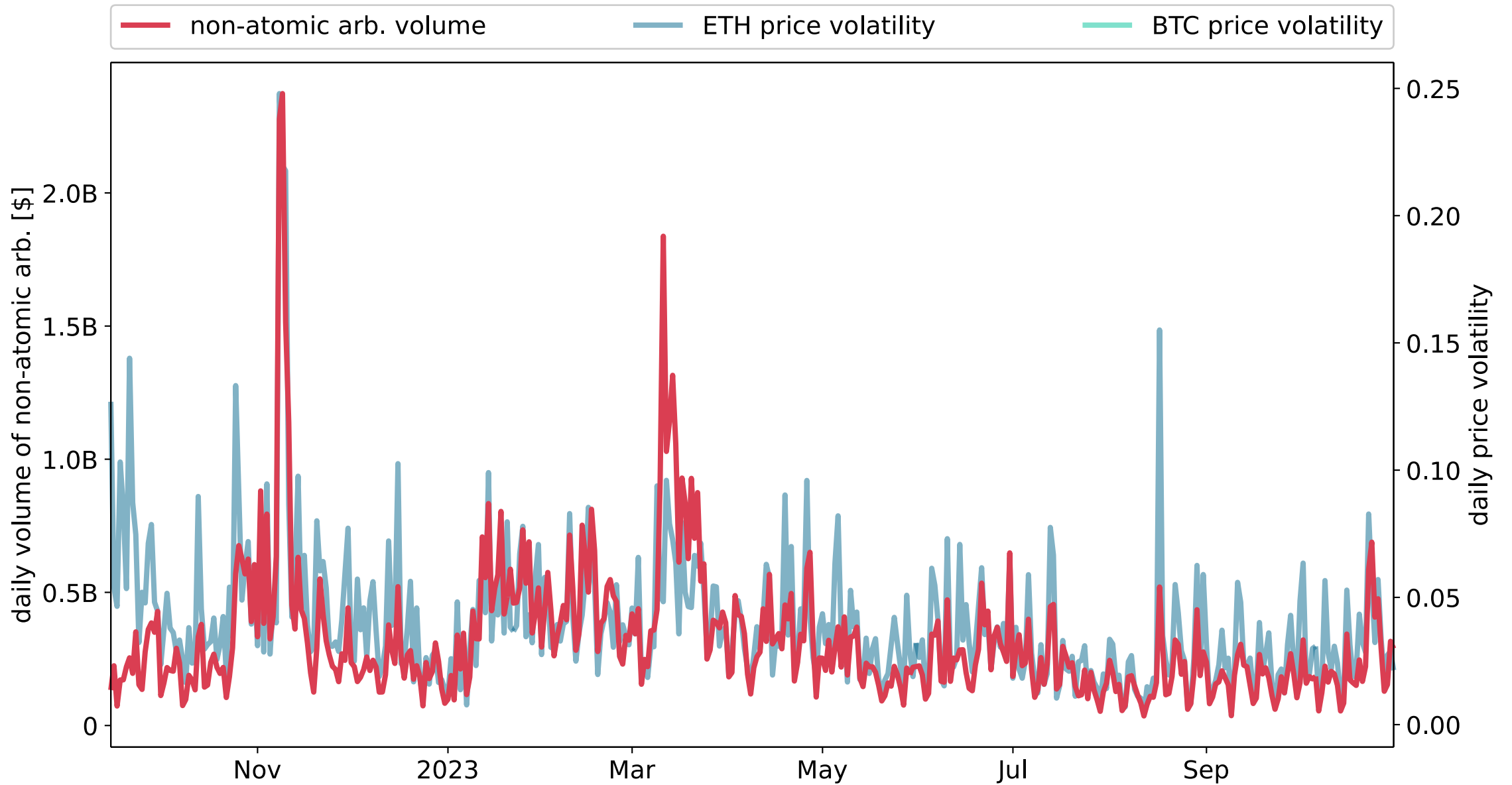
vertical integration

impact

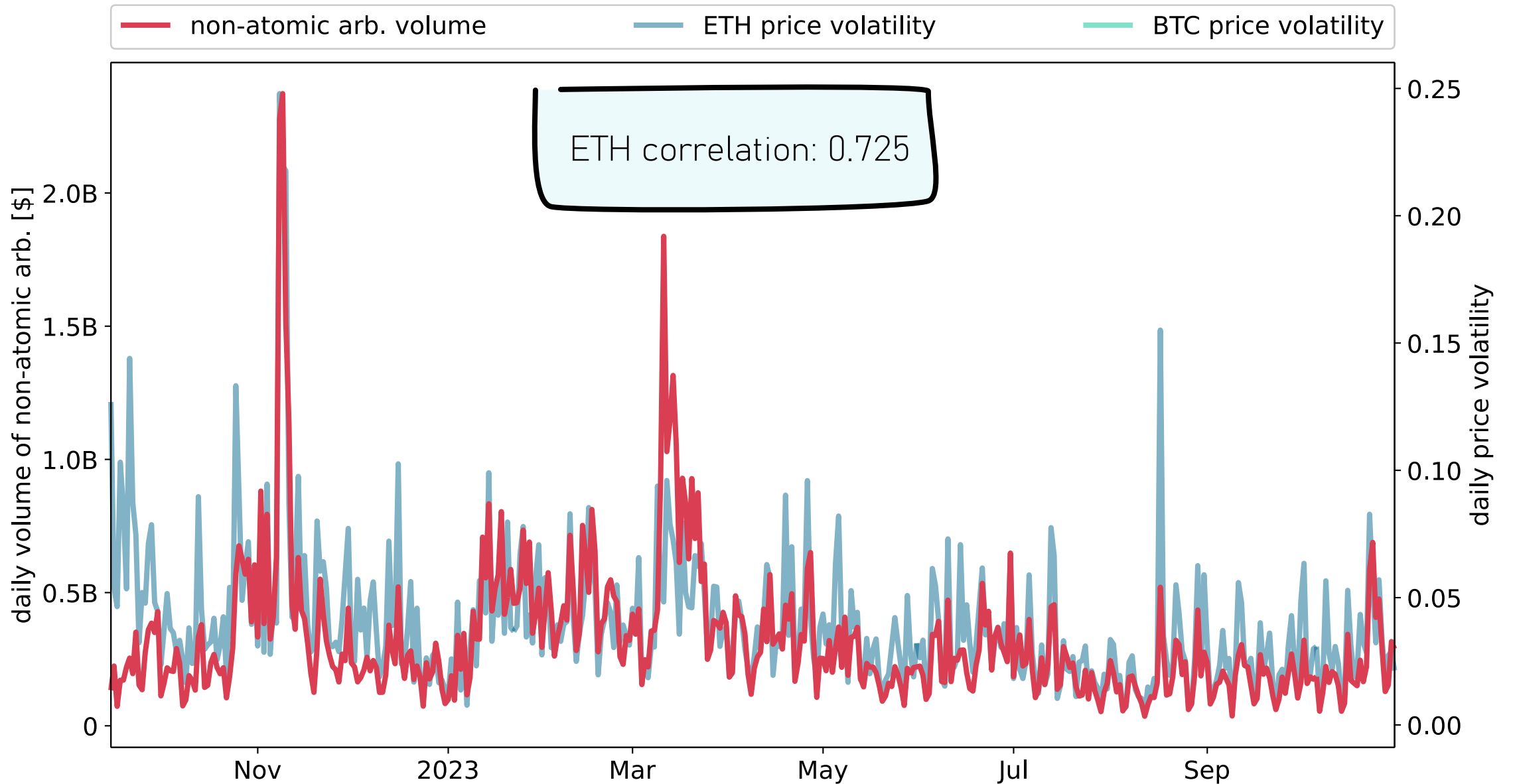
Daily non-atomic arbitrage volume



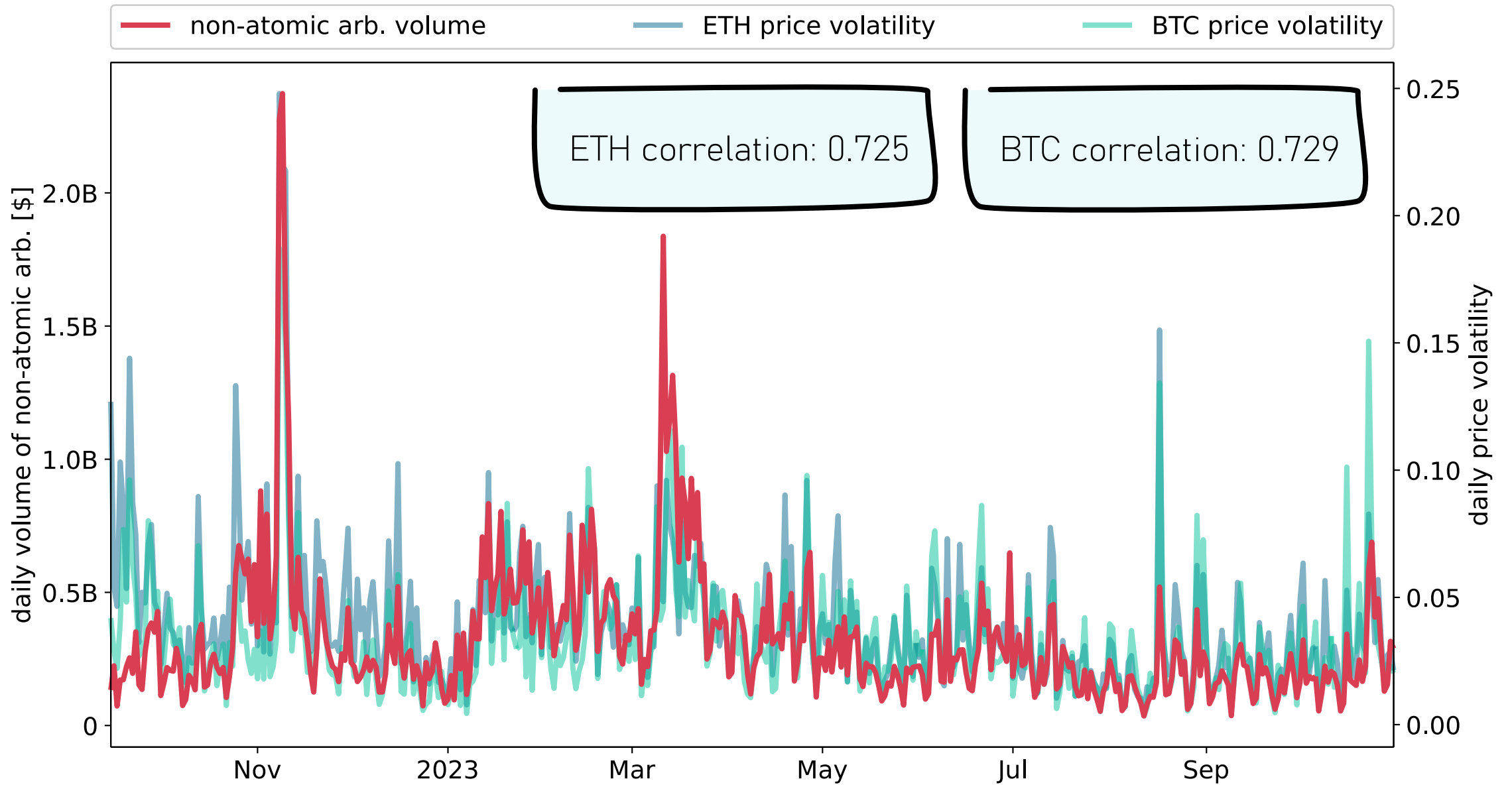
Daily non-atomic arbitrage volume



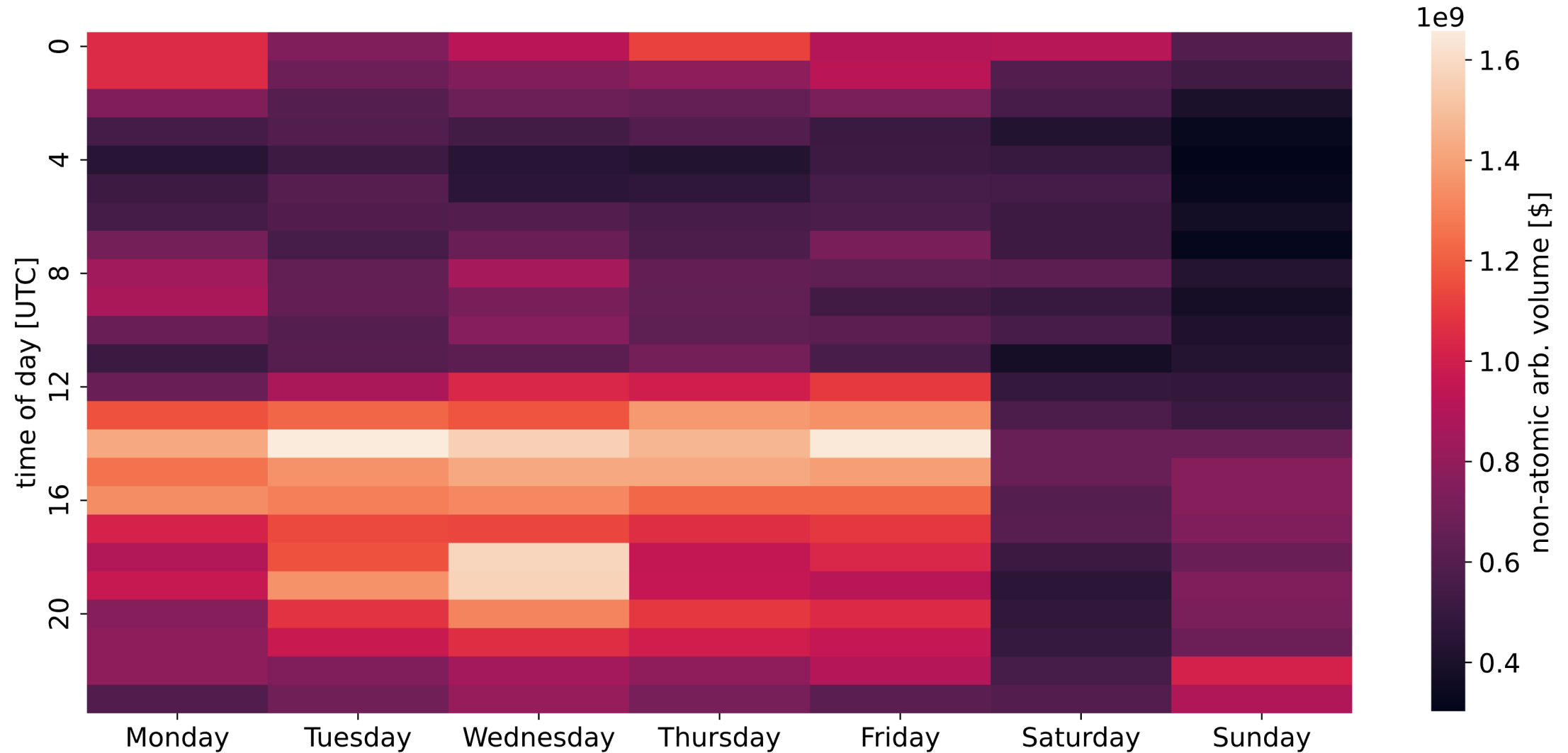
Daily non-atomic arbitrage volume



