Detection and Analysis of Cross-Chain Arbitrages Between Ethereum and Polygon

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Outline

- Background & Motivation
- Research Questions
- Methodology
- Results
- Discussion & Future Work

Background & Motivation

Single-Network Atomic Arbitrage: The Hardware Store Example

Market A

- Located in the western part of town.
- Price of hammers: **$10**
- Lower demand, leading to lower prices.

Bob

Market B

- Located in the eastern part of town.
- Price of hammers: **$15**
- Higher demand, leading to higher prices.

Background & Motivation

Single-Network Atomic Arbitrage: In Blockchains

DEX: Decentralized exchange

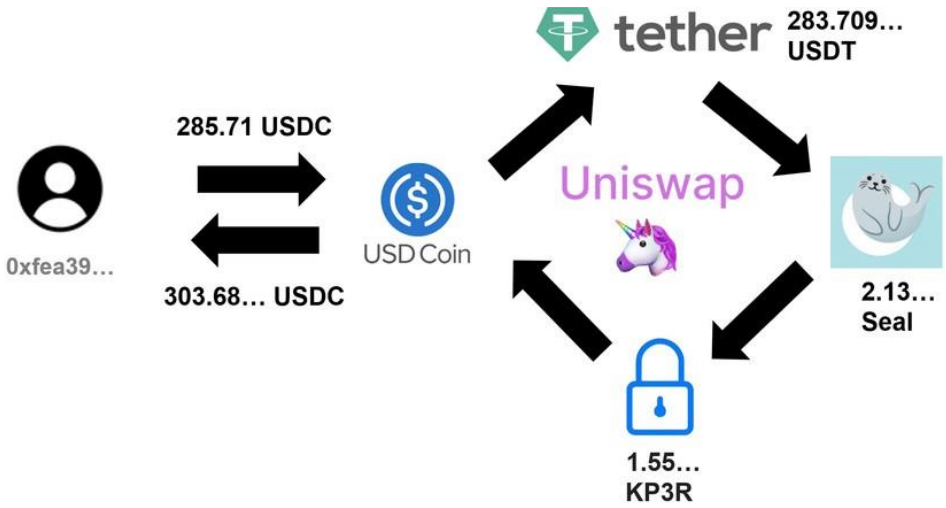
- Peer-to-peer trading without intermediaries.
- Users control their own funds.

Arbitrage Opportunities:

- Price discrepancies between DEXes
- Buy low on one DEX, sell high on another.

Impact on Market:

- Promotes price consistency across DEXes.
- Generally seen as beneficial.



[Researchgate] *Cylic Arbitrage in Decentralized Exchange Markets*

[Blocknative] *The Fundamentals of Cross-Chain MEV*

Background & Motivation

Cross-Network Non-Atomic Arbitrage

Bob sees that hammers are cheaper in Town A than in B. He plans to buy hammers in **Town A** and sell them in **Town B** for profit. **However, he needs a bridge to access the Market in town B.**

Challenges associated with the bridge**:**

- *Time delay:* Transport time can affect profits.
- *Transportation cost:* Fees for using the bridge reduce profits.

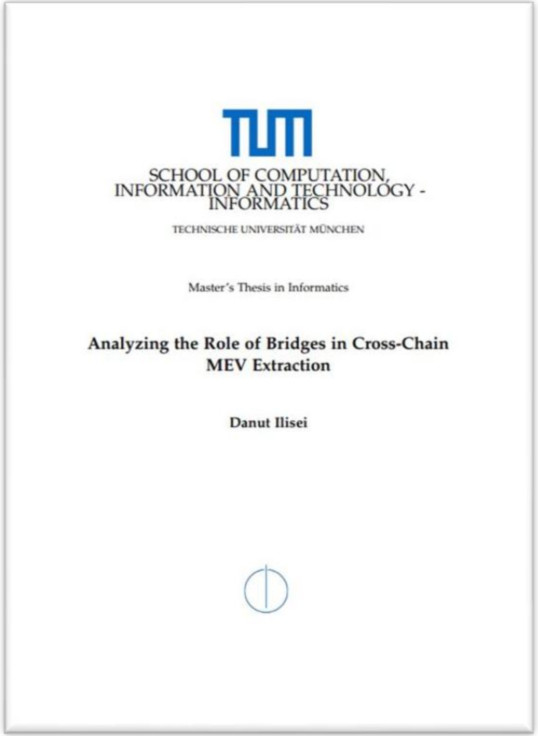
Background & Motivation

Polygon PoS

Polygon PoS:
- A Layer 2 scaling solution (side-chain) for Ethereum.
- Compatible with the Ethereum Virtual Machine (EVM)
- Support for a wide variety of DeFi apps:
  - Aave, SushiSwap, QuickSwap, Uniswap etc.

