

Market Microstructure in Digital Finance

L06: AMMs, Order Books, and Price Discovery

Economics of Digital Finance

BSc Course

Today's Topics

1. Traditional vs. DeFi market structure
2. Automated Market Makers (AMMs)
3. Order book mechanics and depth
4. Price discovery in fragmented markets
5. Impermanent loss for liquidity providers
6. MEV and front-running economics

Learning Objectives

- Compare order book and AMM mechanisms
- Analyze liquidity provision economics
- Understand price discovery in crypto markets
- Evaluate MEV extraction strategies
- Apply microstructure theory to DeFi

This lesson applies market microstructure theory to understand digital asset trading

Centralized Exchanges (CEXs)

Characteristics

- Central limit order book (CLOB)
- Custodial trading
- Professional market makers
- High-frequency trading infrastructure

Examples

- Binance, Coinbase, Kraken
- NYSE, Nasdaq (traditional)

Decentralized Exchanges (DEXs)

Characteristics

- Automated market makers (AMMs)
- Non-custodial trading
- Permissionless liquidity provision
- On-chain settlement

Examples

- Uniswap, Curve, Balancer
- PancakeSwap, SushiSwap

Economic question: Which structure provides better price discovery and lower transaction costs?

Order Book Structure

Key Components

- Bid side (buy orders)
- Ask side (sell orders)
- Spread: ask price - bid price
- Depth: volume at each price level

Price Formation

- Limit orders provide liquidity
- Market orders consume liquidity
- Spread compensates market makers

Economic Theory

Kyle (1985) model:

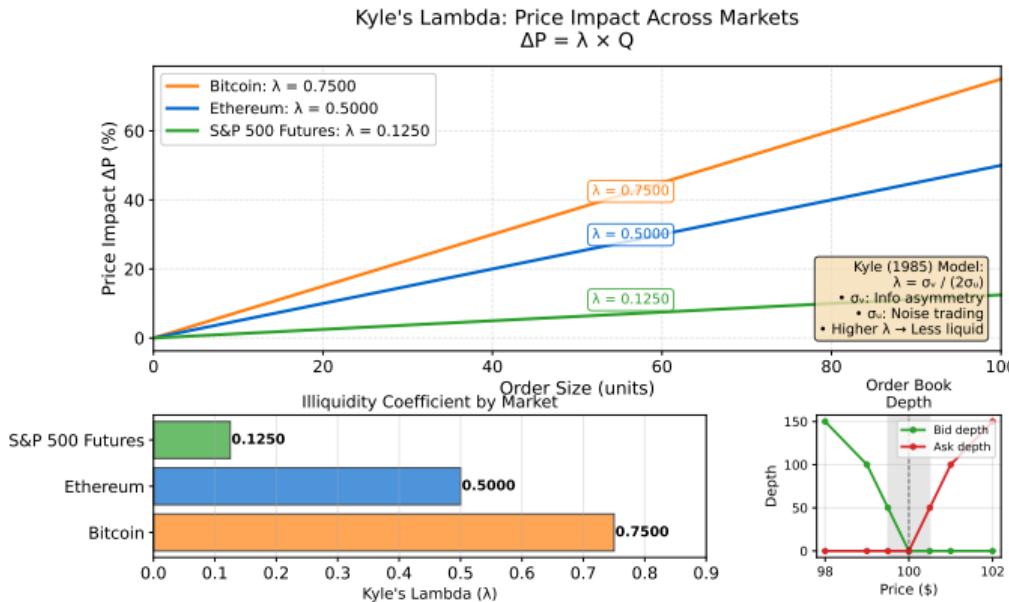
- Price impact: $\lambda = \frac{\sigma_v}{2\sigma_u}$
- Informed trading depth
- Adverse selection costs

Glosten-Milgrom (1985):

- Bid-ask spread reflects asymmetry
- Sequential trade learning

Traditional microstructure assumes informed vs. uninformed traders; crypto markets add MEV extractors

Order Book Depth Visualization



Source: Kyle (1985) "Continuous Auctions and Insider Trading"

Deeper order books reduce price impact for large trades; depth is a key liquidity metric

Automated Market Makers: The Constant Product Formula

How AMMs Work

Constant Product Formula

$$x \cdot y = k$$

where:

- x : reserve of token A
- y : reserve of token B
- k : constant (invariant)