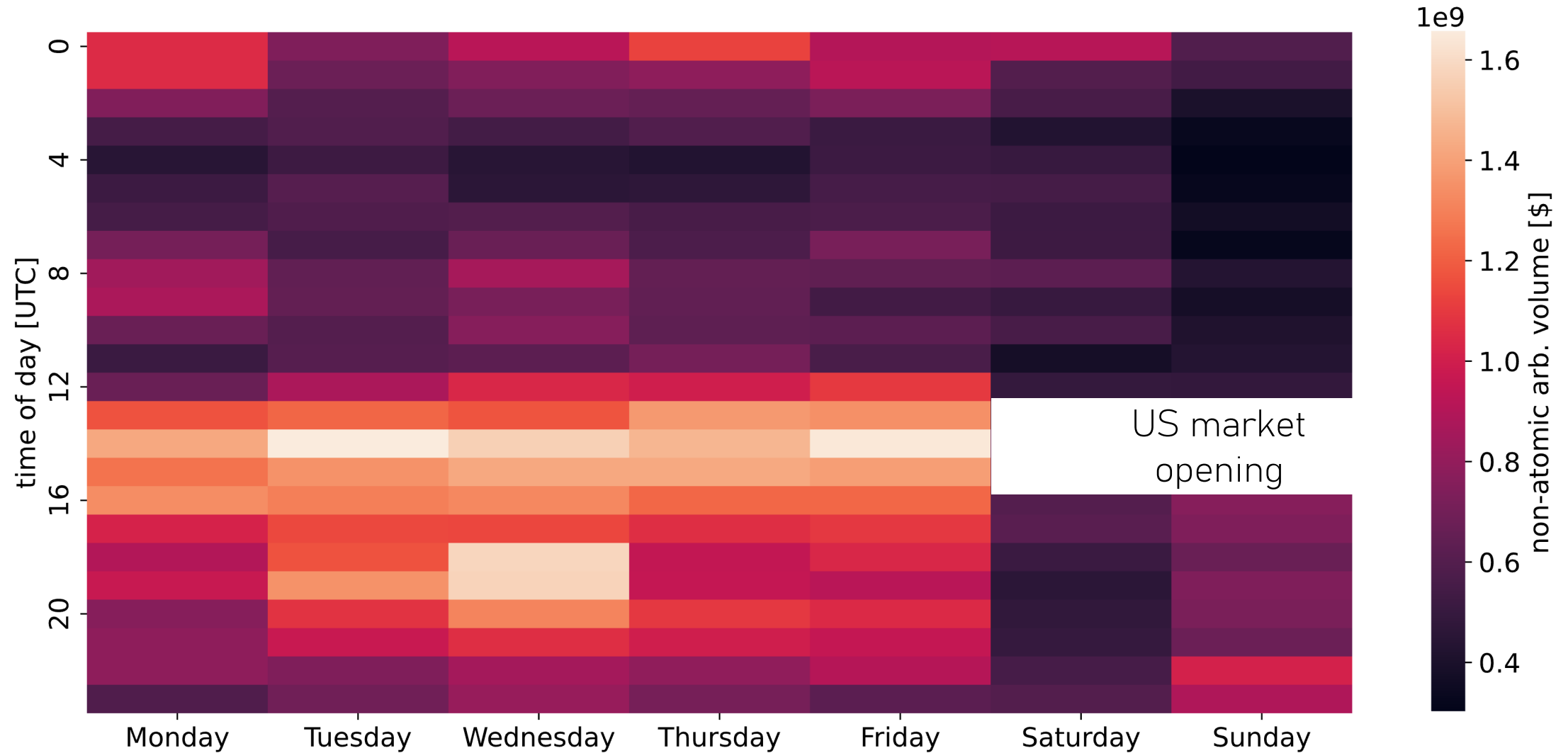
Daily non-atomic arbitrage volume



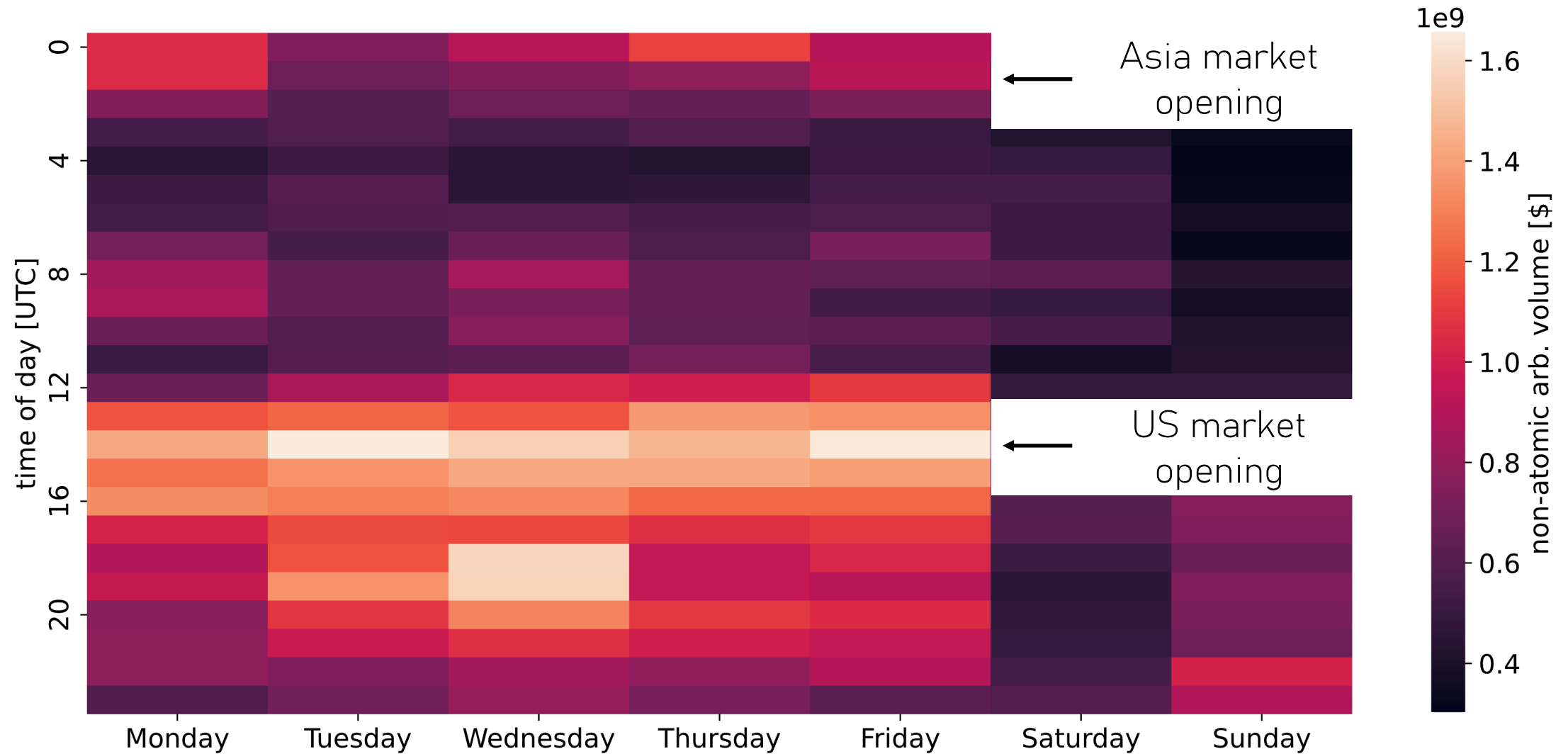
Non-atomic arbitrage volume by time & day



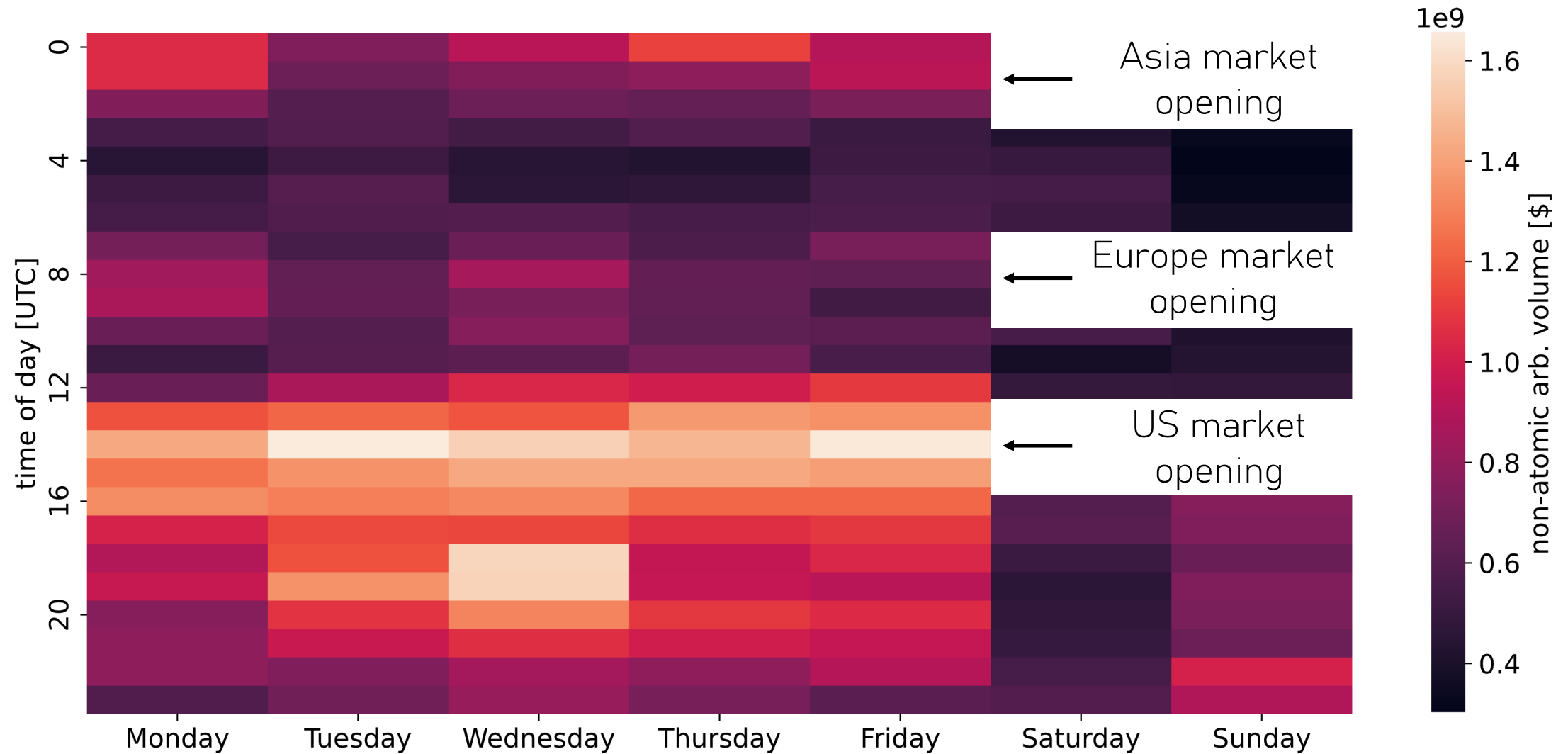
Non-atomic arbitrage volume by time & day



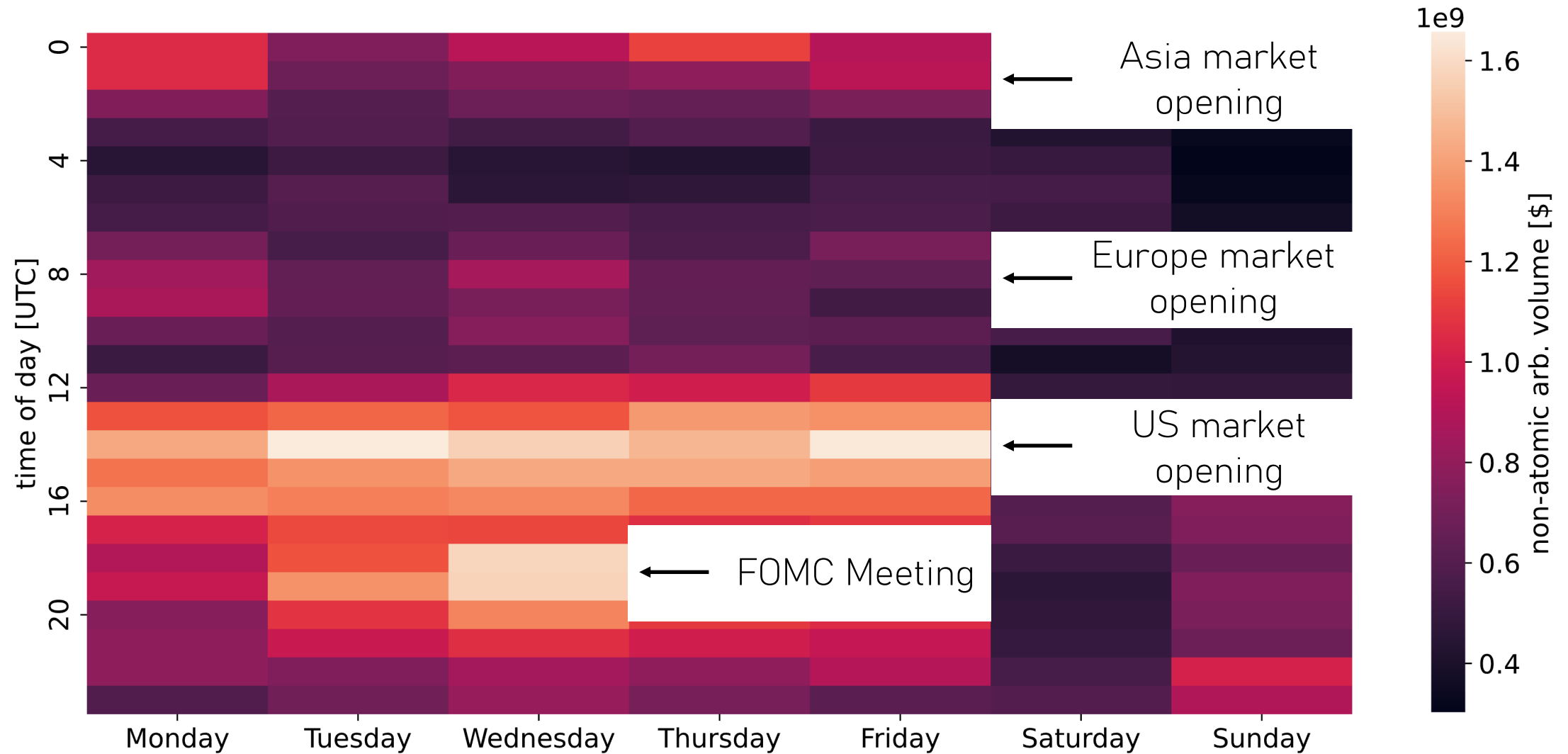
Non-atomic arbitrage volume by time & day