Key takeaways:
- Cross-chain arbitrages do happen, though not very frequent.
- Lesser-known tokens used due to high-volatility of popular tokens.

Open questions:
- Improve heuristics to increase coverage.
- How can we identify the revenue-fee rate of arbitrages?


SCHOOL OF COMPUTATION, INFORMATION AND TECHNOLOGY - INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Master's Thesis in Informatics

Analyzing the Role of Bridges in Cross-Chain MEV Extraction

Danut Ilisei

[Master's Thesis Danut Ilisei]

Research Questions

RQ 01

What is the state-of-art literature on cross-domain profiting strategies in the context of blockchains?

RQ 02

How can we develop a methodology to detect cyclic arbitrages between Ethereum and Polygon PoS using the Polygon bridge?

- *How can we devise heuristics to identify both successful and unsuccessful arbitrages?*

RQ 03

Who executes cross-chain arbitrages between Ethereum and Polygon, and how frequent and profitable are these arbitrages?

- *Which tokens are used for profiting and how long are the bridging times?*
- *Is the Ethereum leg of the arbitrage submitted to the public mempool?*

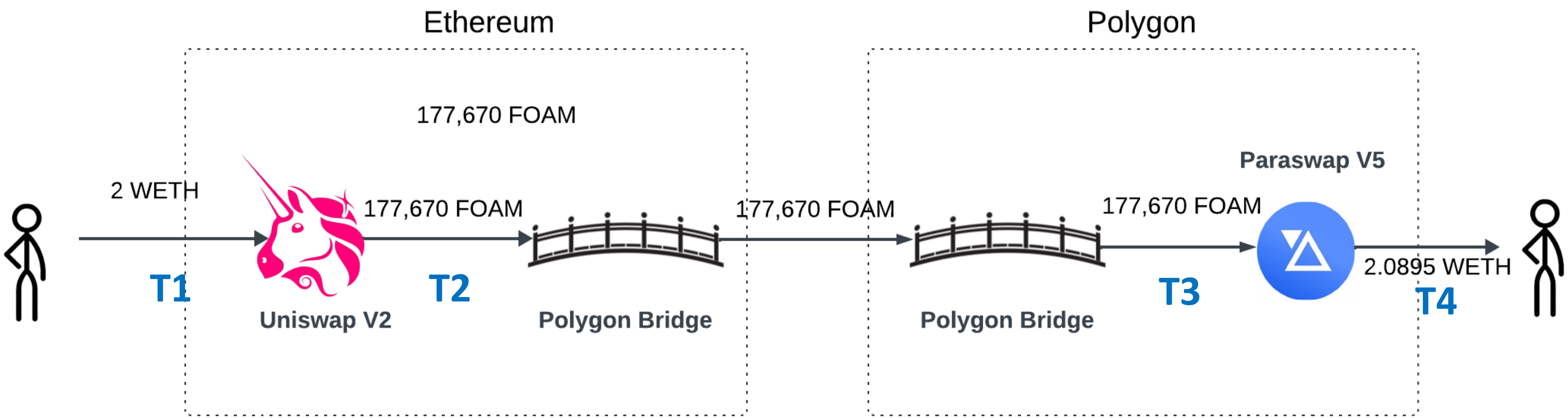
RQ 04

How do our obtained results compare to other profit-making strategies observed on blockchains?

- *Number of occurrence and profitability compared to strategies such as atomic arbitrages,, and sandwich attacks.*