Price Determination

$$P = \frac{y}{x}$$

Economic Properties

Advantages

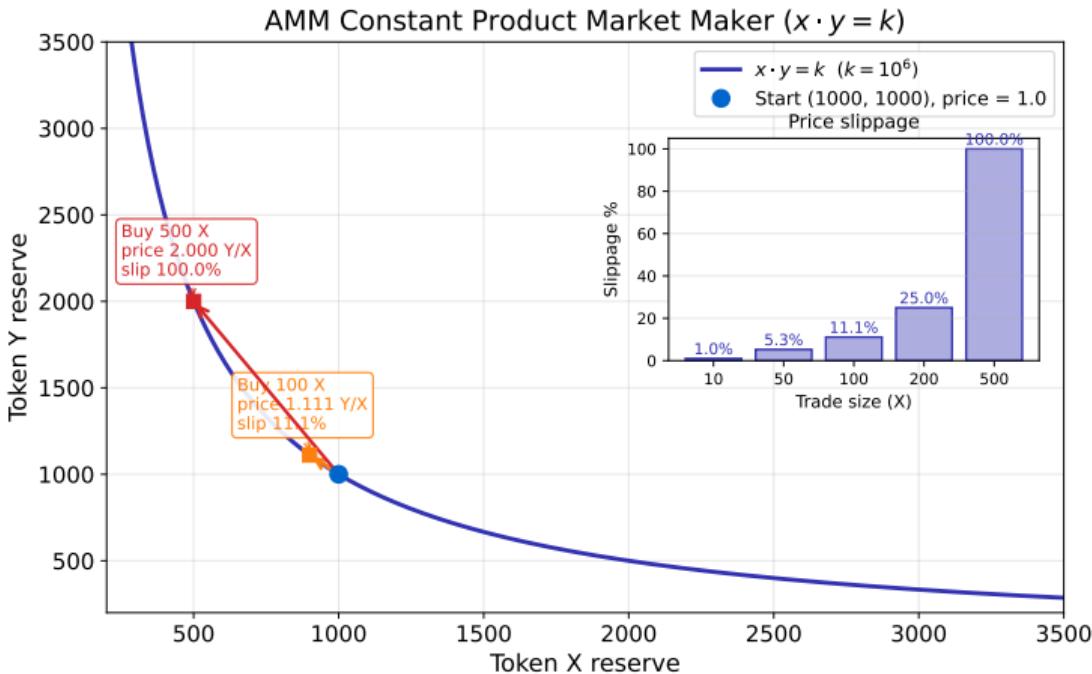
- Always provides liquidity
- Permissionless participation
- No order matching needed
- Transparent pricing

Disadvantages

- Price slippage on large trades
- Impermanent loss for LPs
- Capital inefficiency
- MEV vulnerability

Uniswap pioneered constant product AMM; now the dominant DeFi trading mechanism

Constant Product Curve and Price Impact



Larger trades move farther along the curve, experiencing greater price impact (slippage)

LP Revenue Streams

Fee Income

- Uniswap v2: 0.3% per trade
- Uniswap v3: 0.05%, 0.3%, 1% tiers
- Proportional to pool share