Non-atomic arbitrage volume by time & day



Non-atomic arbitrage volume by time & day



Non-atomic arbitrage

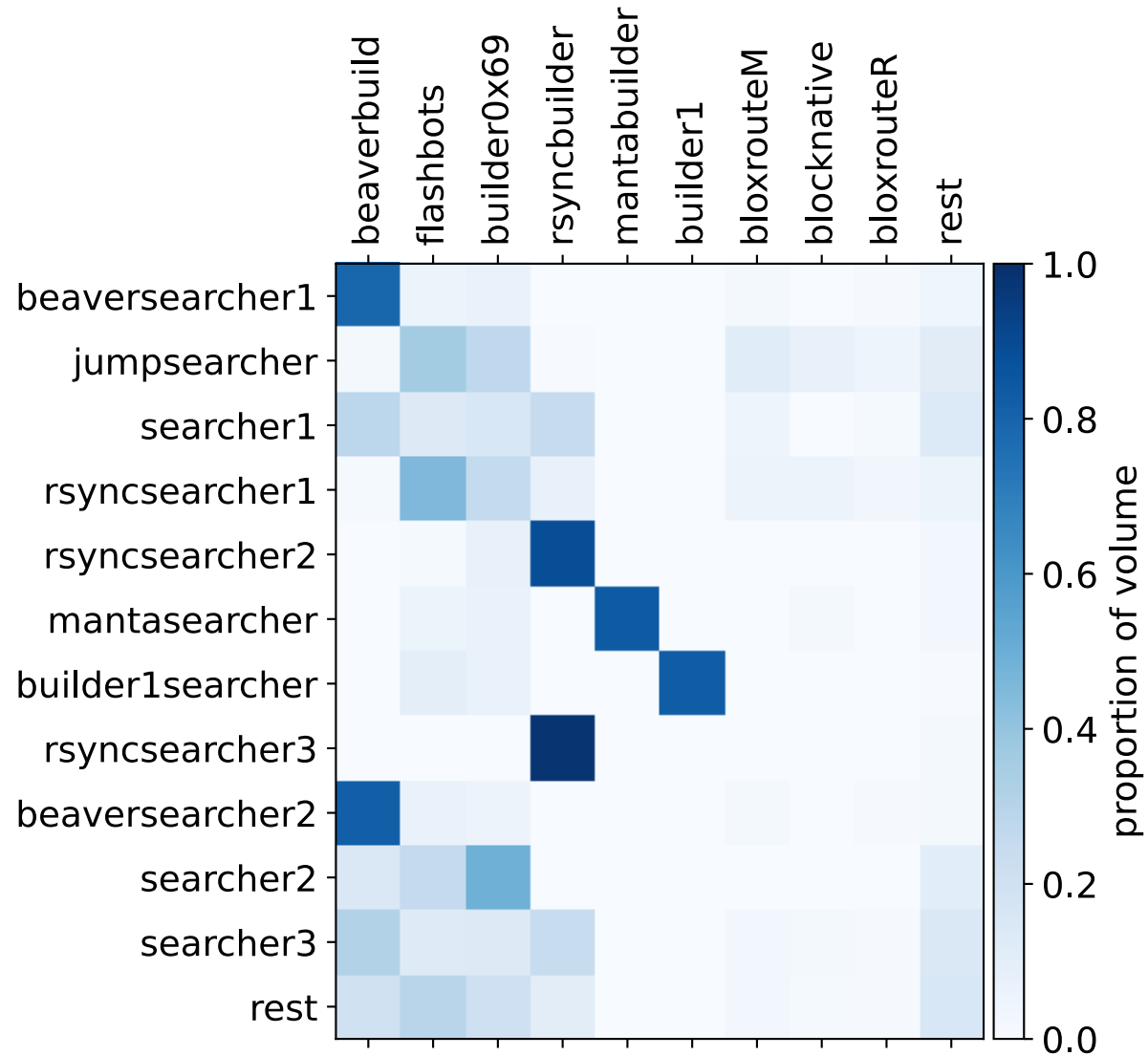
landscape

drivers

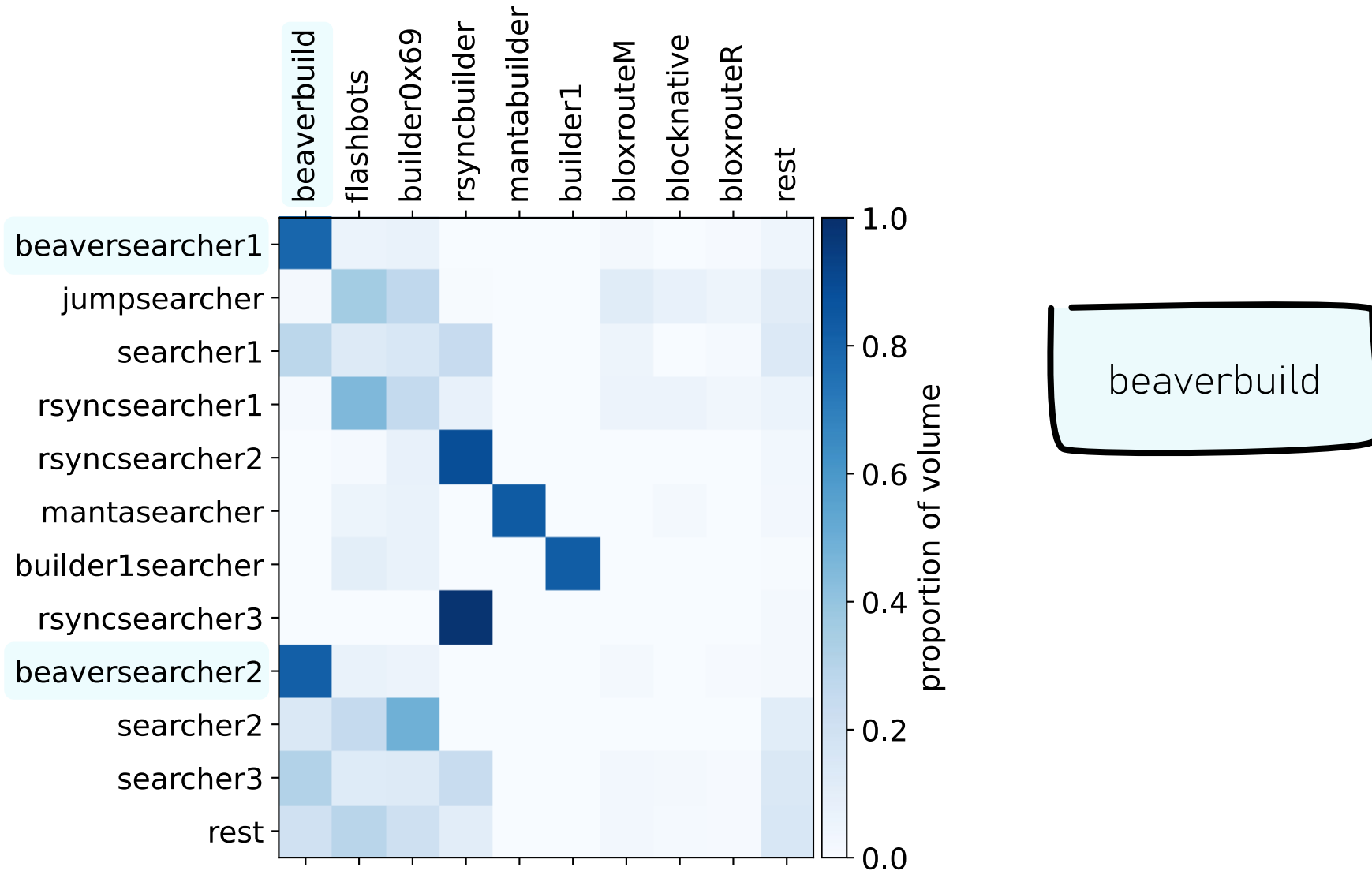
vertical integration

impact

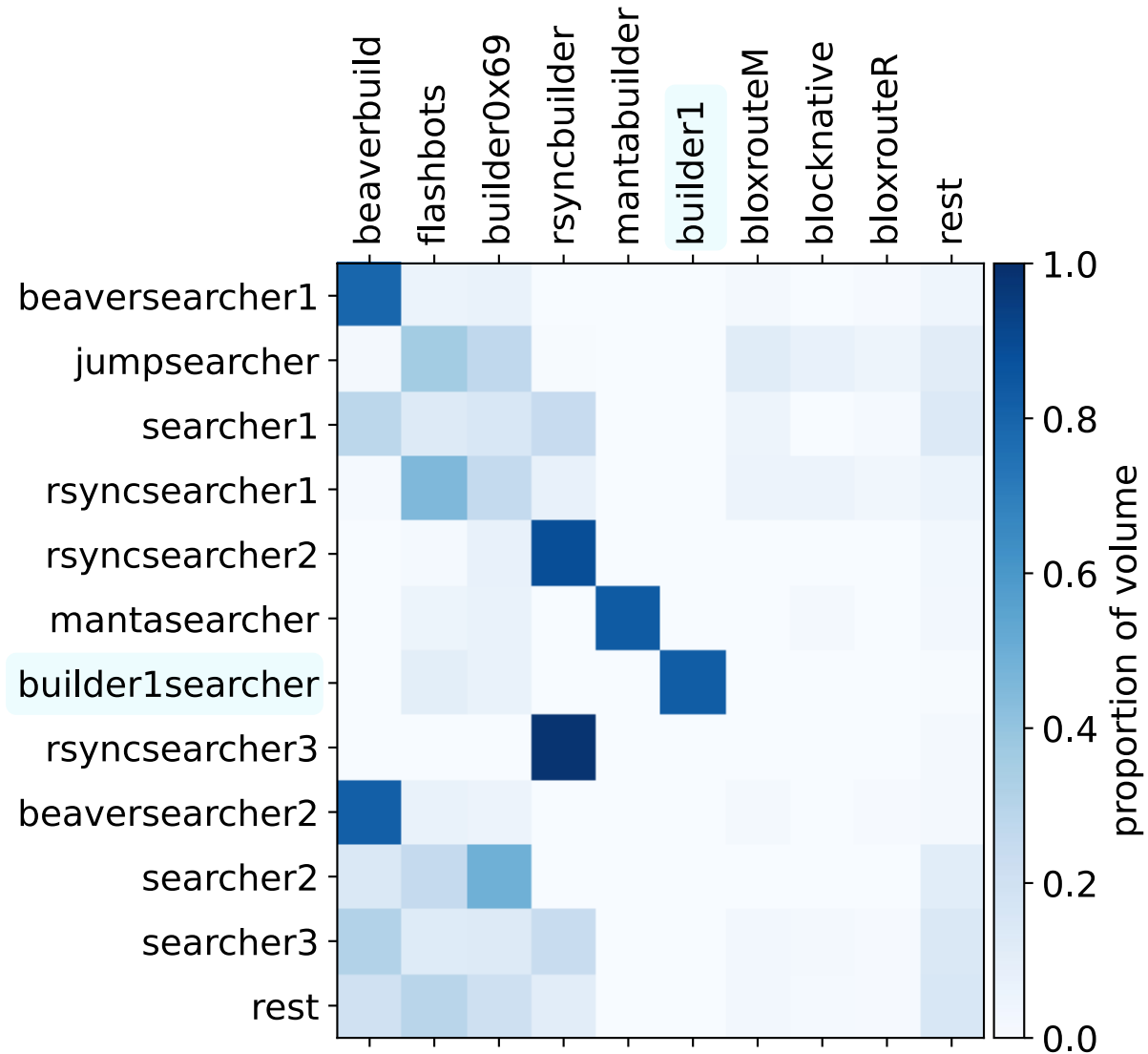
Searcher builder relationship



Searcher builder relationship



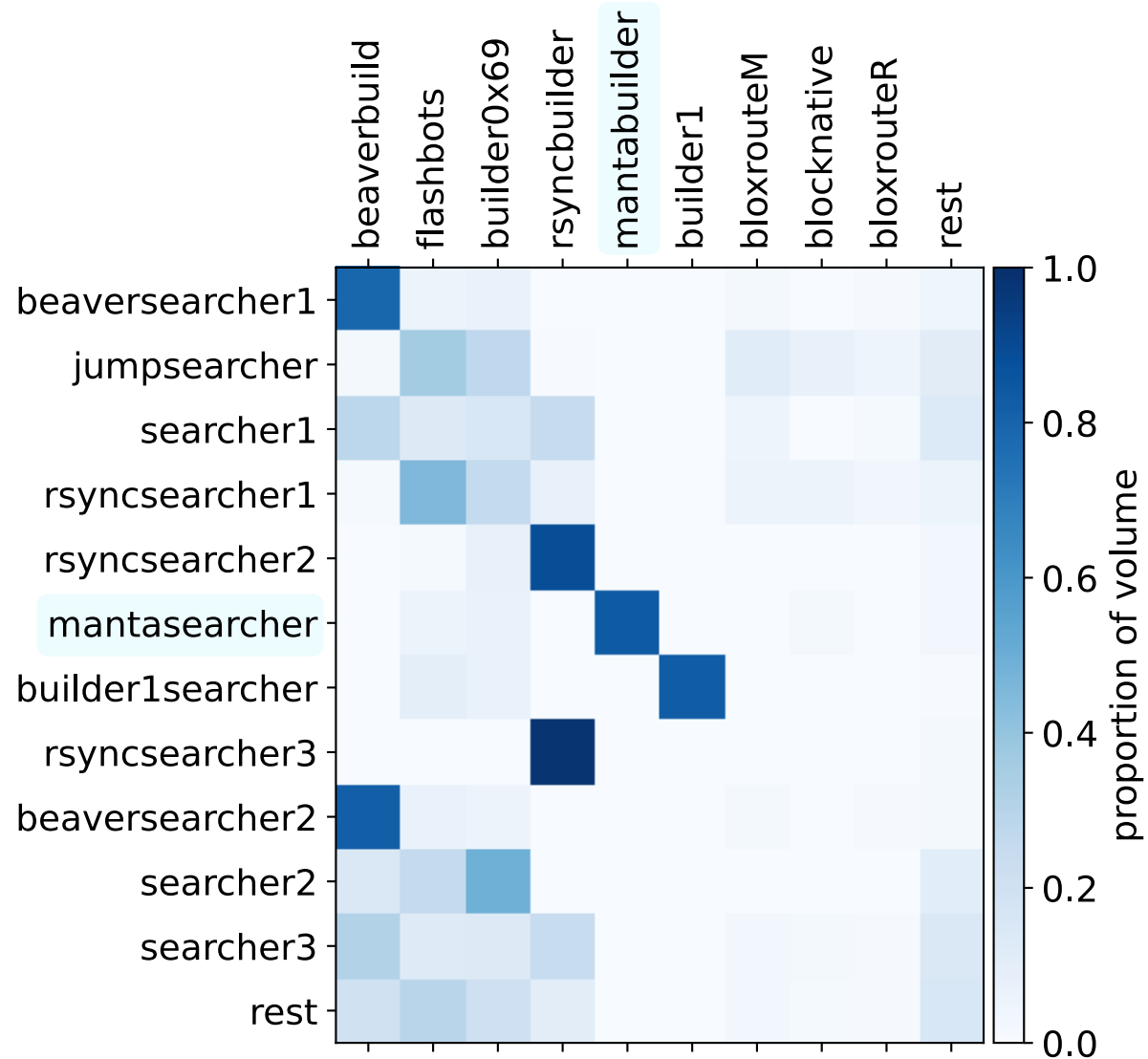
Searcher builder relationship



beaverbuild

builder1

Searcher builder relationship