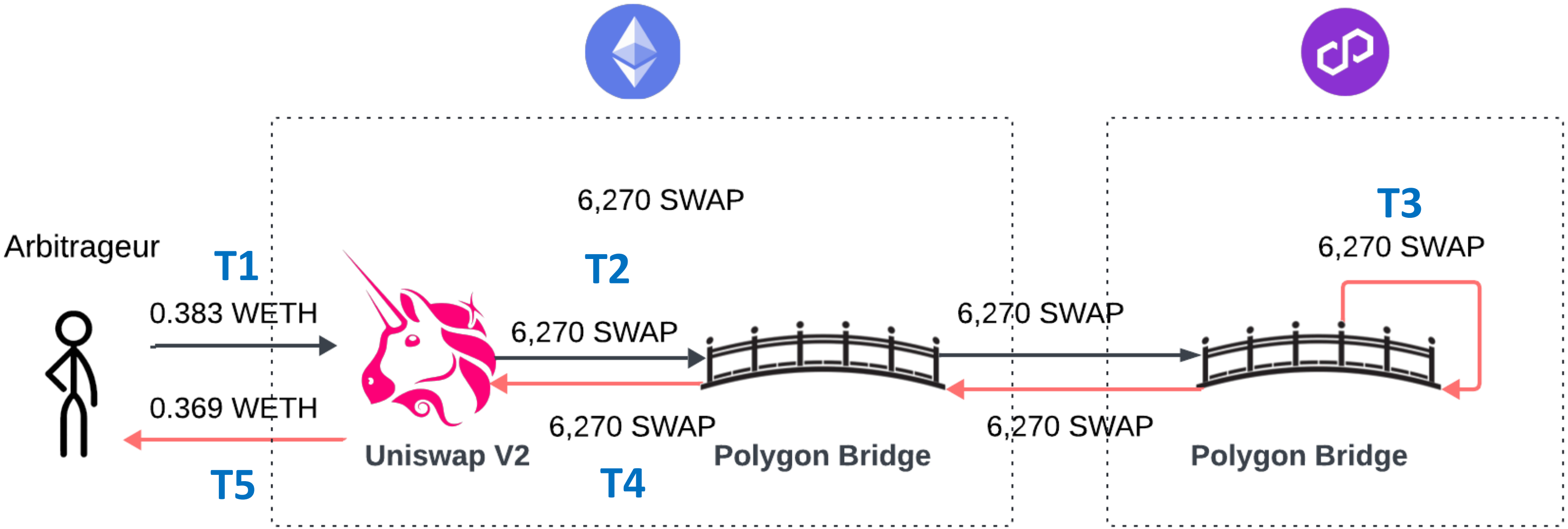
Definitions

Successful Arbitrage



- Arbitrageur starts on the source chain, transfer their assets into the target chain.
- And concludes the arbitrage with an additional swap on the target chain.

Failed Arbitrage Attempt



- Arbitrageur starts on the source chain, transfer their assets into the target chain.
- But instead of concluding the arbitrage on the target, he transfers his assets back to the source chain.
- Possibly reason: arbitrage opportunity may have “expired” by the time tokens were bridged into the target chain.

Definitions

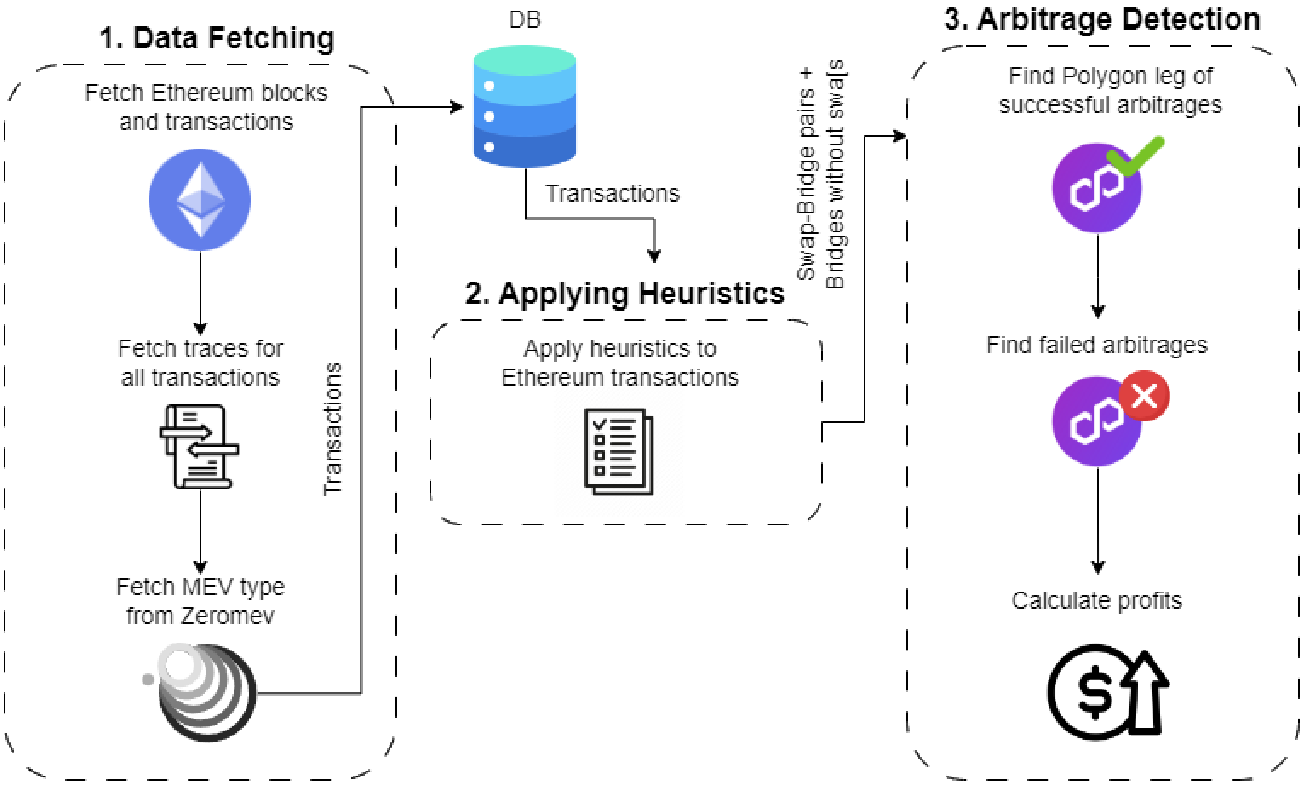
Public Transactions:

- Broadcast to the public mempool.
- Visible to validators and block builders.
- Risk: Vulnerable to front-running (e.g., high-value arbitrages or liquidations).

Private Transactions:

- Directly submitted to block builders via private channels.
- Advantage: Prevents exposing sensitive details, reducing risks like front-running.

Methodology



Results

Overview

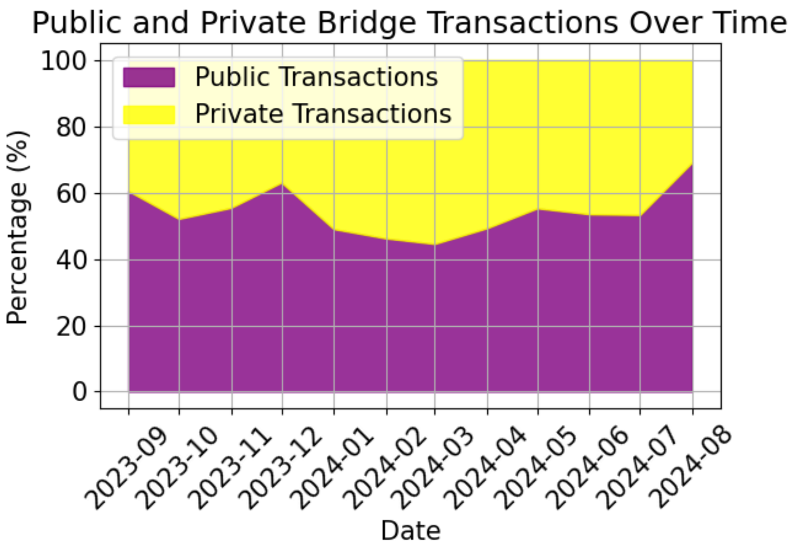
- Analyzed **2.61M** Ethereum blocks (Sep 2023 - Aug 2024).
- Identified **23,404** cross-chain arbitrages (0.89% of blocks).
  - **16,812** cyclic, **6,592** non-cyclic.
  - **1,296** failed arbitrages; **1,092** recovered via additional swaps.
- **58%** Ethereum → Polygon, **42%** Polygon → Ethereum.
- Total profit across all arbitrages **$733,396.72**

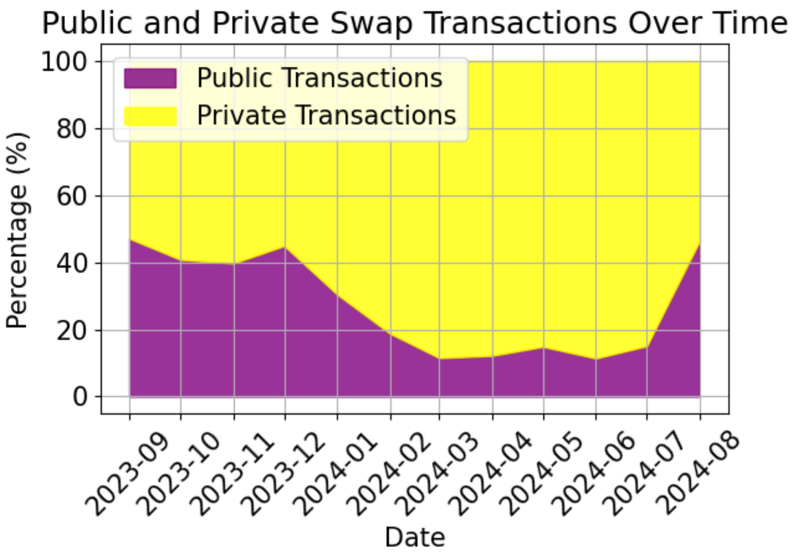
Aspect	Results from [58]	Our Detection
Timeframe	Nov-04-2023 to Mar-23-2024	Nov-04-2023 to Mar-23-2024
Successful Arbitrages	4,488	10,684
Failed Arbitrages	158	554
ETH $\rightarrow$ POL	58%	41.21%
POL $\rightarrow$ ETH	42%	58.79%

