Lesson 21: DeFi Fundamentals

Module 2: Blockchain Fundamentals

Digital Finance

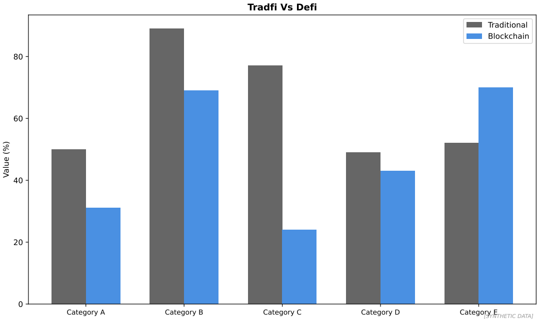
DeFi: Decentralized Finance Revolution

Traditional Finance (TradFi):

- Banks, brokers, exchanges
- Intermediaries control access
- Centralized custody
- Limited hours, geographic restrictions
- KYC/AML required

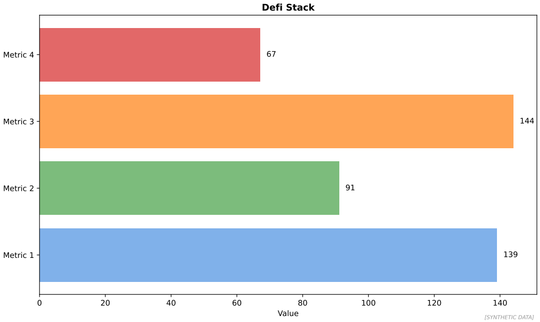
DeFi:

- Smart contracts replace intermediaries
- Permissionless access (anyone with wallet)
- Self-custody
- 24/7 global access
- Pseudonymous (no KYC)



Understanding history helps predict future developments in the technology.

DeFi Primitives



Core Building Blocks:

- **Asset Layer:** Tokens (ERC-20, stablecoins)
- **Protocol Layer:** Lending, DEXs, derivatives
- **Application Layer:** Aggregators, wallets, dashboards
- **Composability:** "Money Legos" – protocols interact seamlessly

DeFi recreates traditional financial services in a permissionless, programmable way.

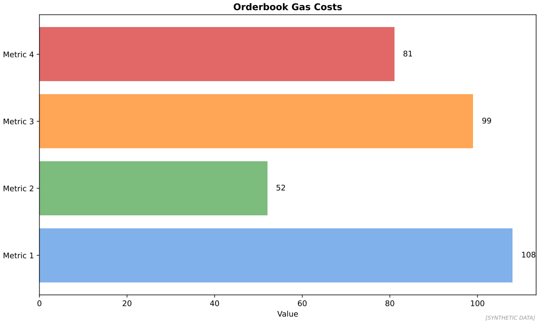
Decentralized Exchanges (DEXs): The Problem

Centralized Exchanges (CEXs):

- Order book model
- Custodial (exchange holds funds)
- Counterparty risk (FTX collapse)
- KYC requirements
- Single point of failure

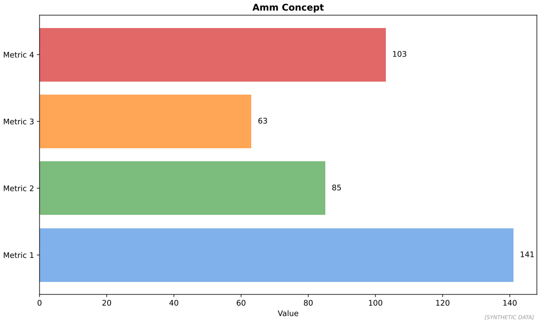
Challenges for DEX:

- On-chain order book too expensive
- Liquidity fragmentation
- Constant price updates



Centralized systems trade trust for efficiency; decentralized systems trade efficiency for trustlessness.

AMM: Automated Market Maker



Key Idea:

- Liquidity pools replace order books
- Algorithmic pricing via bonding curve
- Anyone can provide liquidity (LP)
- Passive market making

Key concepts from this slide inform practical applications in finance.

Constant Product Formula: $x \times y = k$

Uniswap V2 Model:

$$x \times y = k$$

where x = reserve of token A, y = reserve of token B, k = constant

Example: ETH/USDC pool with 100 ETH and 200,000 USDC

$$k = 100 \times 200{,}000 = 20{,}000{,}000$$

Trade: Buy 10 ETH

- New ETH reserve: $x' = 100 - 10 = 90$
- New USDC reserve: $y' = k/x' = 20{,}000{,}000/90 = 222{,}222$
- USDC paid: $222{,}222 - 200{,}000 = 22{,}222$ (effective price $\sim$\$2,222/ETH)