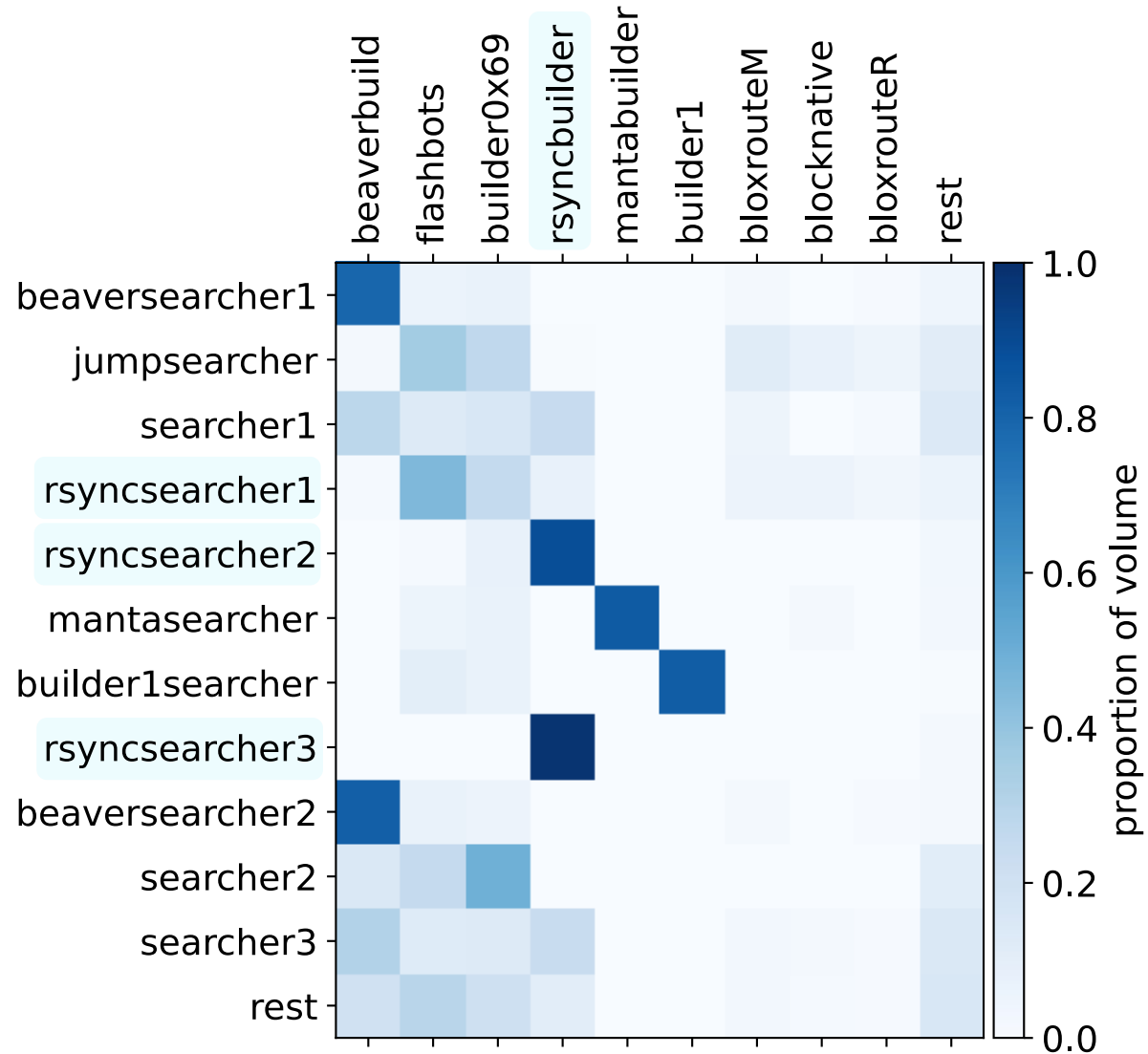


beaverbuild

builder1

mantabuilder

Searcher builder relationship



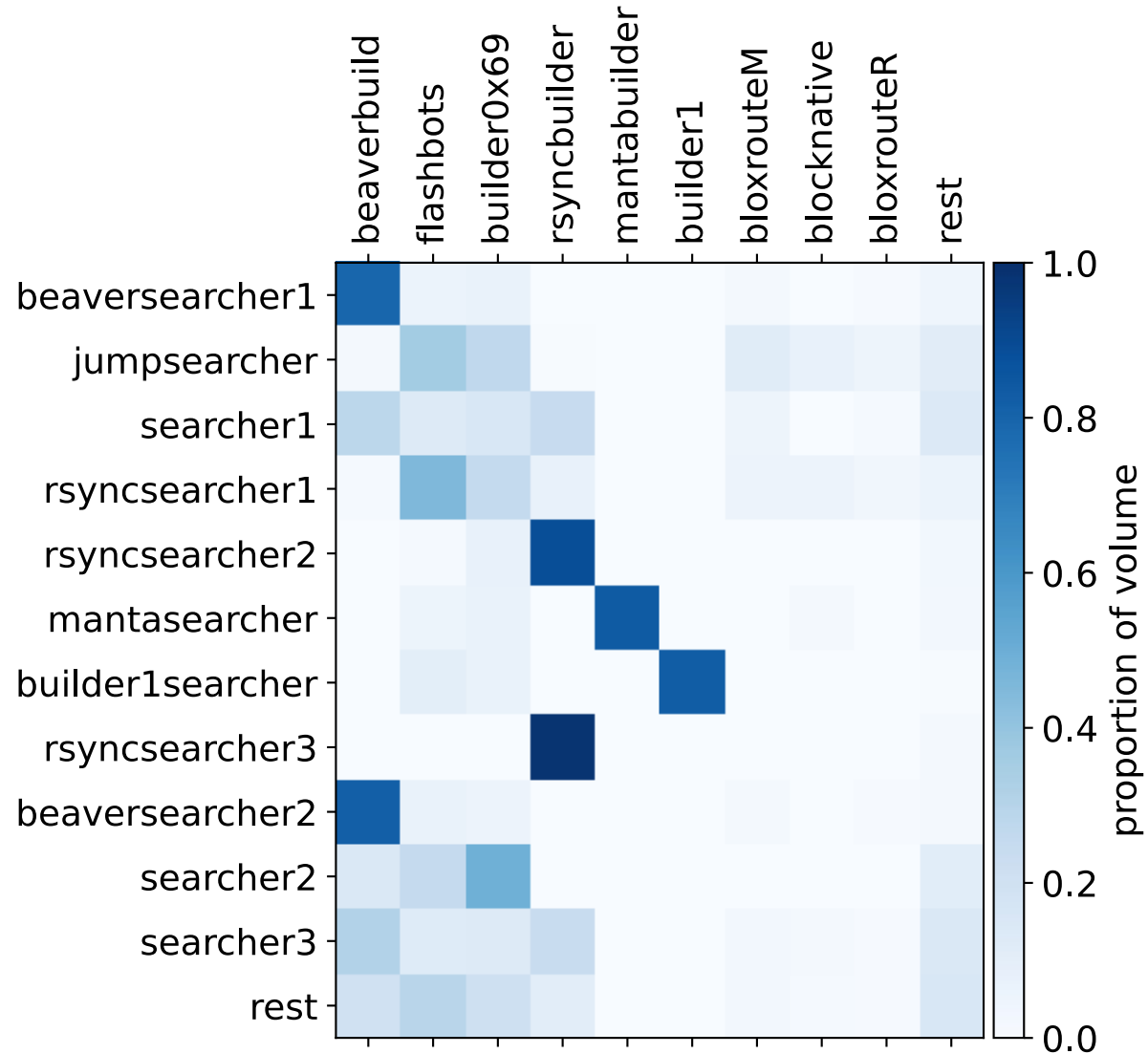
beaverbuild

builder1

mantabuilder

rsyncbuilder

Searcher builder relationship



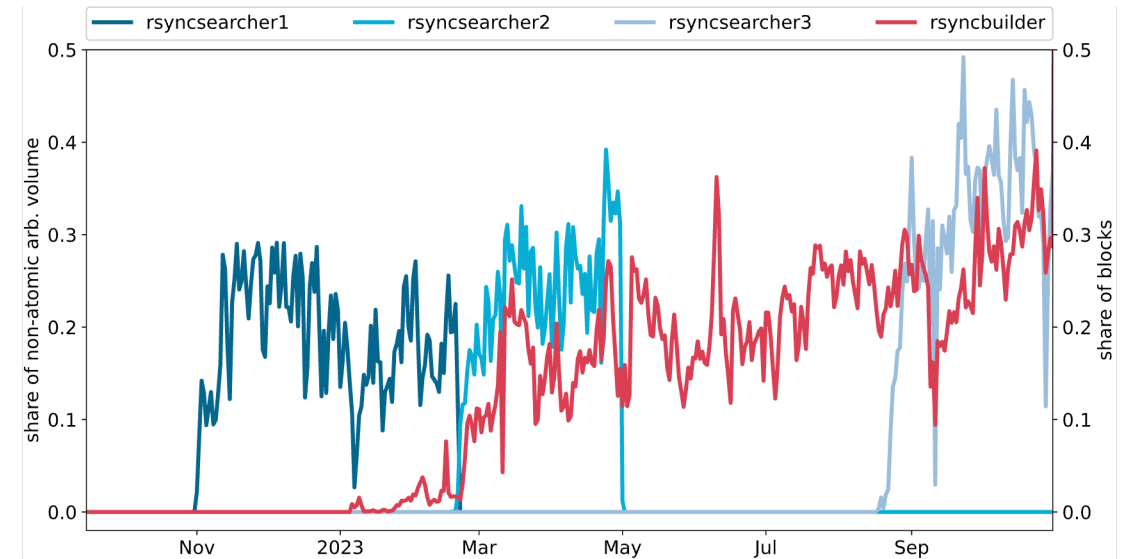
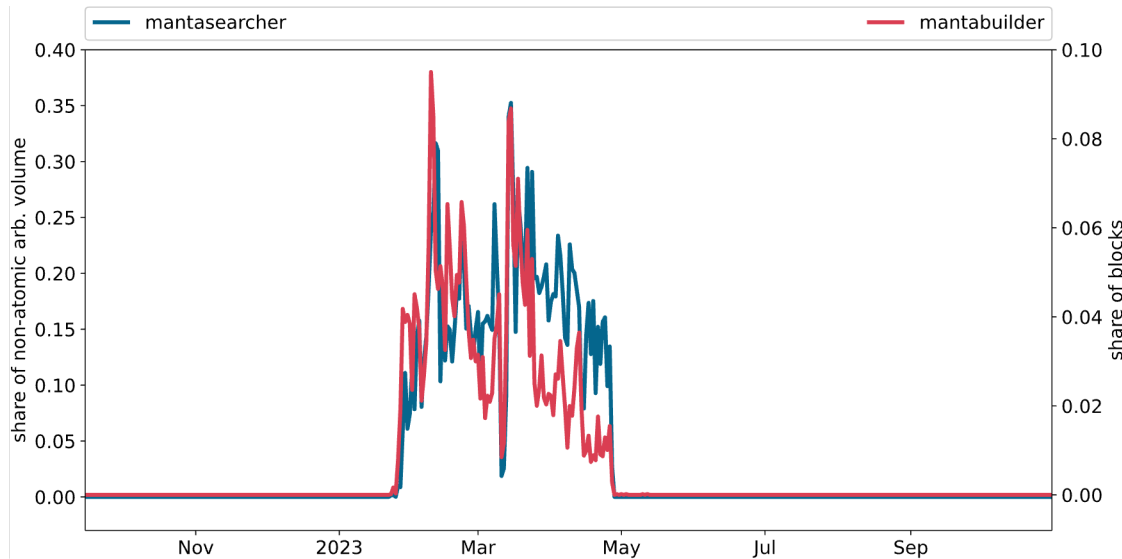
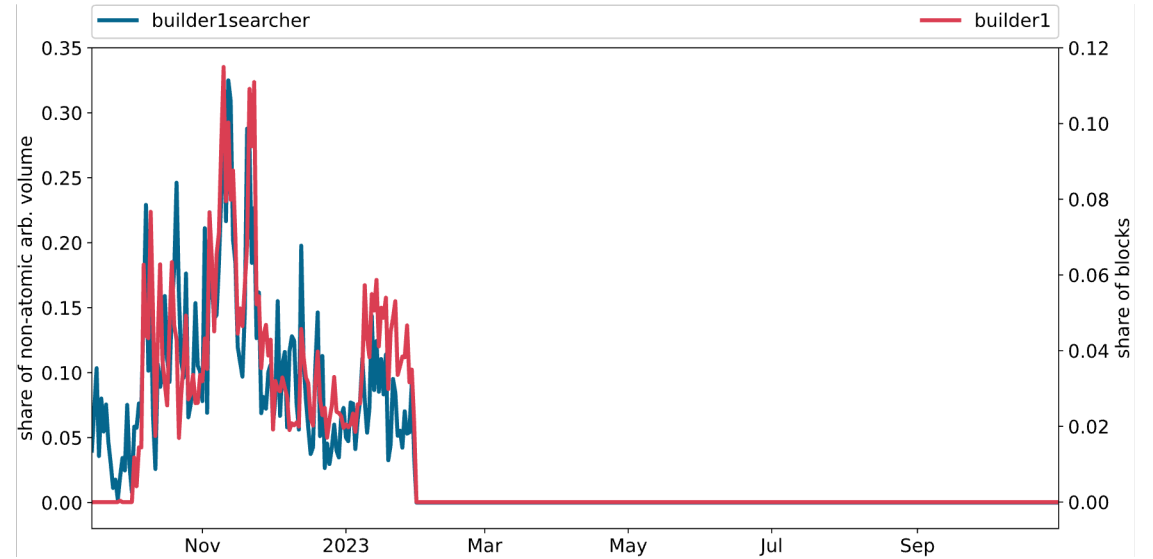
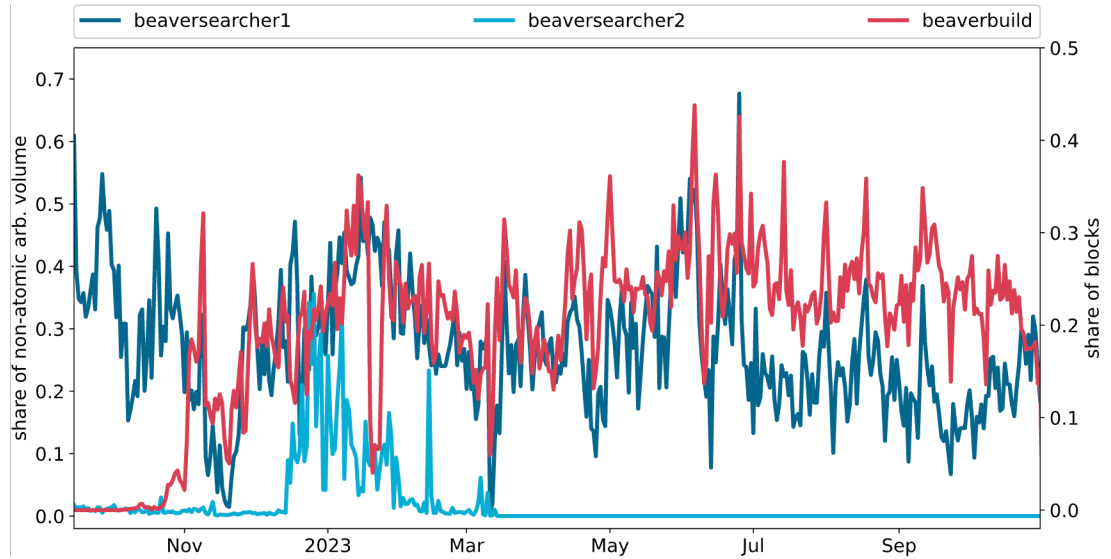
beaverbuild

builder1

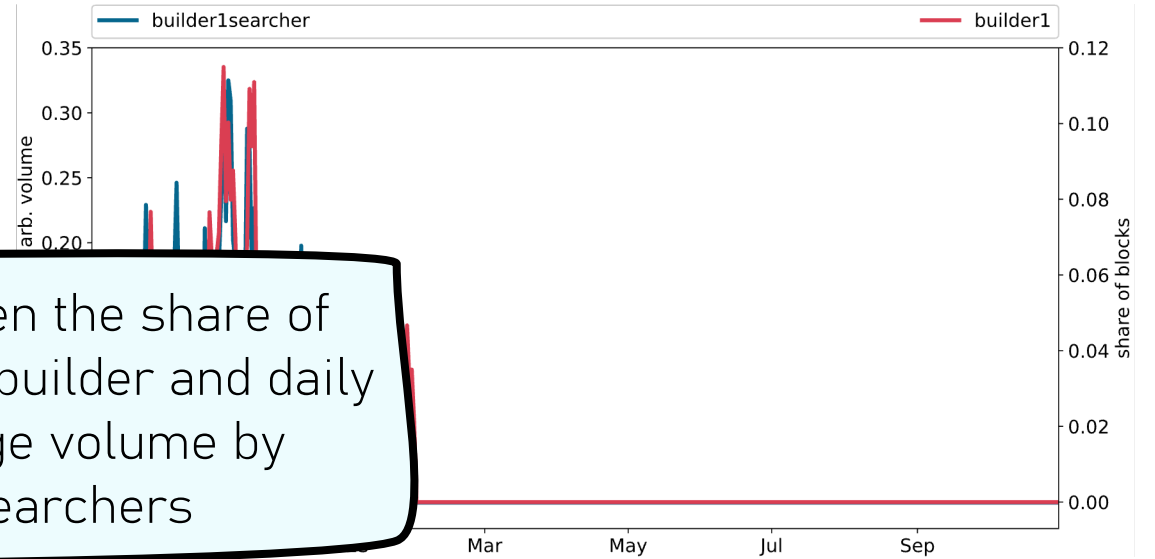
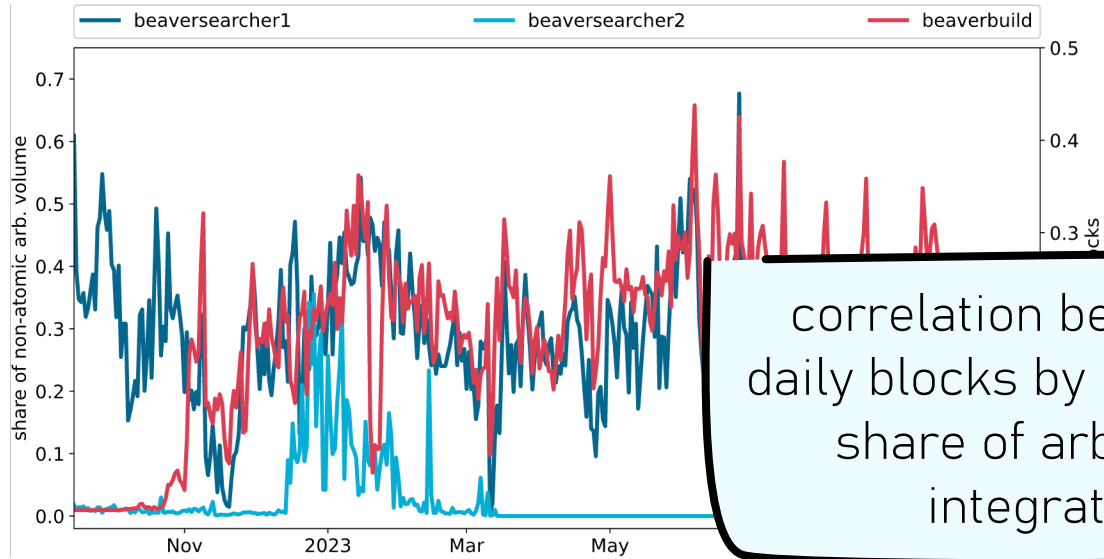
mantabuilder