Table 1. Comparison to prior work by Danut Ilisei

Results

Transparency

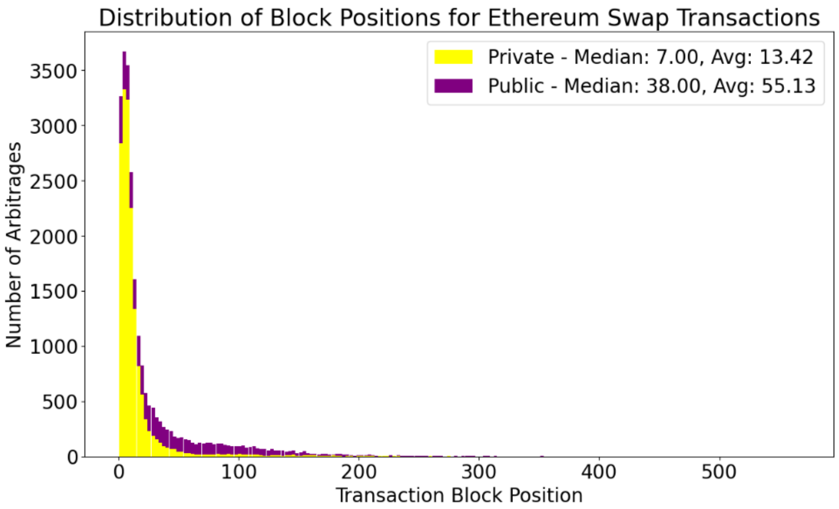


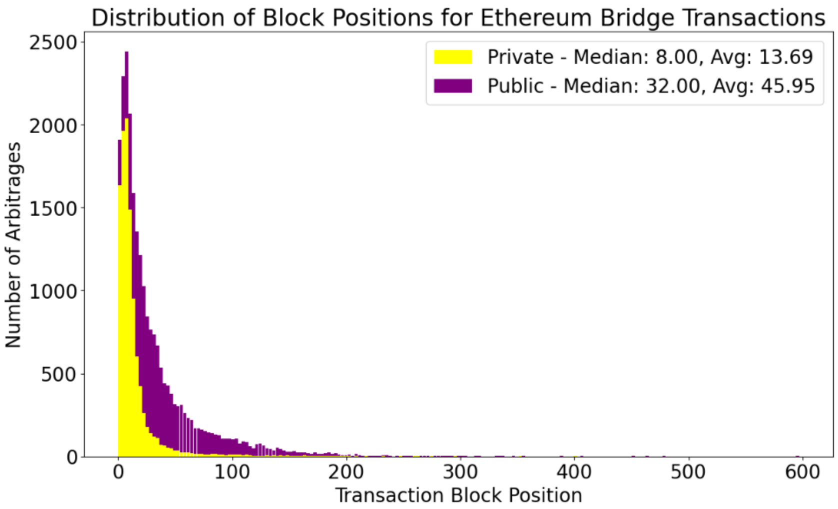


- Bridge Transactions: **45.35%** private, **54.65%** public.
- Swap Transactions: **70.23%** private, **29.77%** public.
- Swaps are more private, likely due to higher-value trades and the need to avoid front-running