Incentive Programs

- Liquidity mining rewards
- Protocol token emissions
- Governance rights

LP Costs and Risks

Impermanent Loss

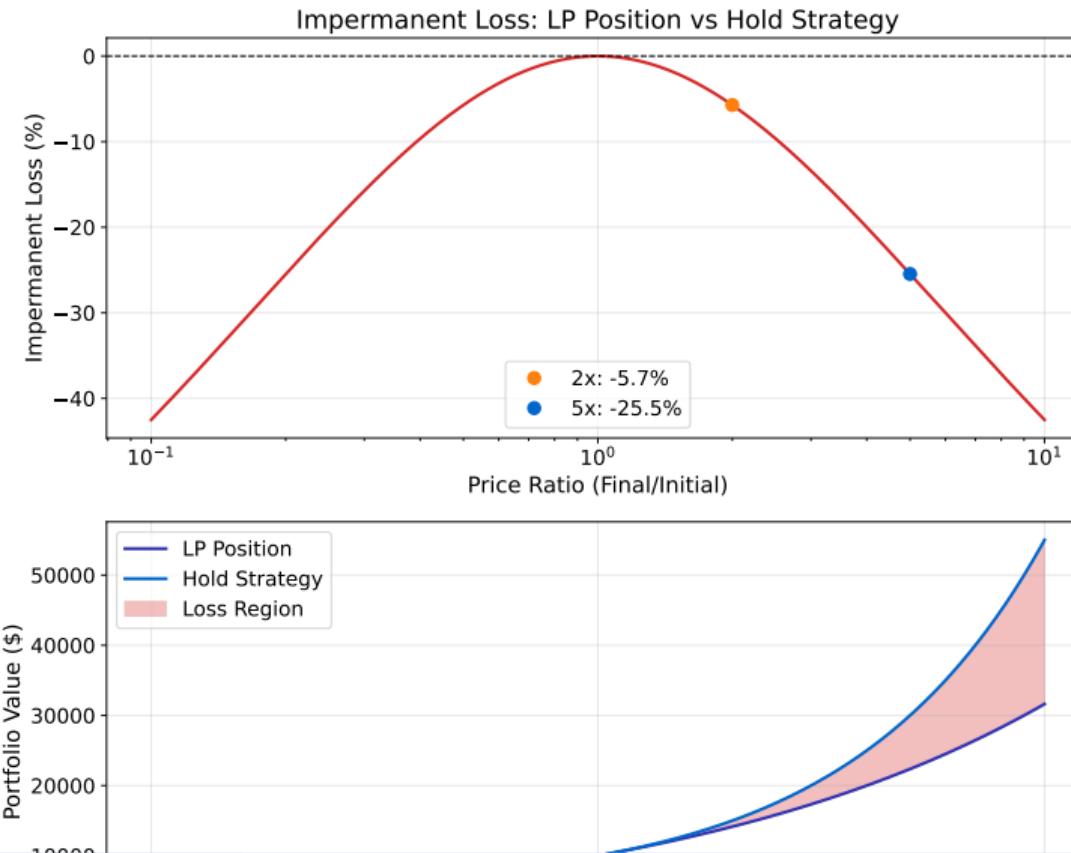
- Loss from price divergence
- Compared to holding assets
- Amplified by volatility

Other Risks

- Smart contract risk
- Gas costs for rebalancing
- MEV extraction

LPs face a trade-off: fee income vs. impermanent loss; only profitable if fees exceed IL

Impermanent Loss Analysis



Market Fragmentation

Sources of Fragmentation

- Multiple DEXs (Uniswap, Curve, etc.)
- Multiple CEXs (Binance, Coinbase, etc.)
- Cross-chain markets
- Different trading pairs

Arbitrage Mechanism

- Arbitrageurs exploit price differences
- Drive convergence across venues
- Extract value from inefficiencies

Information Share

Hasbrouck (1995) information share:

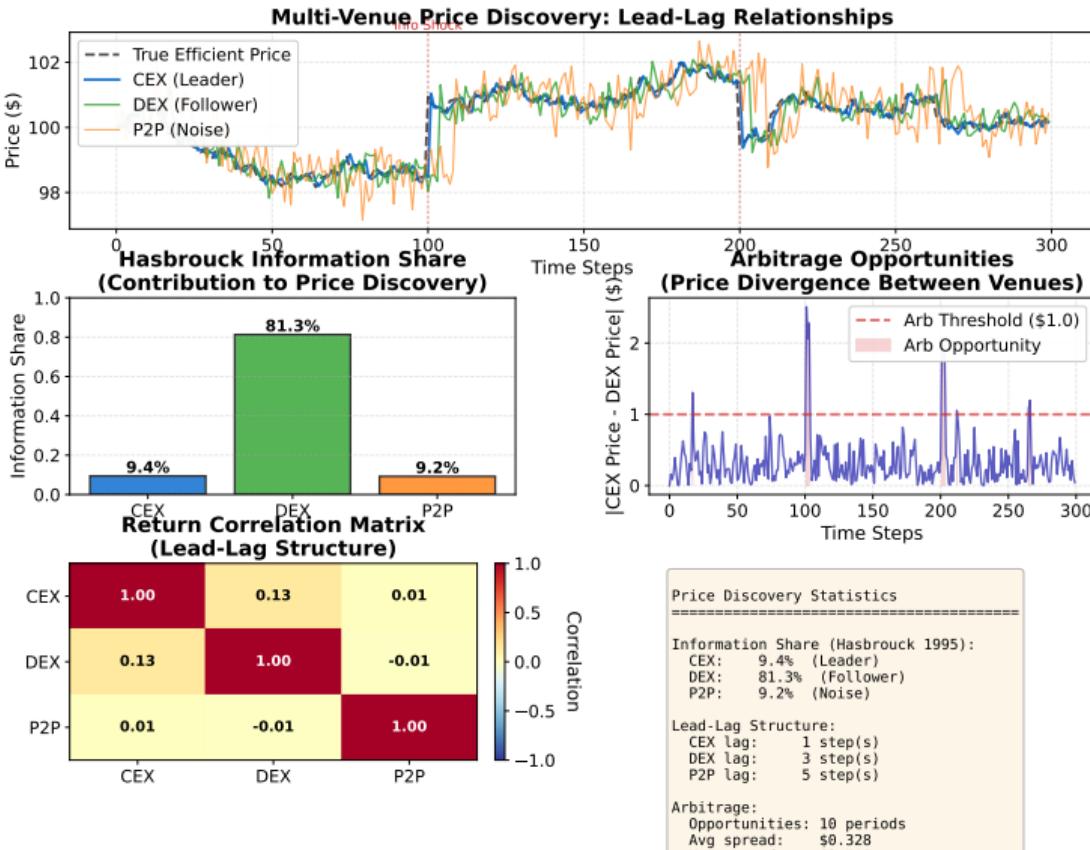
$$IS_i = \frac{\text{Variance contribution of venue } i}{\text{Total price discovery variance}}$$