rsyncbuilder

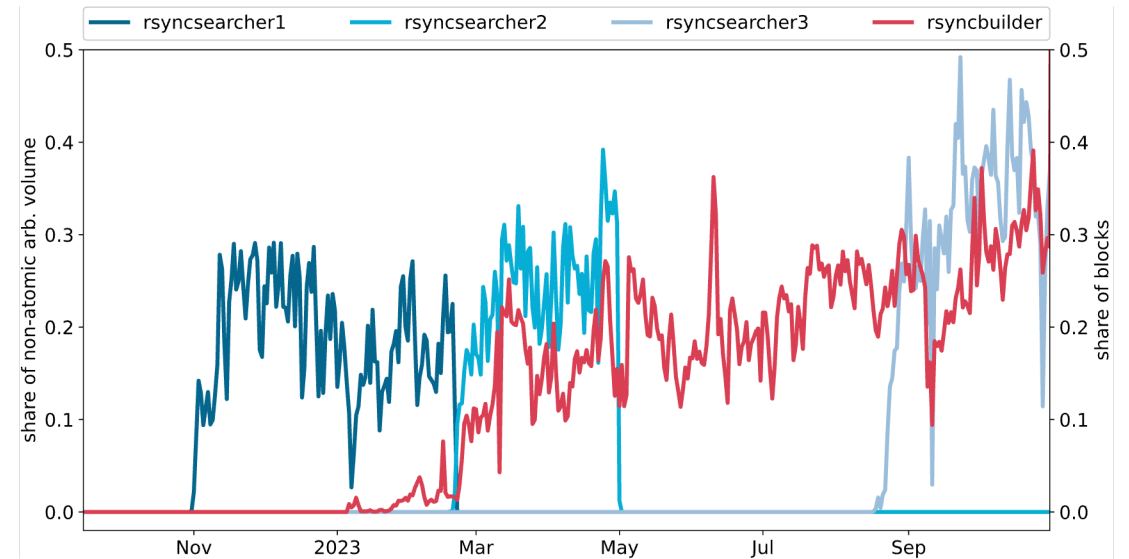
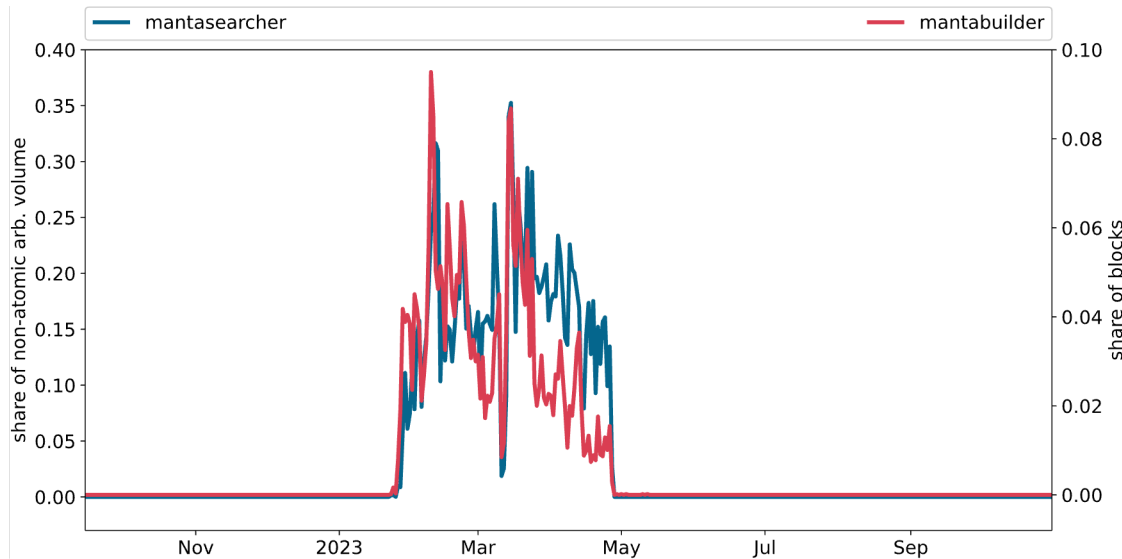
Integrated searcher



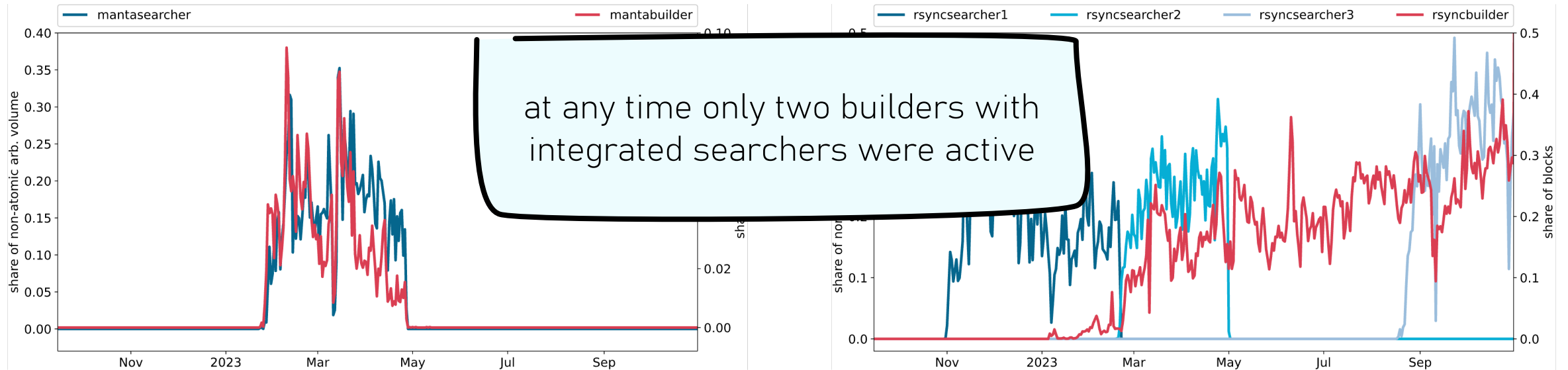
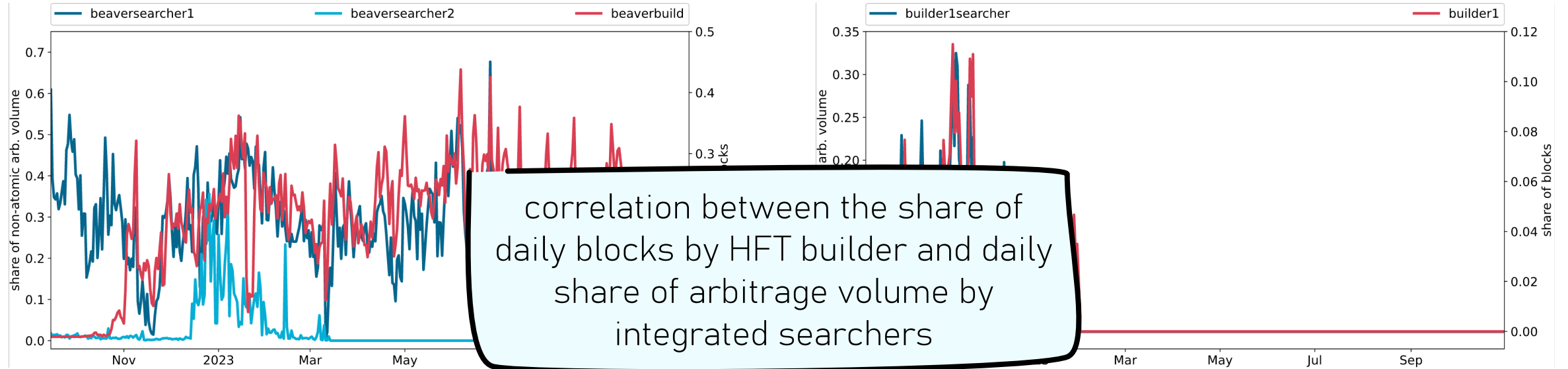
Integrated searcher



correlation between the share of daily blocks by HFT builder and daily share of arbitrage volume by integrated searchers