Results

Block positions

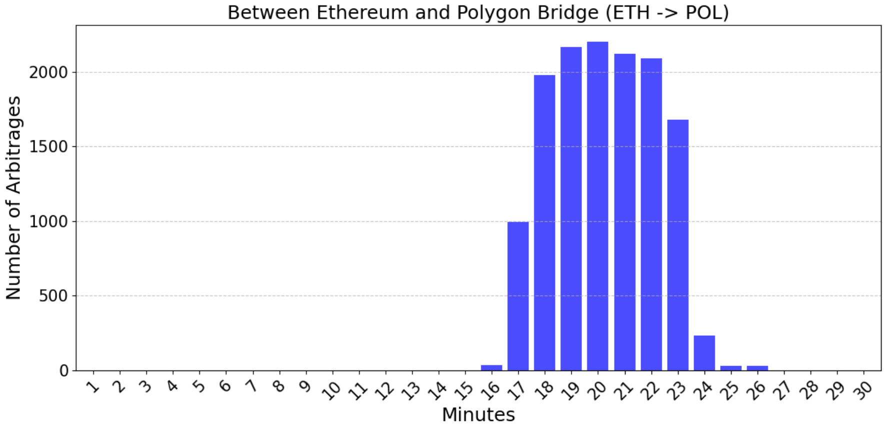


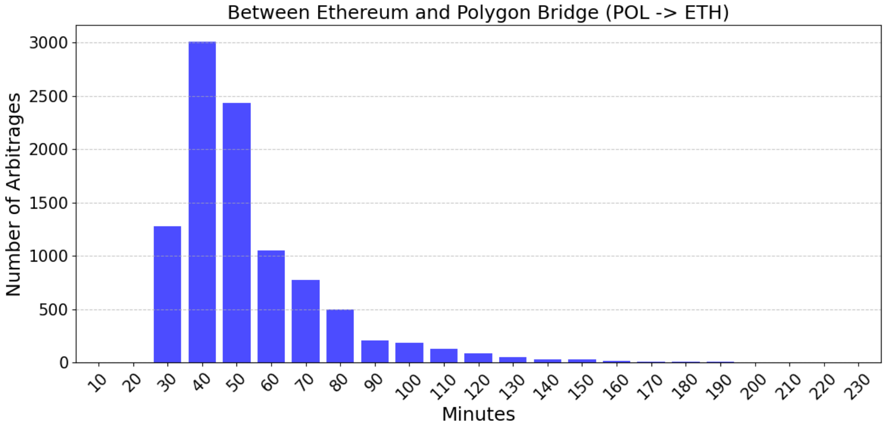


- Both bridge and swap transactions are concentrated in the top positions within blocks.
- On average, private transactions in both categories show a stronger tendency to cluster toward the highest positions.

Results

Durations

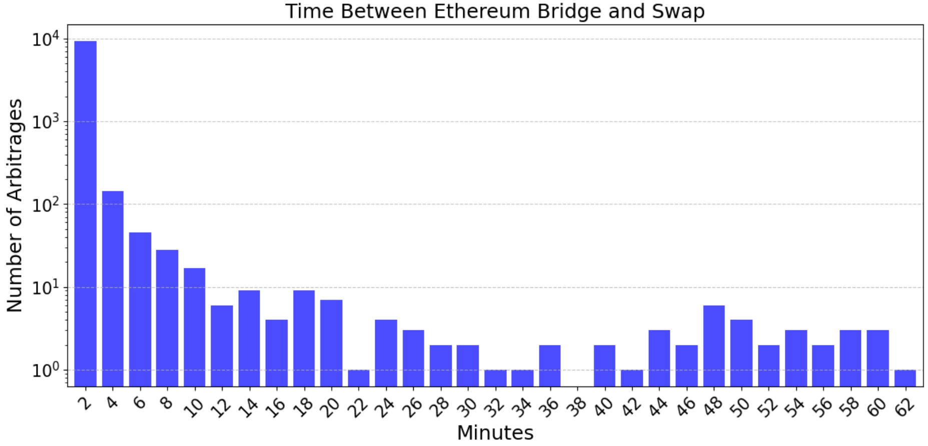


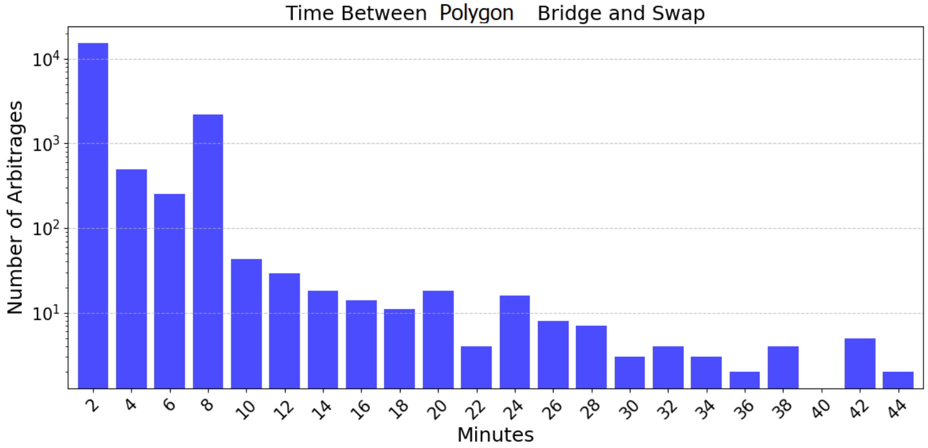


- Average bridging time from Ethereum to Polygon is **~19 minutes**.
- From Polygon to Ethereum it‘s **~48 minutes.**
- Difference is due to the checkpointing process, which is part of Polygon’s security model.