Empirical Findings

- CEXs dominate price discovery
- DEXs lag by seconds to minutes
- Arbitrage costs determine efficiency
- MEV complicates traditional metrics

Crypto markets test traditional price discovery theory due to permissionless arbitrage and MEV

Price Discovery Across Fragmented Venues



Maximal Extractable Value (MEV)

What is MEV?

Definition

- Value extractable by ordering transactions
- Enabled by block producer control
- Zero-sum redistribution (mostly)

Types of MEV

- Front-running
- Back-running
- Sandwich attacks
- Liquidations
- Arbitrage

Economic Impact

MEV Magnitude

- \$600M+ extracted since 2020
- 5-10% of some DEX trades
- Growing with DeFi adoption

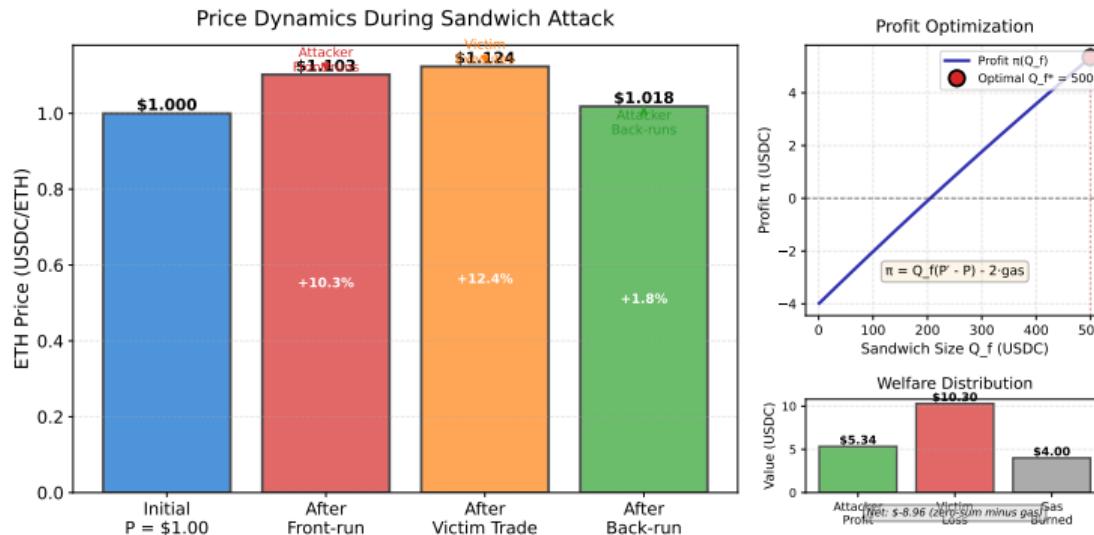
Welfare Effects

- Transfers wealth from traders to extractors
- Increases transaction costs
- May improve price efficiency
- Potential consensus instability

MEV is a new phenomenon requiring new economic models beyond traditional market microstructure

Anatomy of a Sandwich Attack

MEV Sandwich Attack: Optimal Extraction Strategy
Daian et al. (2020): Victim Trade = 100 USDC, Optimal Front-run = 500 USDC



Searchers front-run victim's buy, then back-run with sell, extracting value via price manipulation

MEV Supply Chain

Actors

- Searchers: find MEV opportunities
- Builders: construct blocks
- Validators: propose blocks
- Users: suffer MEV extraction

Competition Dynamics

- Priority gas auctions (PGAs)
- Flashbots auction mechanism
- MEV-Boost infrastructure

Mitigation Strategies

Protocol-Level

- Encrypted mempools
- Fair ordering protocols
- Batch auctions
- Threshold encryption

