Towards Fairer DEXs on Ethereum

One price per token per block

Felix Leupold
CoW Swap
The DEX journey is 0.03% finished

Daily Trading Volume ($B)

$6,000

$4,000

$2,000

$0

2

60

470

6000

DEXs Today

Digital Assets

US Equities

Global Forex
Brief history of DEX markets
To function properly, markets need at least three things [Alvin Roth]:

1. **Thickness** - Bring together a large enough proportion of potential buyers and sellers

2. **Safety** - Incentivize participants to truthfully reveal their preferences

3. **Overcome Congestion** - Give market participants means to make satisfactory choices when faced with a variety of options
On-chain Limit Order Book DEXs

- Etherdelta, Idex, Oasis
- Required **active** market making
- Difficult to bootstrap new pairs
- High cost for managing orders

→ Hard to create **thick** markets
AMMs democratized market making

- Based on Logarithmic Market Scoring Rule [Hanson et al. 2002]
- Given current inventory, automatically compute exchange rate:
  - $x \cdot y = k$ [Uniswap, Bancor]
  - $\prod_{i=1}^{n} R_i^{w_i} = k$ [Balancer]
  - $An^n \sum x_i + D = ADn^n + \frac{D^{n+1}}{n^n \prod x_i}$ [Curve]
  - ...

Solved the problem of bootstrapping liquidity allowing **thick markets** for **long tail tokens**
Problem with AMMs: Pay as Bid Pricing & MEV

Volatility & revert risk requires users to incorporate "slippage tolerance" into their bids.

Block producer manipulate prices to match tolerance & extract risk free profit.
Traders need to **under-report** their slippage tolerance

AMMs are **unsafe** by design
Advantages of “safe” markets

1. **Simplicity**: Optimal strategy & behavior is easier to predict & reason about, makes it easier to find the “right” answer.

2. **Efficiency**: Truthful revelation of preferences leads to more efficient outcomes.

3. **Fairness** to the least sophisticated participants.

“No market succeeds if it’s not viewed as fair. It’s as simple as that.”

[Maureen O’Hara]
Leading to wider market adoption

Daily Trading Volume ($B)

- $6,000
- $4,000
- $2,000
- $0

- DEXs Today
- Digital Assets
- US Equities
- Global Forex

6000
Building Safety on top of AMMs
Root Cause

One asset, many prices

E.g. Block 15673043:

>1.05% price range for ETH/USD trades
Prices that depend on (arbitrary) intra-block ordering make the market unsafe.
**Solution:**

One price per token per block

<table>
<thead>
<tr>
<th>Asset</th>
<th>Price</th>
<th>Trades</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETH</td>
<td>$1300</td>
<td>0x2473… 0xb61b…</td>
</tr>
<tr>
<td>WBTC</td>
<td>$19000</td>
<td>0x9caa… 0xf437… 0x8a84…</td>
</tr>
<tr>
<td>MATIC</td>
<td>$0.7</td>
<td>0xb61b…</td>
</tr>
</tbody>
</table>
How to build a batch auction on Ethereum in 6 “simple” steps...
Multi-Dimensional trade intents

1. Users express their trades intents (approval + signed message) across all token pairs

2. Intents combined with on-chain liquidity (AMMs, RFQ, etc) create a thick market
Settlement without ordering priority

3. Goal is to find uniform price clearing and execution path such that demand equals supply

4. This poses an NP-hard problem which can be approximated by maximizing user surplus

<table>
<thead>
<tr>
<th>Asset</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETH</td>
<td>1300</td>
</tr>
<tr>
<td>WBTC</td>
<td>19000</td>
</tr>
<tr>
<td>MKR</td>
<td>770</td>
</tr>
<tr>
<td>USDC</td>
<td>1</td>
</tr>
<tr>
<td>DAI</td>
<td>1</td>
</tr>
</tbody>
</table>
Solver competition to ensure best pricing

5. A permissionless competition allows for distributed solving based on different heuristics & algorithms

6. Best solution receives a reward
<table>
<thead>
<tr>
<th>Proof of Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proof of Stake</td>
</tr>
<tr>
<td>Proof of Optimality</td>
</tr>
</tbody>
</table>
Clearing Price: $48.2

$2300 of added surplus from batching:
  - $800 Reduced LP fees
  - $1500 Reduced price impact
MEV Protection in Practice

- Negative Slippage
  - 64.7%
  - 35.3%

- Positive Slippage
  - 96.0%
  - 29.2%
  - 70.8%
Proposer Builder Separation
Crypto is in the business of constantly rediscovering the basic ideas of financial history.