Results

Durations

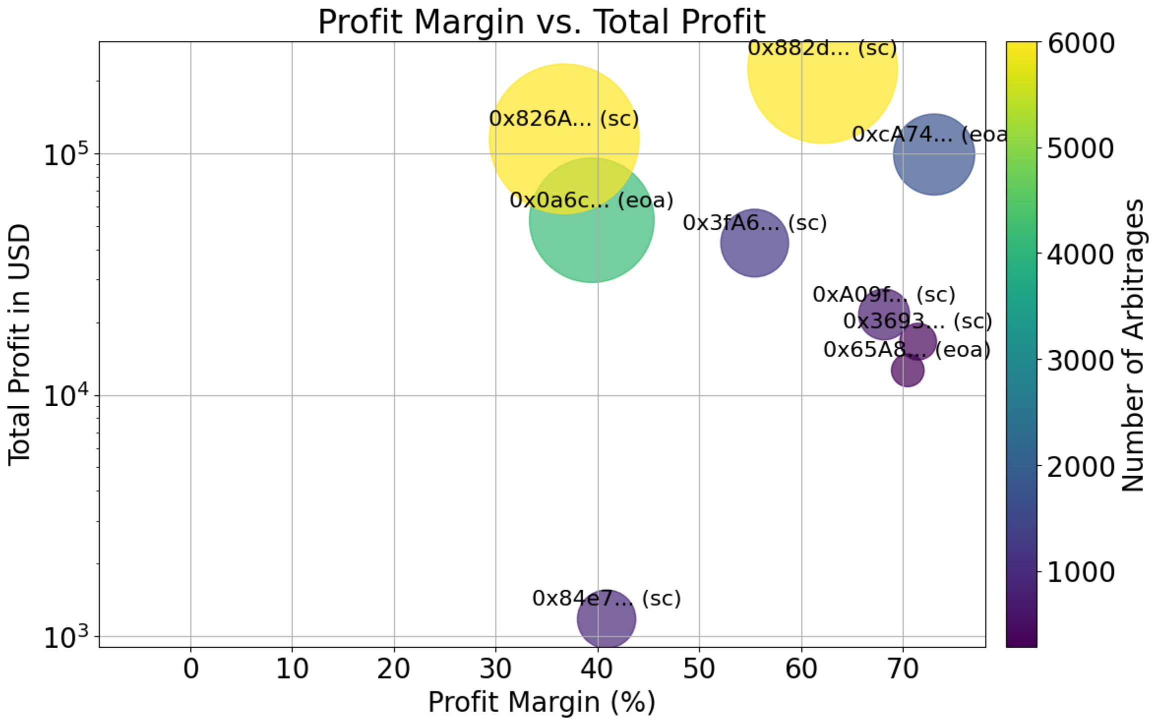




- Majority of these transactions occur within a minute of each other
  E.g., on Polygon, the average time difference of 57.39 seconds

Results

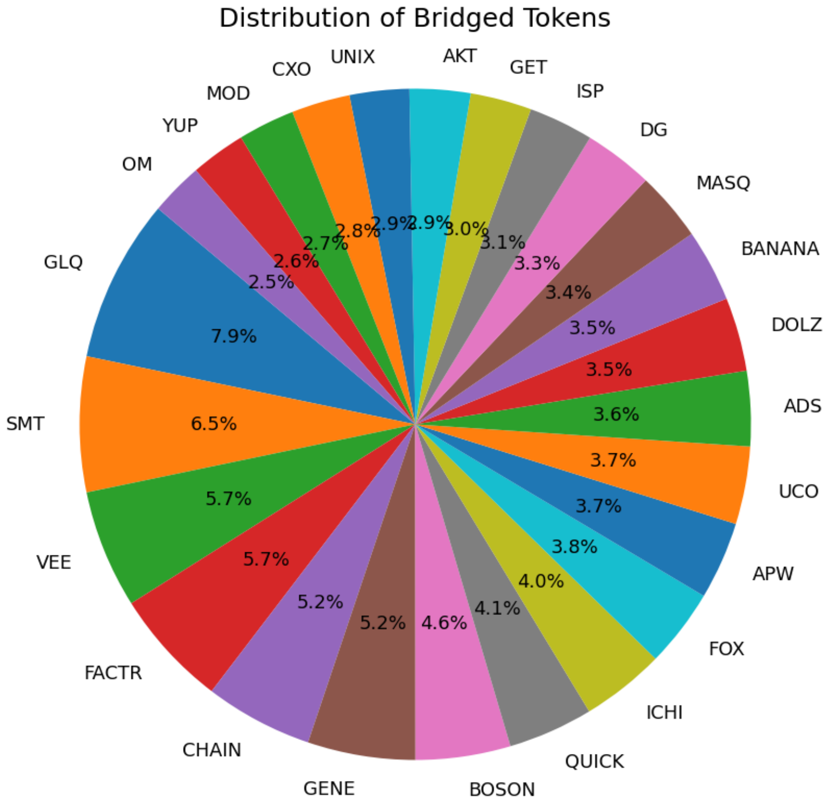
Durations



- A small minority of searchers are responsible for much of the network activity.
- **85.68%** of all arbitrages are conducted by top 6 searchers.