Application-Level

- MEV-protected RPCs
- Slippage tolerance limits
- Time-weighted average pricing
- Private order flow

MEV creates tension between validator revenue and user welfare; no clear solution yet

Efficiency Metrics

Spread and Depth

- Bid-ask spreads wider than TradFi
- Lower depth for most pairs
- Improving over time

Price Discovery Speed

- Fast arbitrage (seconds)
- Cross-exchange efficiency
- 24/7 trading advantage

Informational Efficiency

Challenges

- High retail participation
- Limited fundamental anchors
- Sentiment-driven volatility
- Manipulation concerns

Advantages

- Transparent on-chain data
- Permissionless arbitrage
- No trading halts
- Global liquidity pools

Crypto markets exhibit mixed efficiency: fast arbitrage but high volatility and manipulation risk

Automated Market Makers

Strengths

- Guaranteed liquidity (always tradable)
- Simple passive LP participation
- Transparent pricing formula
- No counterparty matching needed

Weaknesses

- High price impact for large trades
- Impermanent loss risk
- Capital inefficiency (idle reserves)
- MEV vulnerability

Order Books

Strengths

- Better for large trades (lower slippage)
- Sophisticated order types (limit, stop)
- Professional market making
- Familiar interface

Weaknesses

- Requires active market makers
- Liquidity can disappear
- Higher technical complexity
- Custodial risk on CEXs

Optimal structure depends on asset liquidity, trade size, and user preferences; hybrid approaches emerging

Uniswap v3: Concentrated Liquidity

Innovation

- LPs choose price ranges
- Higher capital efficiency
- Customizable fee tiers

Trade-offs

- Active management required
- Higher impermanent loss risk
- Complexity barrier

Curve: Stableswap

Innovation

- Optimized for low-volatility pairs
- Hybrid constant sum + constant product
- Lower slippage for stablecoins

Balancer: Weighted Pools

- Multi-asset pools
- Customizable weights
- Index fund functionality

AMM innovation continues; trend toward capital efficiency and specialization by asset type

Key Findings

Liquidity and Trading Costs

- DEX spreads 2-5x CEX spreads
- Improving with liquidity growth
- Uniswap v3 narrows gap

Impermanent Loss

- Most LPs lose vs. HODL
- Fee income often insufficient
- Incentive programs crucial

MEV Impact

Magnitude

- 5-10% implicit cost on some trades
- Concentrated in large trades
- Growing with DeFi TVL

Price Discovery

- CEXs lead by 30-60 seconds
- Arbitrage profitable despite costs
- Cross-chain discovery slower

Research from Lehar & Parlour (2021), Barbon & Ranaldo (2022), Adams et al. (2024) on AMMs and MEV

Technical Innovation

Emerging Mechanisms

- Dynamic fees (volatility-adjusted)
- Just-in-time liquidity
- Intent-based architectures
- ZK-rollup order books

MEV Solutions

- Encrypted mempools
- Fair ordering protocols
- MEV redistribution to users

Economic Research Needs

Open Questions

- Optimal LP compensation design
- MEV welfare impact measurement
- Cross-chain price discovery
- Decentralized governance efficiency

Policy Implications

- Market manipulation regulation
- Investor protection in DeFi
- Systemic risk from MEV

DeFi market microstructure is rapidly evolving; economic theory must adapt to new mechanisms

Key Takeaways

Core Concepts

1. AMMs use constant product formula for automated trading
2. Order books rely on active market makers
3. Impermanent loss is key LP risk
4. MEV extracts value via transaction ordering
5. Price discovery faster but less efficient than TradFi

Application to Practice

Market microstructure theory helps evaluate DEX design, understand LP economics, and assess efficiency of crypto trading venues.

Economic Insights

- Trade-offs between decentralization and efficiency
- Liquidity provision requires compensation for IL
- MEV creates new welfare considerations
- Market fragmentation enables arbitrage
- Innovation continues with v3, Curve, etc.

Next lesson: Regulatory Economics of Digital Finance

Foundational Papers

- Kyle (1985): "Continuous Auctions and Insider Trading"
- Hasbrouck (1995): "One Security, Many Markets"
- Adams et al. (2024): "Uniswap v3: The Economics of Concentrated Liquidity"
- Lehar & Parlour (2021): "Systemic Fragility in Decentralized Markets"

MEV Research

- Daian et al. (2020): "Flash Boys 2.0"
- Qin et al. (2022): "Quantifying MEV on Ethereum"
- Barbon & Ranaldo (2022): "On the Quality of Cryptocurrency Markets"

All readings available on course platform