Integrated searcher



Non-atomic arbitrage

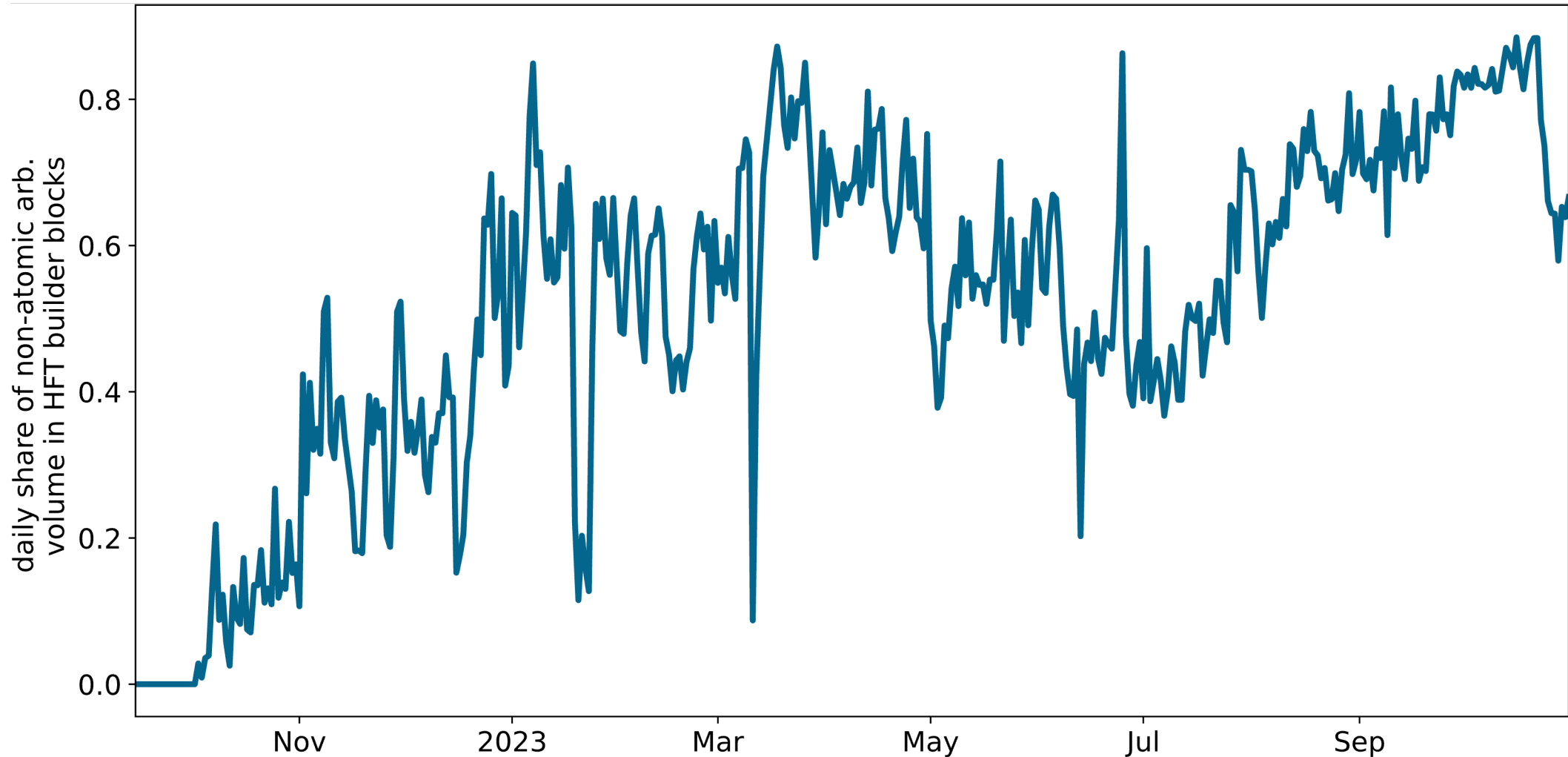
landscape

drivers

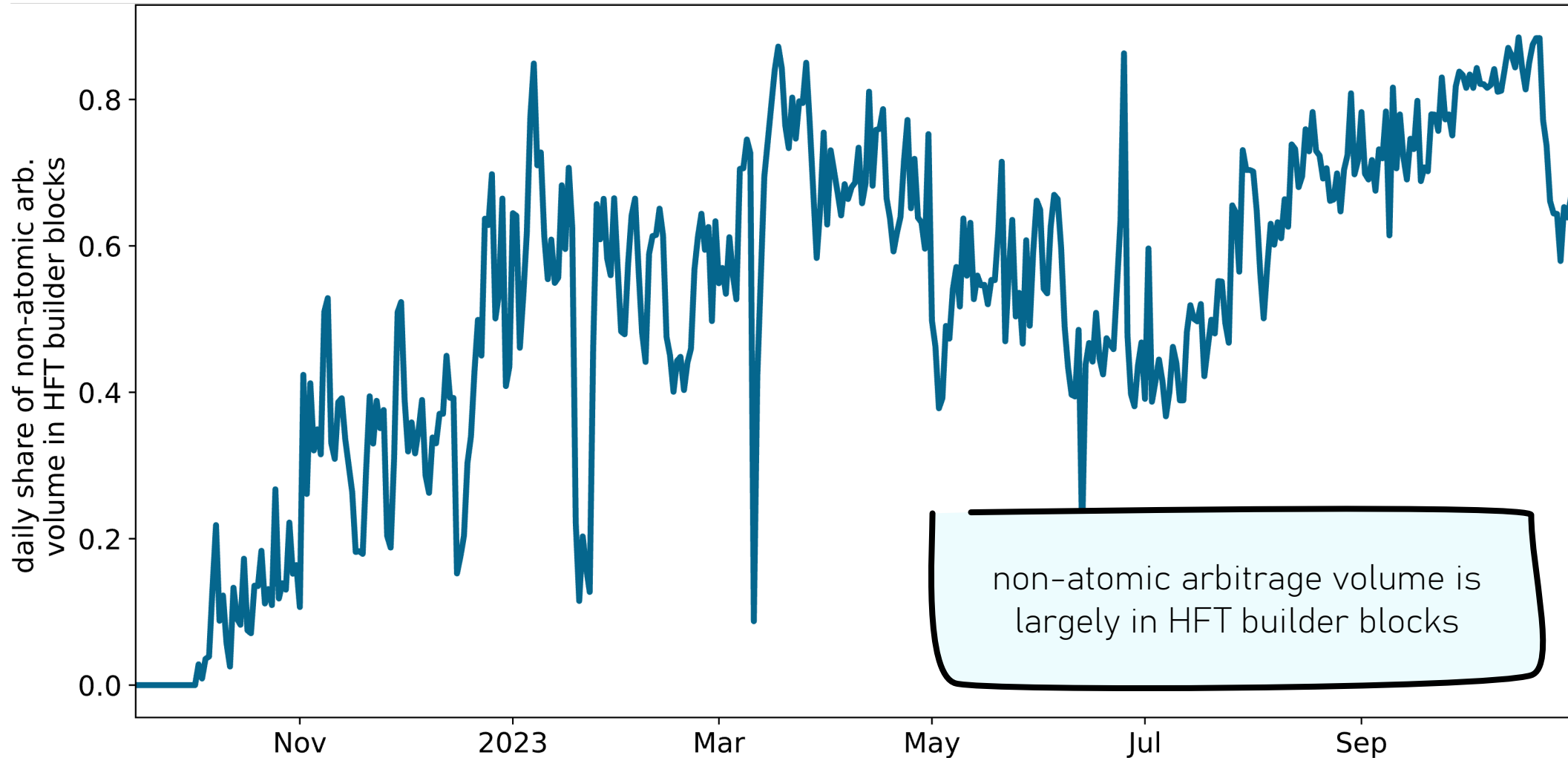
vertical integration

impact

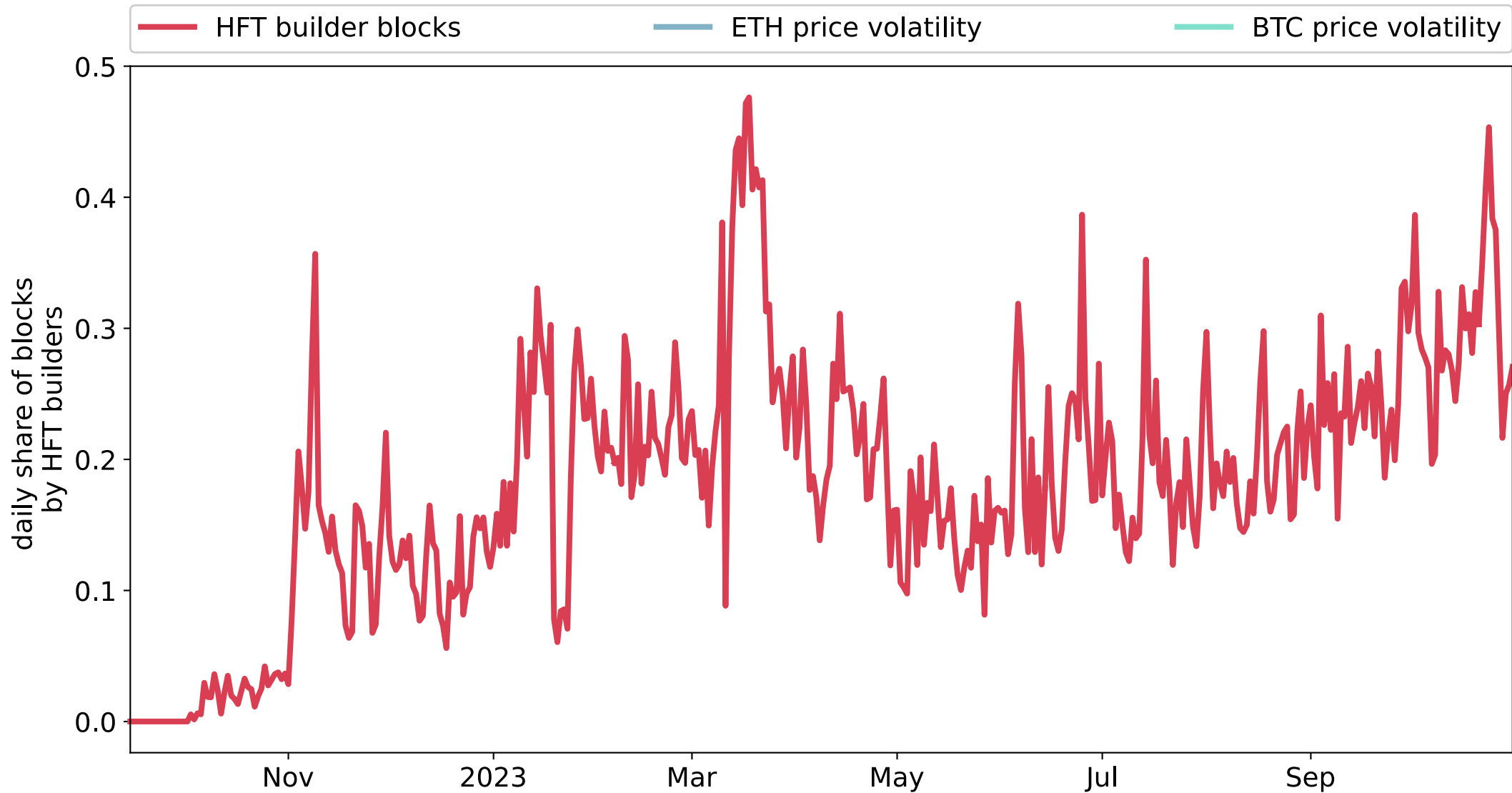
Non-atomic arbitrage volume in HFT builder blocks



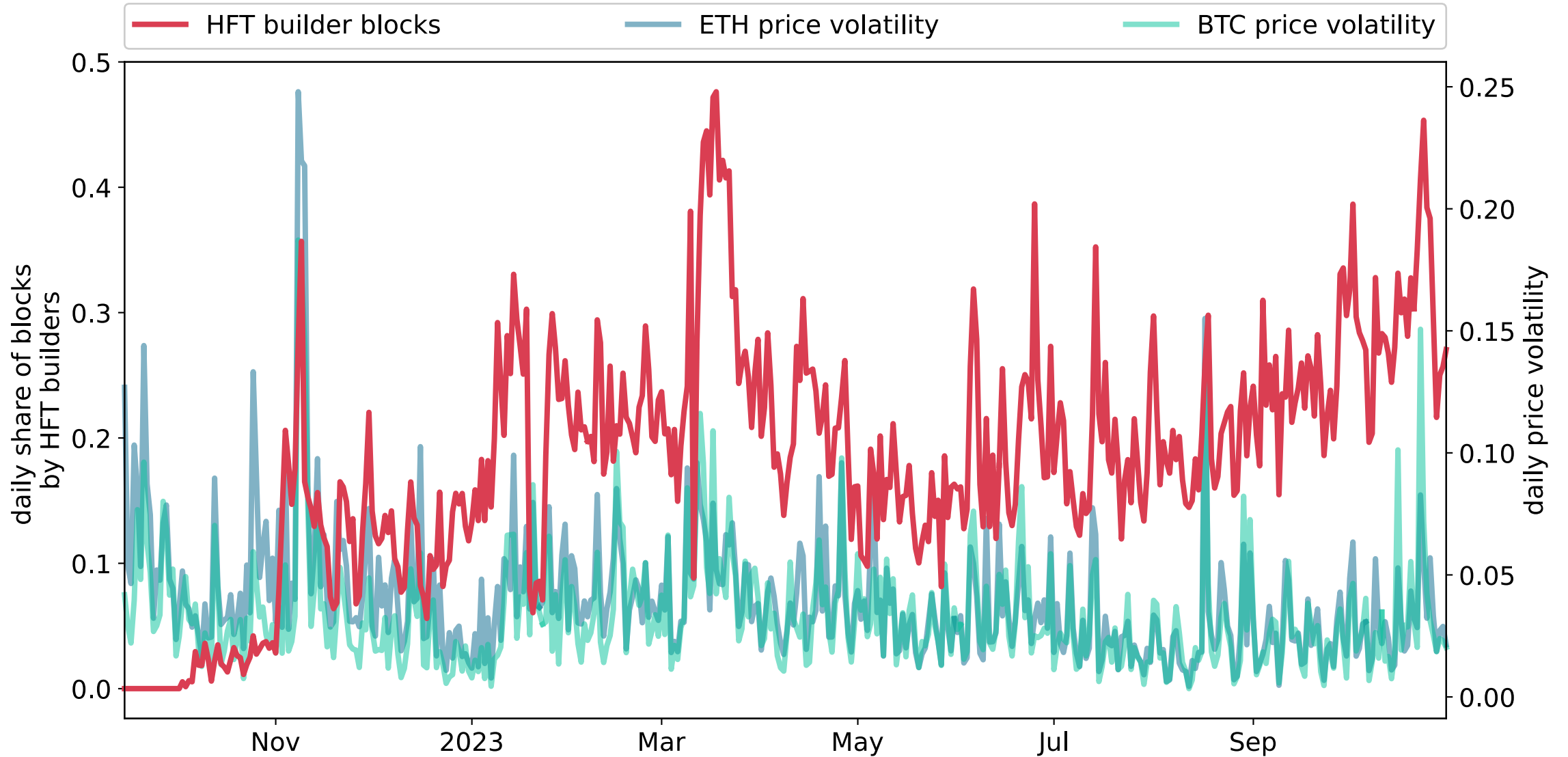
Non-atomic arbitrage volume in HFT builder blocks