Results

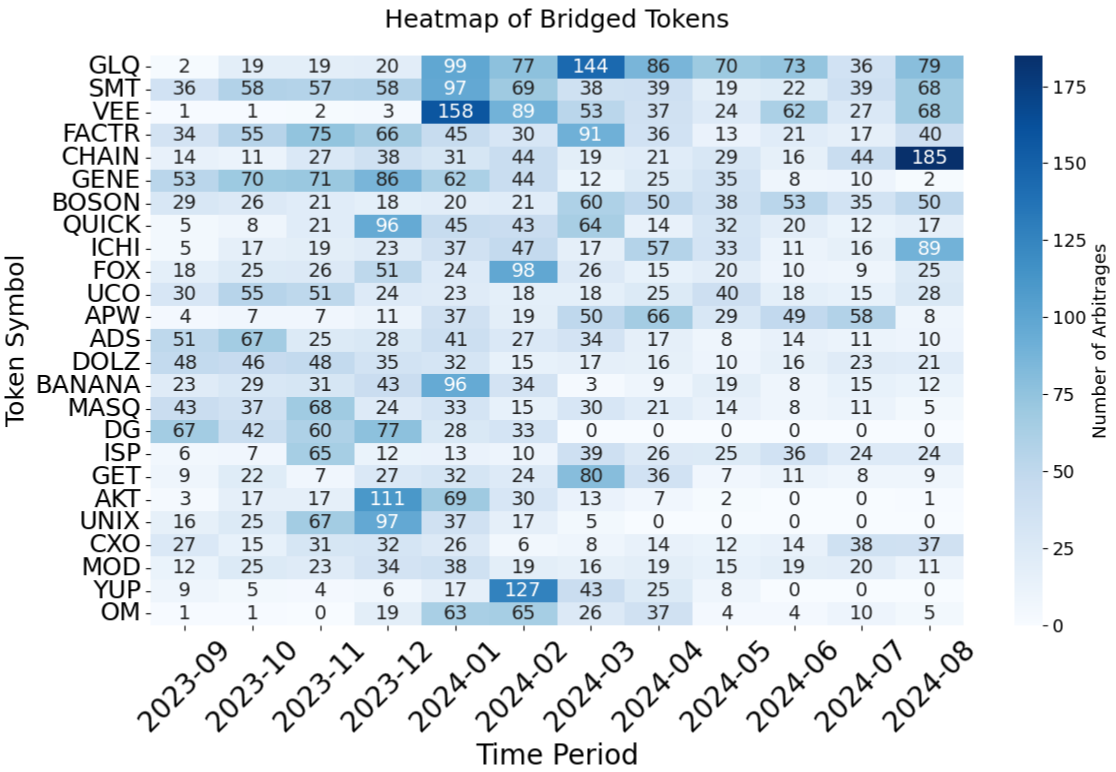
Tokens



- Stablecoins and highly liquid tokens rarely used due to low fees and quick price corrections on CEXs/DEXs.
- Cross-chain arbitrages focus on less liquid tokens primarily traded on DEXs.
- Extended bridging times reduce the appeal of stablecoins.

Results

Tokens



- Some tokens (e.g., SMT, FACTR) show consistent usage.
- Long-tail tokens: DG, UNIX (short-lived popularity).
- BANANA: Consistent usage, indicating sustained community interest.

Comparison

Category	Data Source	Count	Profit
Cross-Chain Arbitrages	Our Results	23,400	$743,368.86
Atomic Arbitrages (Ethereum)	Dune, EigenPhi	> 3.6 million	> $300 million
Atomic Arbitrages (Polygon)	[52]	7.7 million	> $213 million
Sandwich Attacks	Dune, EigenPhi	> 1.5 million	> $48 million

Table 2. Comparison of cross-chain arbitrages with other profit-making strategies

- 23,404 detected (Ethereum–Polygon only); Ethereum also engages with other blockchains.
- Atomic arbitrages include all Ethereum DEXes
- Non-atomic arbitrage challenges: costs (bridging fees, coinbase transfers); risks (liquidity across networks, bridging delays, missed opportunities).
- Arbitrageurs focus on low-risk, high-certainty trades.

Discussion and Future Work

01 Arbitrages

Cross-chain arbitrages do occur, but in far less numbers their atomic counterparts, i.e., ~0.89% of all blocks

02 Searchers

Most of the network activity is concentrated in the hands of 6 searchers.

03 Tokens

High liquidity or more well-known tokens are not bridged. Arbitrageurs opt for less-know tokens

04 Future Work

Future work can focus on more EVM-compatible chains and investigate non-bridge-based arbitrage opportunities.

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