Matt Levine (MoneyStuff)
Where Ethereum is headed

Intent: Sell USDC for ETH

Tx: uni.swap(1000)

Block Builder

Block Proposer

Other builders
Where Ethereum is headed

Intent
Sell USDC for ETH

free transactions
Payment for order flow

Wallets
uni.swap(1000)

Block Builder
block

Block Proposer
Traditional Finance

WALLETS
Broker

Block Builder
Market Maker

Block Proposer
Clearing House

free transactions
Payment for order flow
MEV maximization vs minimization

Can they coexist?

The goal, from day one, has been to minimize MEV as much as we can and to maximize the democratic extraction of what's left.

Love to see both sides being done. Let's keep it up.

What is a better MEV auction?

- more private
- more decentralized
- more competitive
- more transparent
- more user-friendly

- more robust
- more efficient
- more geographically diverse
- fewer network externalities
- (still) fewer first-party deals

@bertcmiller 🌟 @bertcmiller · Sep 10
There are less sandwiches on Ethereum today than the day that Flashbots launched. twitter.com/bertcmiller/st...
MEV maximization leads to dangerous incentives

- Adopting a MEV reducing mechanism is a repeated prisoner’s dilemma
- Block builders operating without rent from MEV receive lower rewards compared to others
- Only if all builders co-operate we reach a new equilibrium with larger social returns
- Block builders are incentivized to stick to the status quo (perhaps even fight new entrants)

<table>
<thead>
<tr>
<th></th>
<th>extract</th>
<th>minimize</th>
</tr>
</thead>
<tbody>
<tr>
<td>extract</td>
<td>(1, 1)</td>
<td>(2, 0)</td>
</tr>
<tr>
<td>minimize</td>
<td>(0, 2)</td>
<td>(3, 3)</td>
</tr>
</tbody>
</table>
Let’s grow the pie, rather than splitting it.
Thank you!

Felix Leupold
CoW Swap

@fleupold_
Why is this a better mechanism?
Advantages of “intent based trading”

1. Decoupling the “what to trade” from the “how to trade”
2. Transaction management abstracted away from the user
3. Introduces composability
Advantages of batch auctions

1. Peer to peer matching (coincidence of wants) leads to better prices
   - No price impact
   - No LP fee
   - Reduced gas fees (even when trading in the same direction)

2. Uniform price clearing removes intra-batch MEV

3. Ring trades re-aggregate fragmented markets (e.g. stablecoins)
Criticism (1) - Shared price impact

- This is not true in expectation: big trades could go in opposite direction with equal probability.
- In reality, the chance of 🐠 getting ordered before 🐳 in the face of MEV is small.

Consider a sequence of T trades w/ sizes T, 1, ..., 1 — 1 🐠, T-1 🐠 — ID’ing where the 🐠’s trade gets executed can be viewed as a threshold function (WhaleTradeOrder > k).

Batch auctions are bad for this sequence: they make the worst case price impact Ω(T) — 🐠 pay for the 🐳. 

Massive increase in price and volatility!

Ding sideways in a narrow price range.
Criticism (2) - Batch auctions are slow

“[Batching] ... means that users face higher latencies for trade confirmation”
[Chitra, Angeris, Evan 2021]

- While in practice CoW Swap auctions are slow today, it is possible to run one auction per block
- Ethereum confirmation time (12s) is the lower bound for trade confirmation
Difference to Flashbots protect / PF0F

- While the type of optimisation (finding optimal routing/arbitrage) is similar, the outcome is the exact opposite
Are Batch Auctions Safe?

- Uniform clearing prices make intra batch price manipulation impossible
- Competition allows users to specify their true limit price (slippage tolerance)
Enter your main point / statement here.
Here’s the timeline.

Event 1

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam.

Event 2

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam.

Event 3

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam.
Regulation ensures “fair” pricing

Buys from market maker at $1305

Sells to market maker at $1290

National Best Bid
$1290

National Best Offer
$1310

$10 spread

$1295

$1305
Lessons from traditional finance

1. Pay for order flow may lead to centralization
2. Centralization leads to regulation and a higher barrier to entry
3. High barrier to entry stifles permissionless innovation
Root Cause

One asset, many prices

E.g. Block 15634029:

>0.75% price range for ETH/USD trades

<table>
<thead>
<tr>
<th>Transaction</th>
<th>Type</th>
<th>Index</th>
<th>Price (Ξ/$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x280a...</td>
<td>Buy</td>
<td>1</td>
<td>$1344.7</td>
</tr>
<tr>
<td>0x2473...</td>
<td>Buy</td>
<td>2</td>
<td>$1346.2</td>
</tr>
<tr>
<td>0xb61b...</td>
<td>Sell</td>
<td>3</td>
<td>$1348</td>
</tr>
<tr>
<td>0x9caa...</td>
<td>Sell</td>
<td>14</td>
<td>$1337.6</td>
</tr>
<tr>
<td>0xf437...</td>
<td>Buy</td>
<td>15</td>
<td>$1336.7</td>
</tr>
<tr>
<td>0x8a84...</td>
<td>Buy</td>
<td>55</td>
<td>$1336.7</td>
</tr>
</tbody>
</table>
MEV maximization leads to dangerous incentives

- Adopting a MEV reducing mechanism is a repeated prisoner’s dilemma
- Block builders operating without rent from MEV receive lower rewards compared to others
- Only if all builders co-operate we reach a new equilibrium with larger social returns
- Block builders are incentivized to stick to the status quo (perhaps even fight new entrants)

*Project start date: April 2015. We are especially grateful to Larry Gaten and Terry Hendershoff for serving as discussants of an early version of this project. We also thank Jason Alaxlick, Susan Athey, John Campbell, Dennis Carlton, Judy Chevalier, John Cochrane, Christopher Cusack, Peter Cranton, Doug Diamond, David Easley, Alex Frankel, Joel Hasbrouck, Kate Ho, Anil Kashyap, Pete Kyle, Donald MacKenzie, Neale Mahoney, Paul Milgrom, Ariel Pakes, Al Roth, Fiona Scott Morton, Andrei Shleifer, Jeremy Stein, Mike Whinston, Heidi Williams, Luigi Zingales, and numerous industry practitioners and seminar participants for helpful discussions and suggestions. Paul Kim, Cameron Taylor, Matthew O’Keefe, Natalia Drudoff, and Ethan Che provided exceptional research assistance. Budish acknowledges financial support from the Fannie-Miller Center, the

Will the Market Fix the Market?
A Theory of Stock Exchange Competition and Innovation*

Eric Budish† Robin S. Leef and John J. Shim§

February 27, 2019

Abstract
As of early 2019, there are 13 stock exchanges in the U.S., across which over 1 trillion shares ($50 trillion) are traded annually. All 13 exchanges use the continuous limit order book market design, a design that gives rise to latency arbitrage—arbitrage rents from symmetrically observed public information—and the associated high-frequency trading arms race (Budish, Cranton and Shim, 2015). Will the market adopt new market designs that address the negative aspects of high-frequency trading? This paper builds a theoretical model of stock exchange competition to answer this question. Our model, shaped by institutional details of the U.S. equities market, shows that under the status quo market design: (i) trading behavior across the many distinct exchanges is as if there is just a single “synthesized” exchange; (ii) competition among exchanges is fierce on the dimension of traditional trading fees; but (iii) exchanges capture and maintain significant economic rents from the sale of speed technology—arms for the arms race. Using a variety of data, we document seven stylized empirical facts that align with these predictions. We then use the model to examine the private and social incentives for market design innovation. We show that the market design adoption game among exchanges is a repeated prisoner’s dilemma. If an exchange adopts a new market design that eliminates latency arbitrage, it would win share and earn economic rents; perhaps surprisingly, the usual coordination problems associated with getting a new market design off the ground are not central. However, imitation by other exchanges would result in an equilibrium that resembles the status quo with competitive trading fees, but now without the rents from the speed race. We conclude that although the social returns to adoption are large, the private returns are much smaller for an entrant exchange and negative for an incumbent that currently derives rents from the inefficiencies that the new design eliminates. Nevertheless, our analysis does not imply that a market-wide market design mandate is necessary. Rather, it points to a more circumscribed policy response that would tip the balance of incentives and encourage the “market to fix the market.”

*Project start date: April 2015. We are especially grateful to Larry Gaten and Terry Hendershoff for serving as discussants of an early version of this project. We also thank Jason Alaxlick, Susan Athey, John Campbell, Dennis Carlton, Judy Chevalier, John Cochrane, Christopher Cusack, Peter Cranton, Doug Diamond, David Easley, Alex Frankel, Joel Hasbrouck, Kate Ho, Anil Kashyap, Pete Kyle, Donald MacKenzie, Neale Mahoney, Paul Milgrom, Ariel Pakes, Al Roth, Fiona Scott Morton, Andrei Shleifer, Jeremy Stein, Mike Whinston, Heidi Williams, Luigi Zingales, and numerous industry practitioners and seminar participants for helpful discussions and suggestions. Paul Kim, Cameron Taylor, Matthew O’Keefe, Natalia Drudoff, and Ethan Che provided exceptional research assistance. Budish acknowledges financial support from the Fannie-Miller Center, the