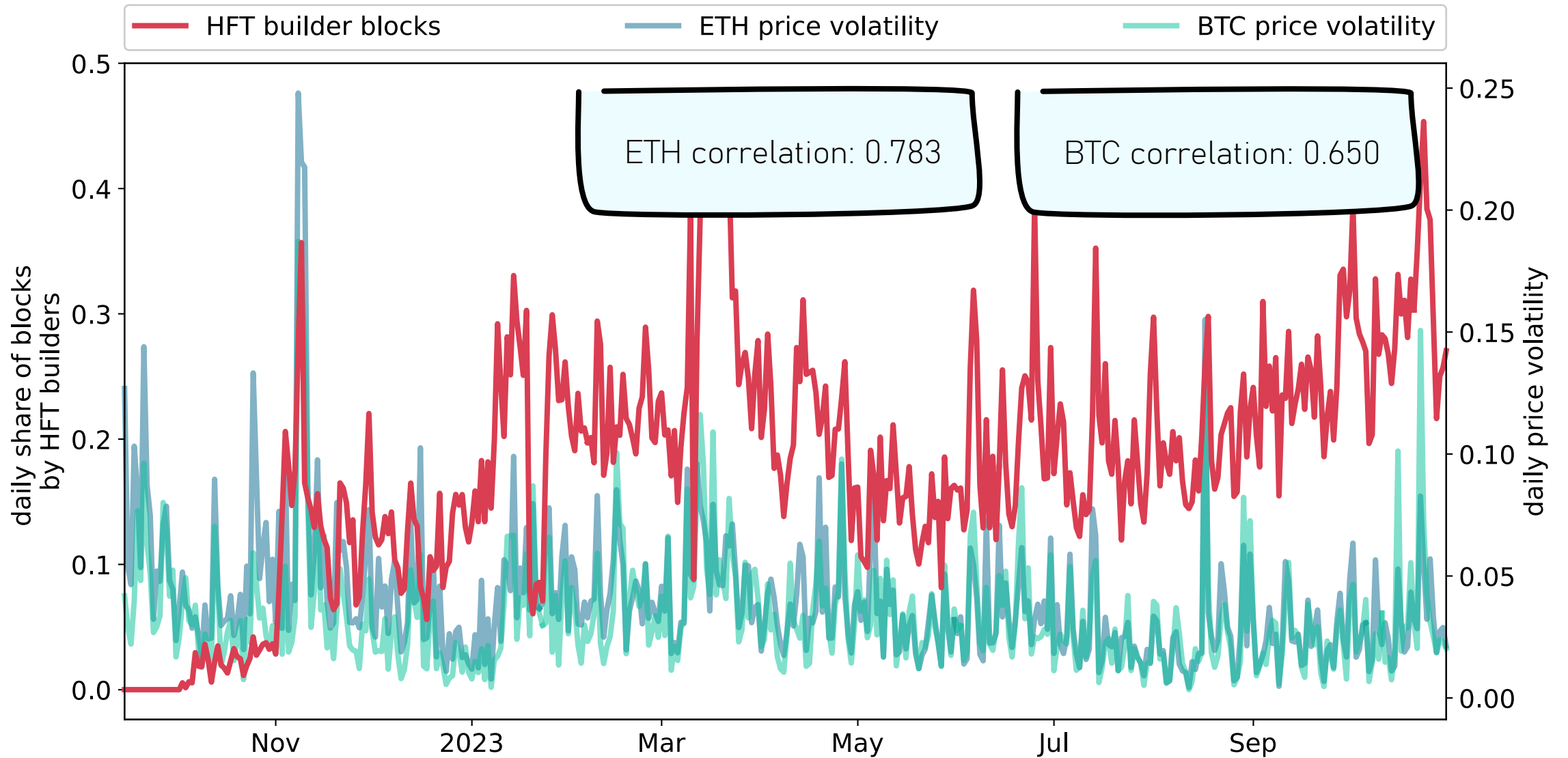
Daily share of HFT builder blocks



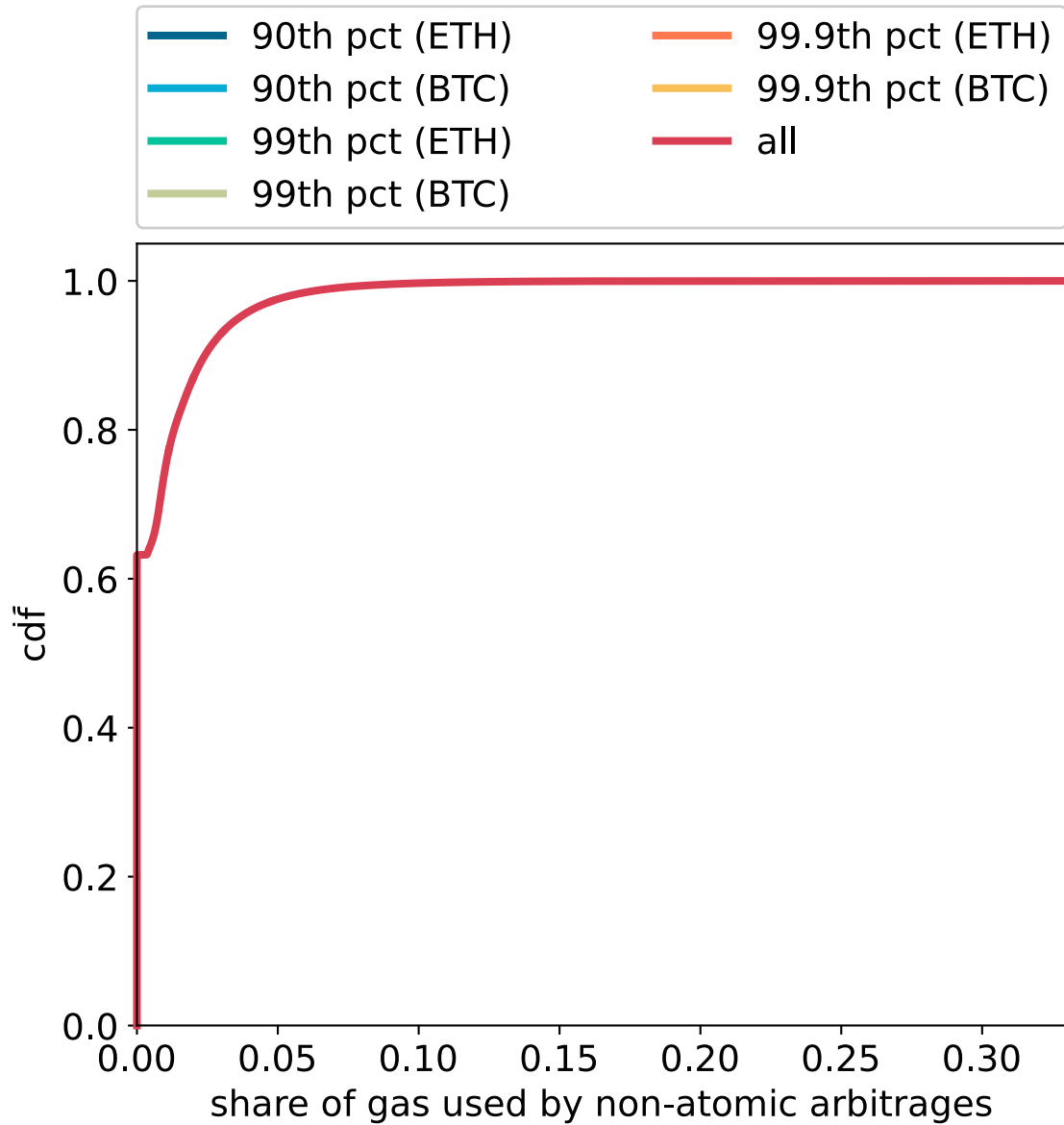
Daily share of HFT builder blocks



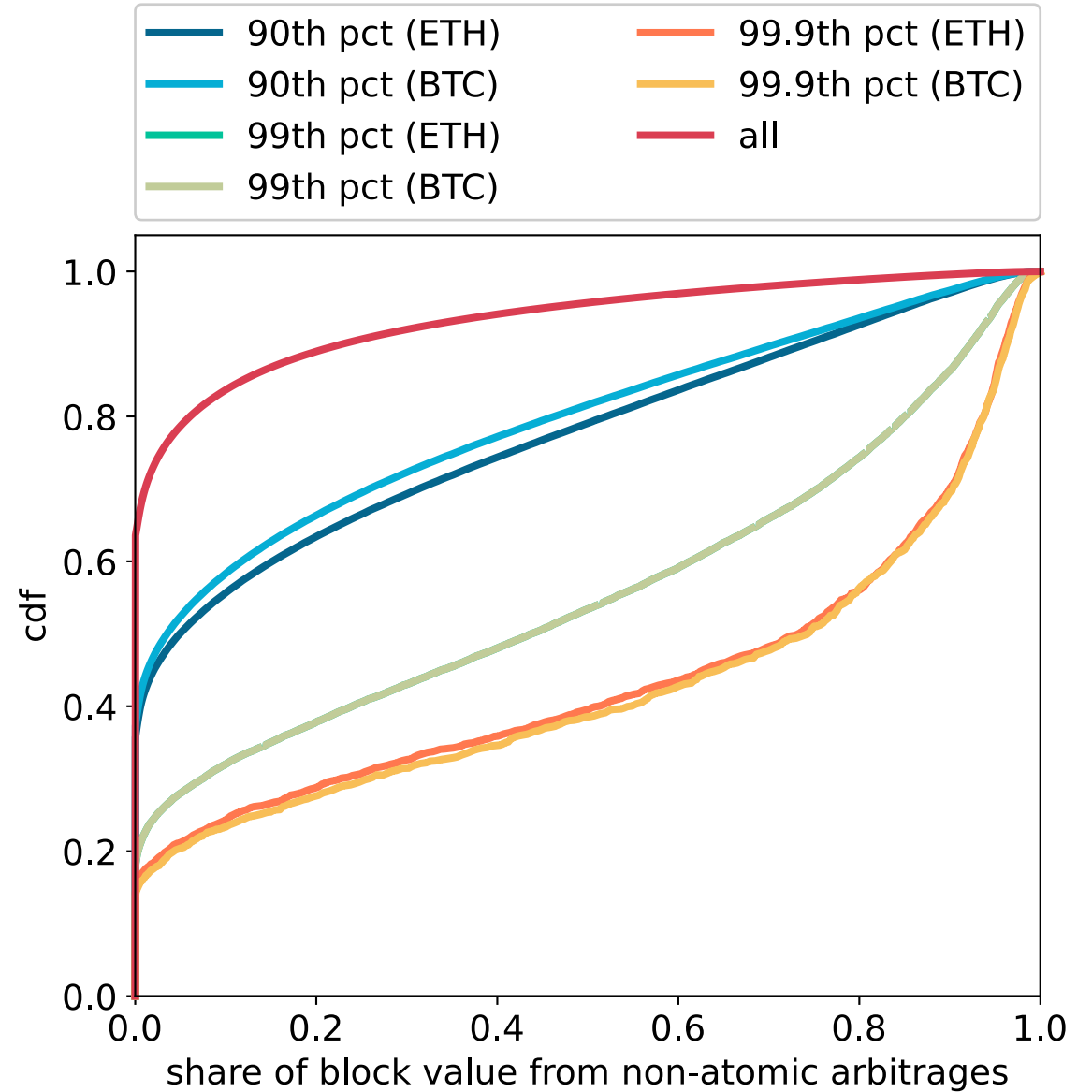
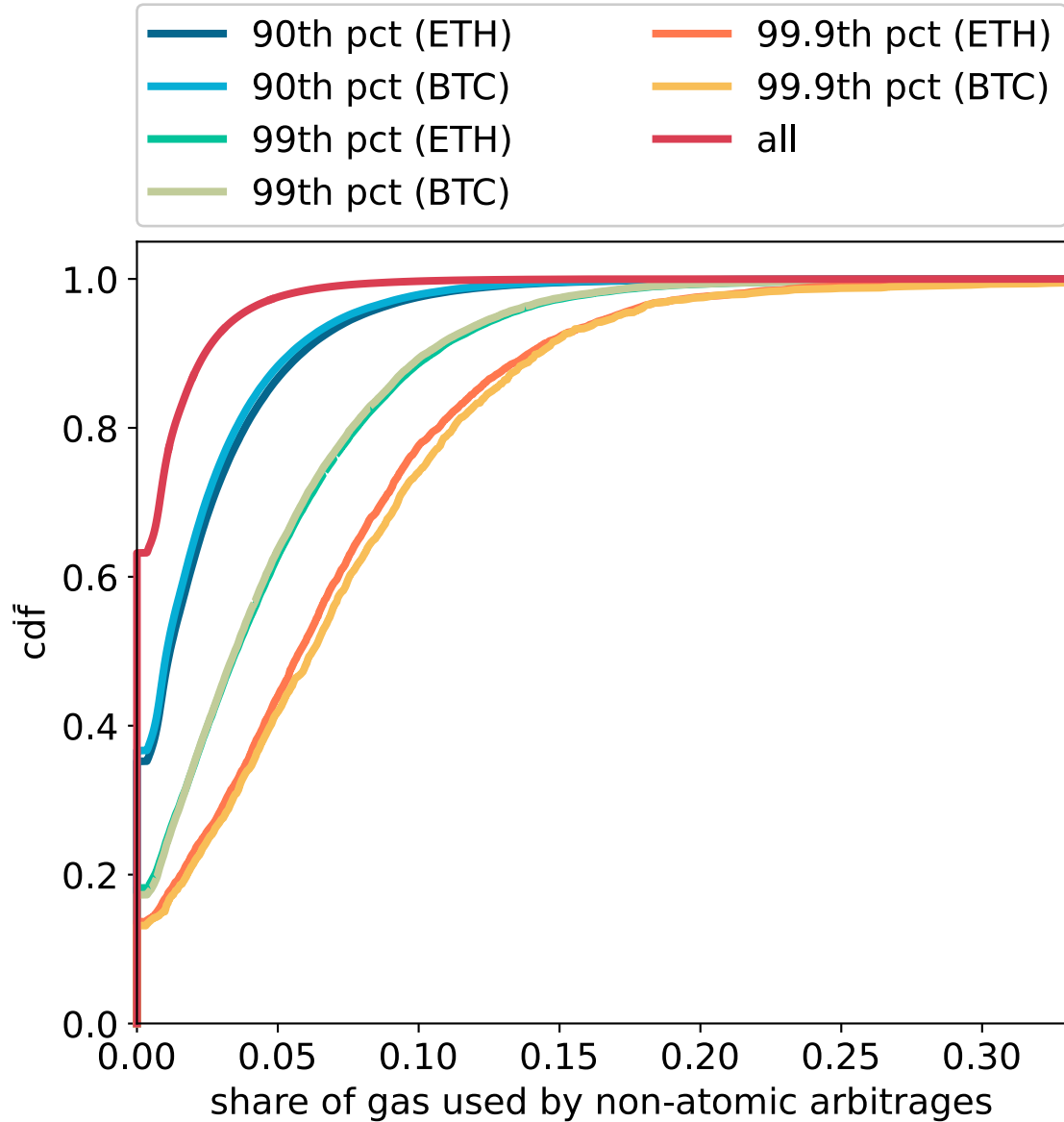
Daily share of HFT builder blocks



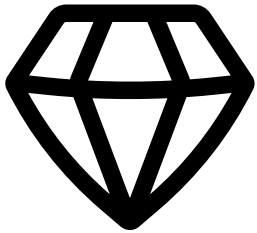
Gas usage and block value



Gas usage and block value

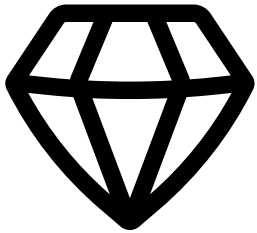


Conclusion

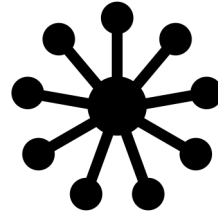


>25% of DEX volume &
>10% Ethereum block
value

Conclusion

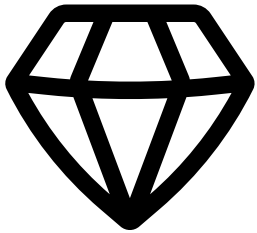


>25% of DEX volume &
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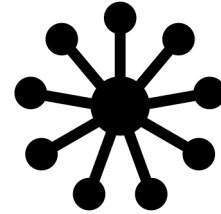


centralized landscape

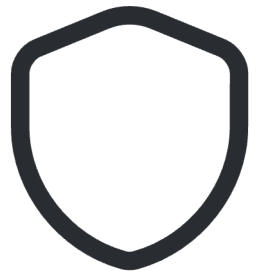
Conclusion



>25% of DEX volume &
>10% Ethereum block
value

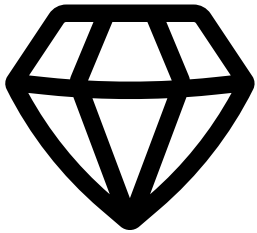


centralized landscape

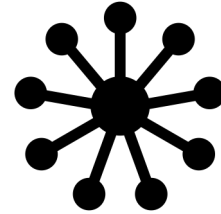


(security) risk

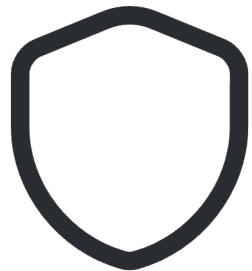
Conclusion



>25% of DEX volume &
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centralized landscape

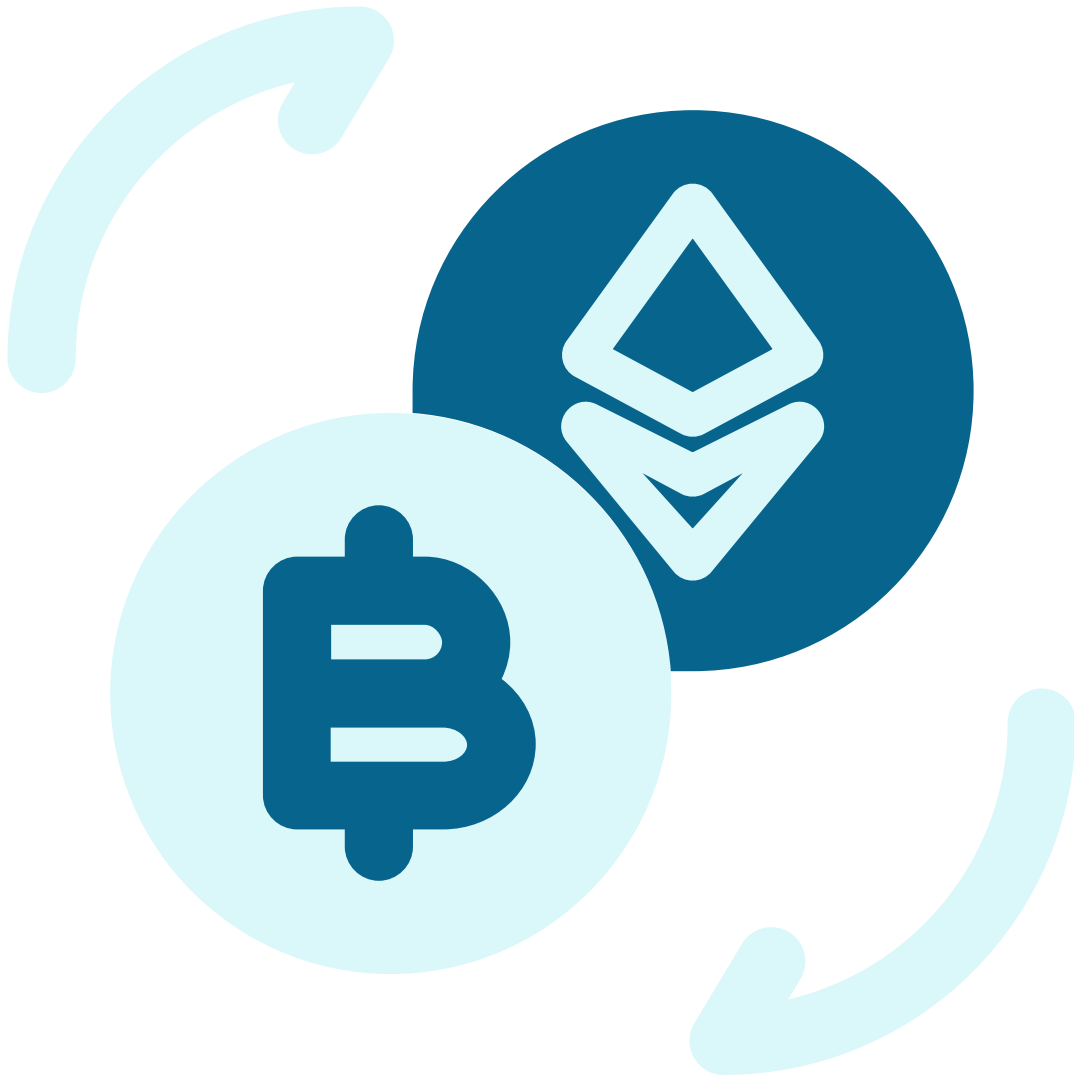


(security) risk



mitigations

Non-Atomic Arbitrage in Decentralized Finance



Questions?



@liobaheimbach



hlioba@ethz.ch

Implications

high value transactions

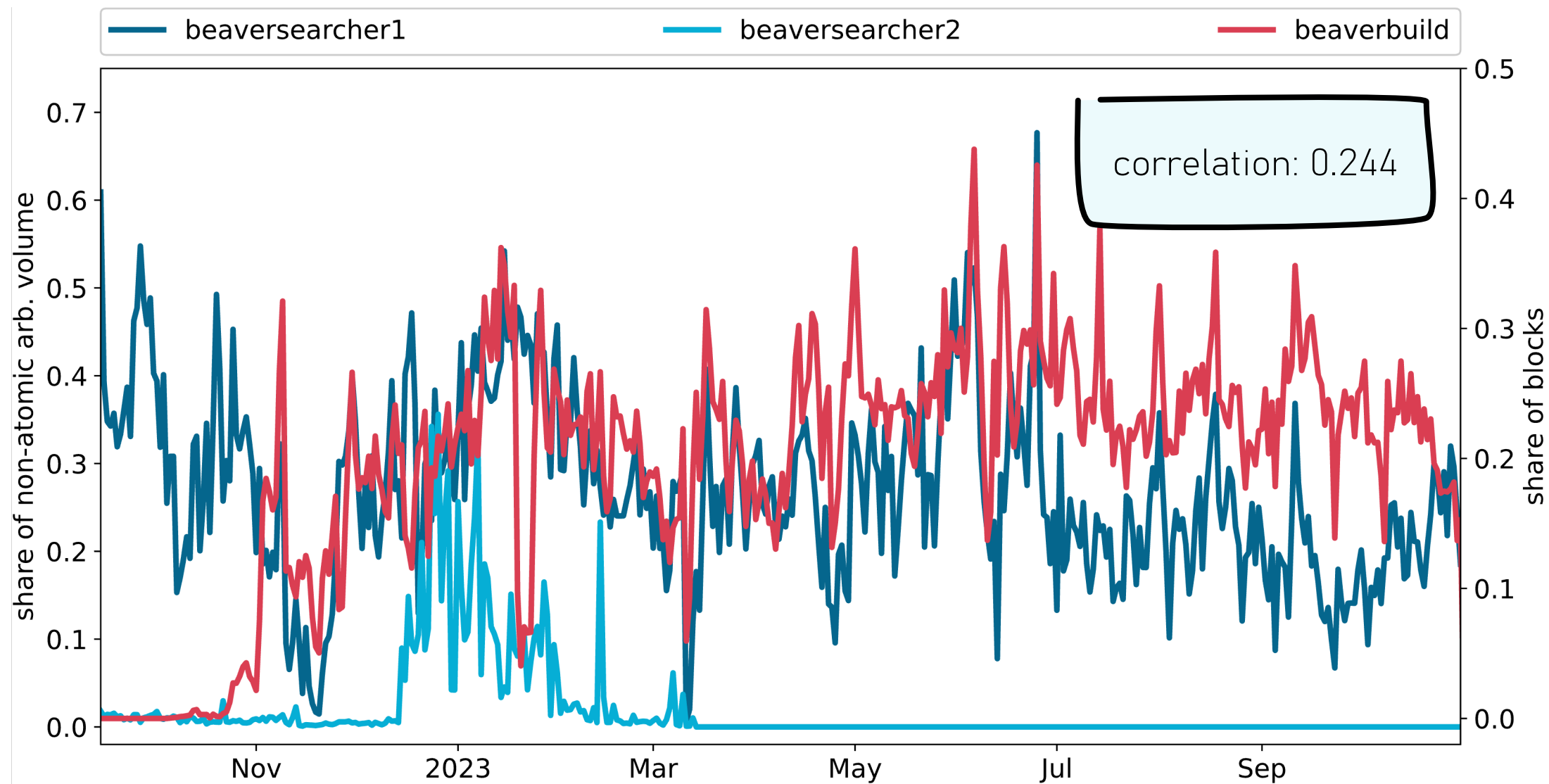
centralizing block building

Mitigations

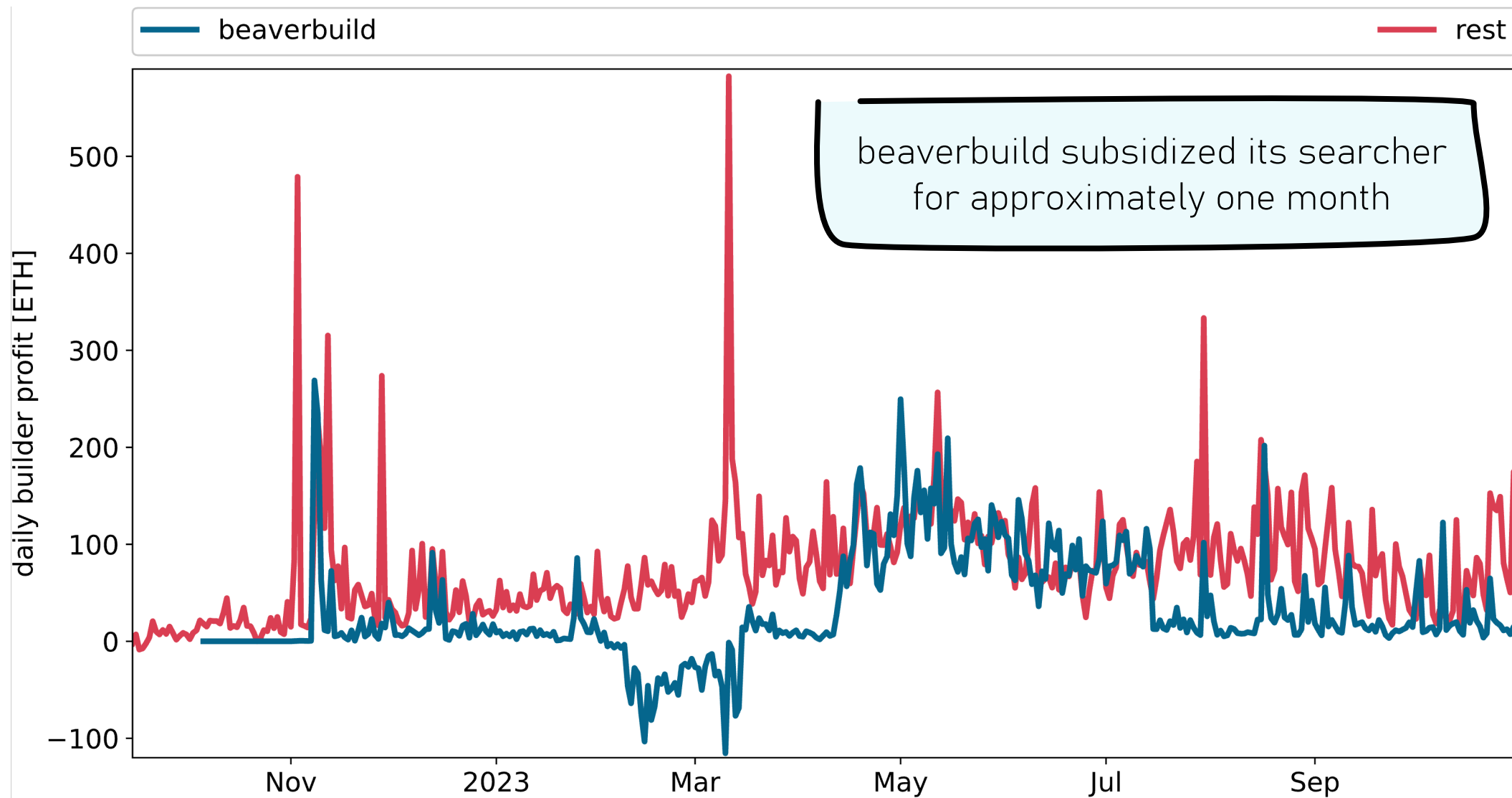
separating top of block
opportunities

block time reduction

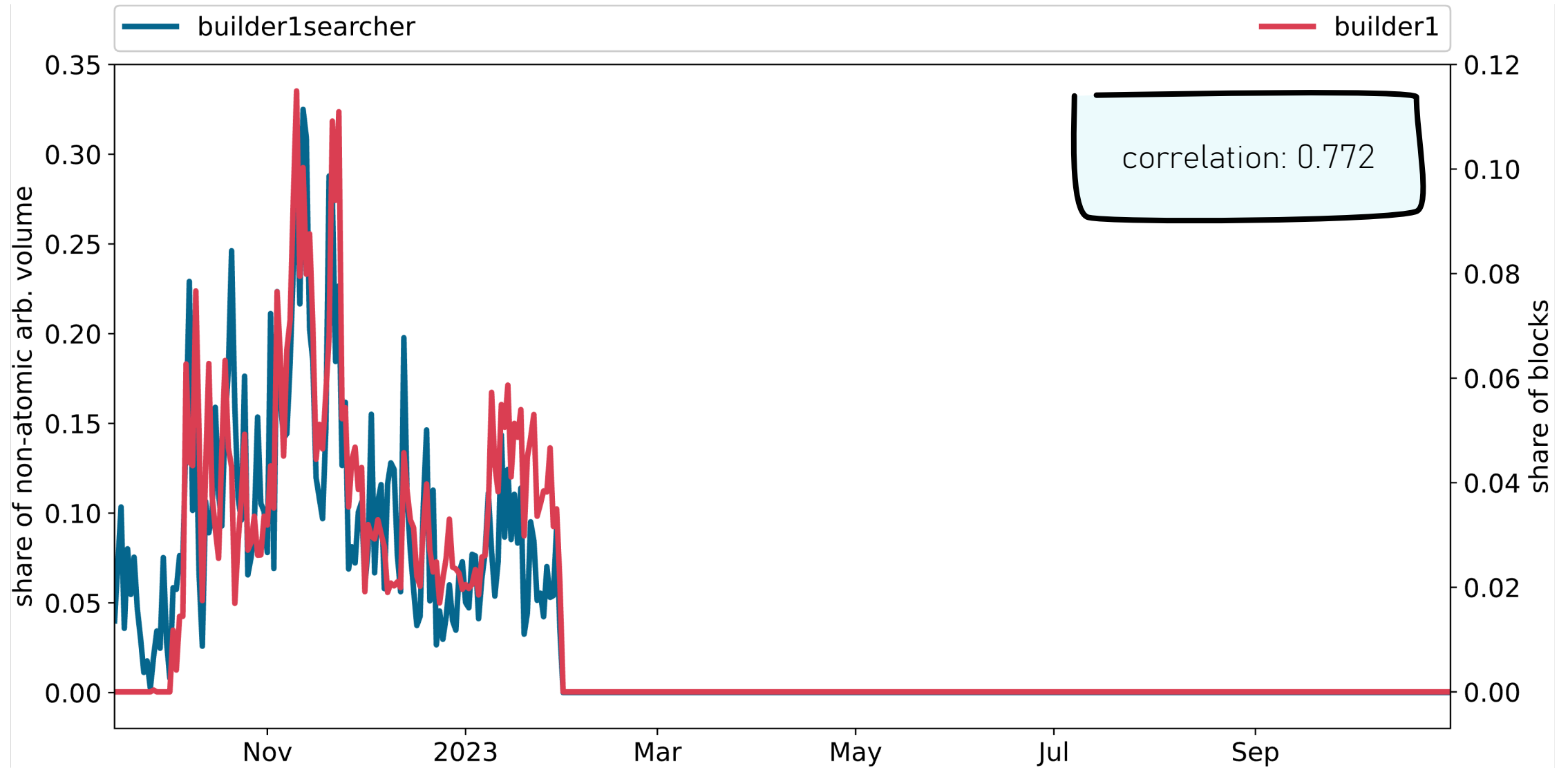
Beaverbuild



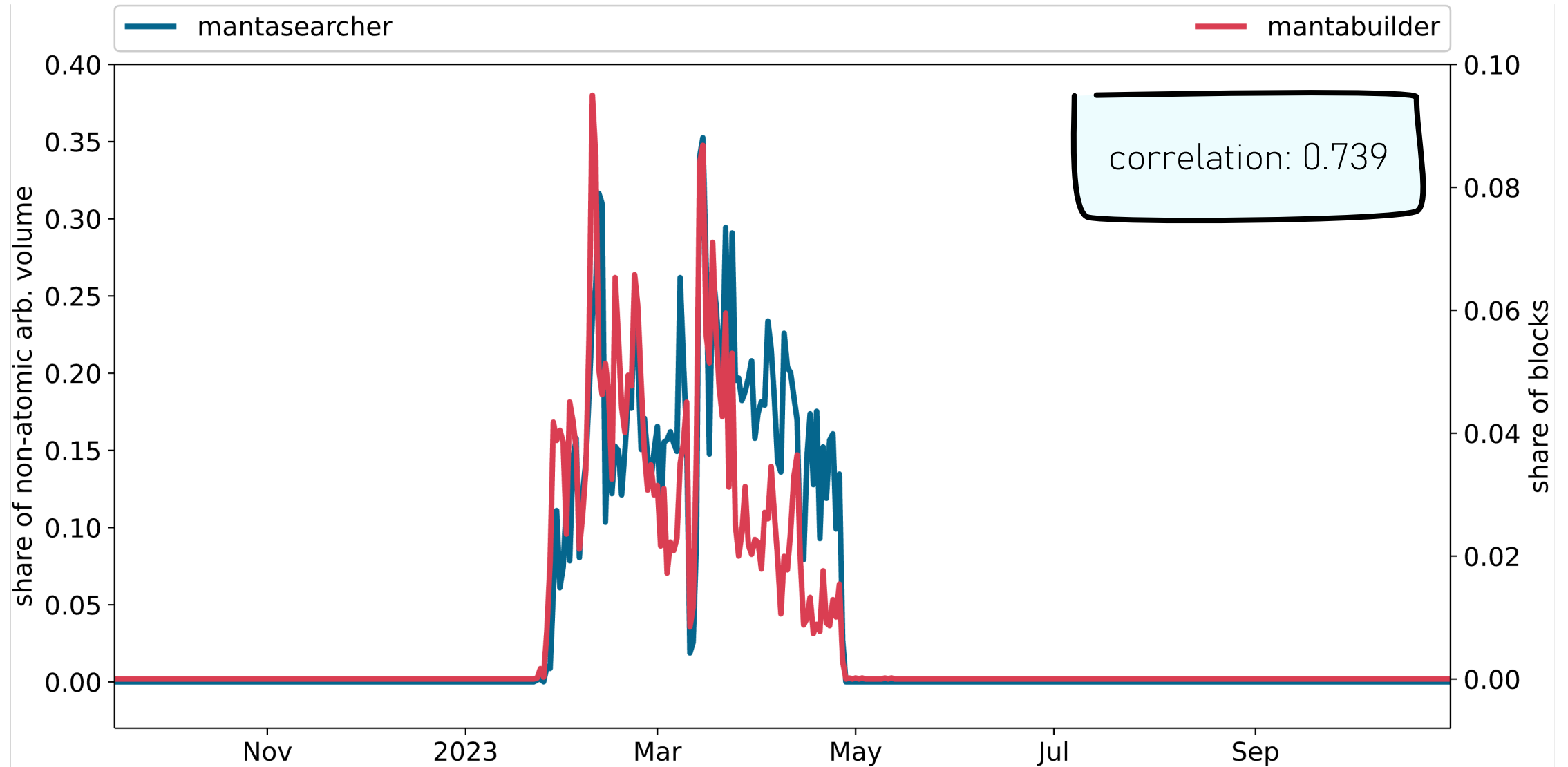
Beaverbuild



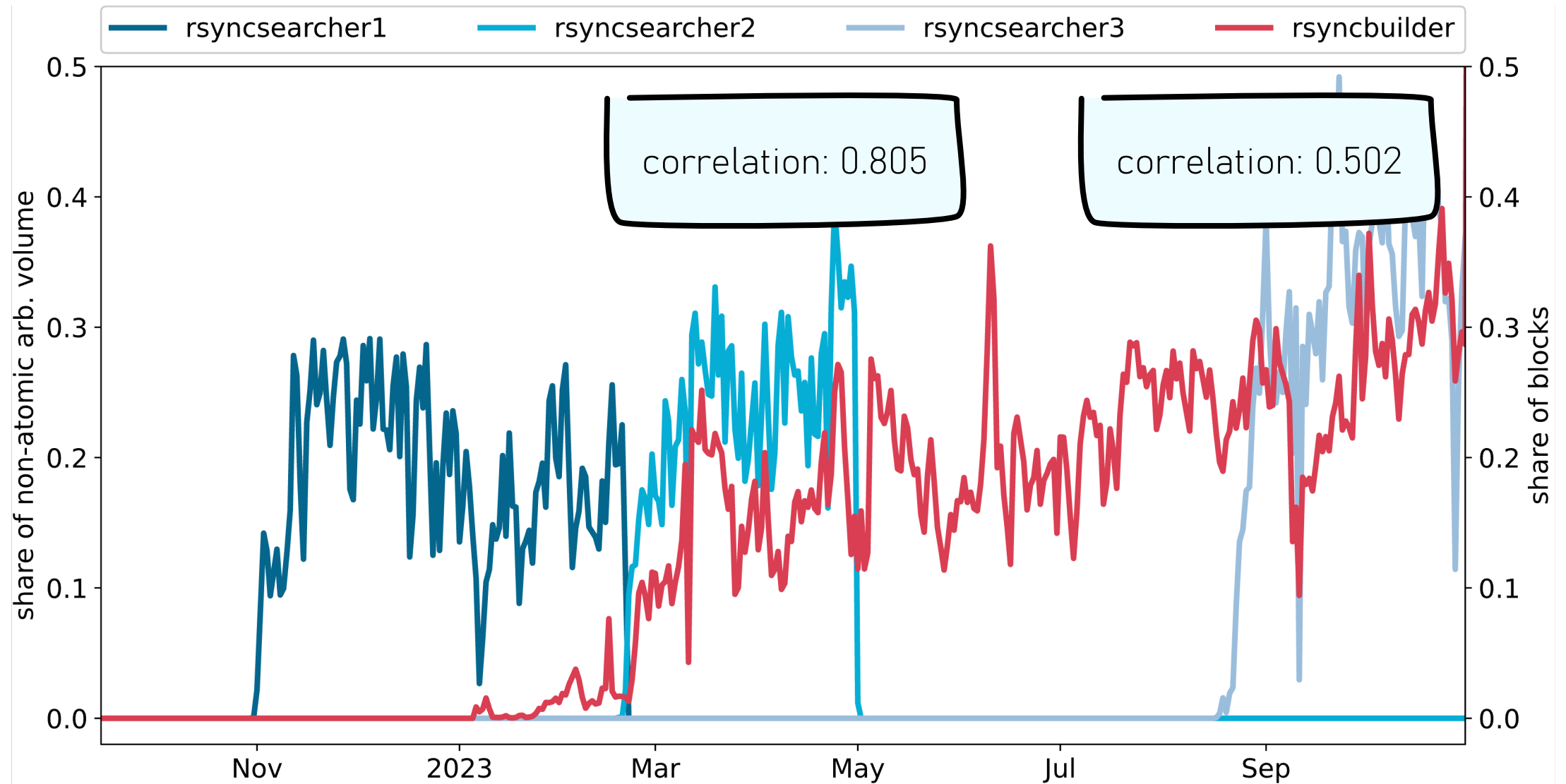
Builder 1



Mantabuild



Rsyncbuilder



Integrated searcher

	beaverbuild	rsyncbuilder	builder1	mantabuilder
sandwich attacks per block	0.041	0.043	0.000	0.001
cyclic arbitrage per block	0.008	0.006	0.003	0.001