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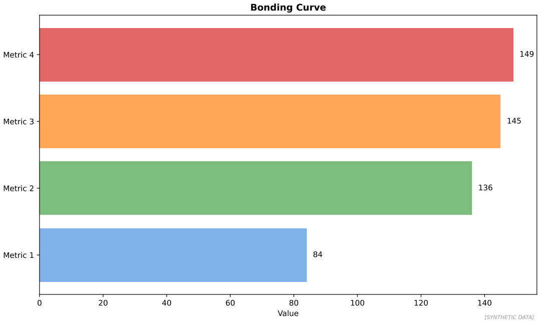
AMM Bonding Curve Visualization



Properties:

- Price = slope of curve at current point: $P = y/x$
- Larger trades move price more (slippage)
- Infinite liquidity (asymptotic, but expensive for large trades)
- No order book needed

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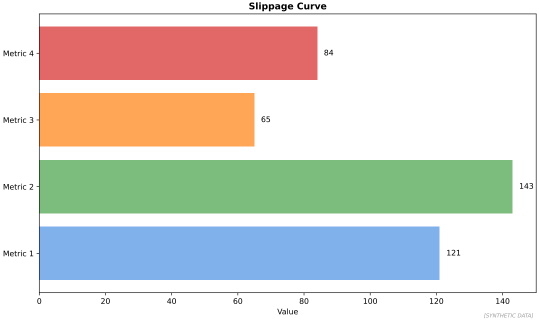
Price Impact and Slippage

Price Impact:

- How much your trade moves the price
- Larger trade $\longrightarrow$ worse price
- Function of trade size relative to pool depth

Slippage:

- Difference between expected and executed price
- Set slippage tolerance (e.g., 0.5%)
- Trade reverts if exceeded



Formula: Price impact $\approx \Delta x/(x+\Delta x)$

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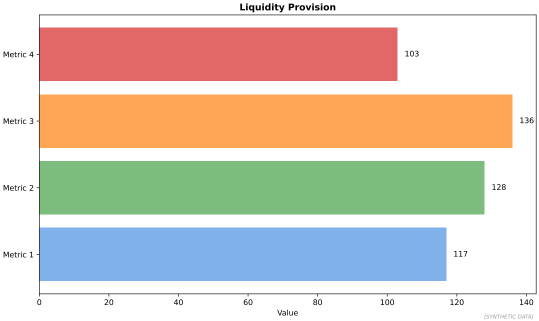
Liquidity Providers: Earning Fees

How it Works:

1. Deposit equal value of both tokens
2. Receive LP tokens (claim on pool share)
3. Earn 0.3% of all trades (Uniswap V2)
4. Withdraw anytime (burn LP tokens)

Example:

- Pool: 1,000 ETH + 2M USDC
- You deposit: 10 ETH + 20K USDC (1%)
- Daily volume: 500K USDC
- Your daily fees: $500{,}000 \times 0.003 \times 0.01 = \$15$



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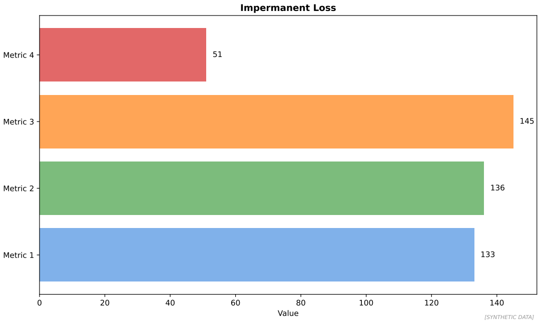
Impermanent Loss: The Hidden Cost



Definition: Loss compared to holding tokens vs providing liquidity

Example:

- Deposit 1 ETH (\$2000) + 2000 USDC when ETH = \$2000
- ETH rises to \$3000
- Pool rebalances: 0.816 ETH + 2449 USDC = \$4449 total
- Holding: 1 ETH + 2000 USDC = \$5000
- Impermanent loss: \$551 (11%)

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Exact Formula:

$$\mathrm{IL} = \frac{2\sqrt{r}}{1+r} - 1$$

where r = price ratio change (final price / initial price)

Price Change	**Ratio (r)**	**Impermanent Loss**
+25%	1.25	-0.6%
+50%	1.5	-2.0%
+100% (2x)	2.0	-5.7%
+400% (5x)	5.0	-25.5%
-50%	0.5	-5.7%

Mitigation: Fees earned over time can offset IL (especially in high-volume pairs)

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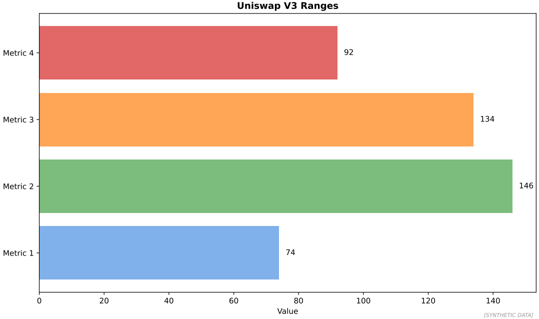
Uniswap V3: Concentrated Liquidity

V2 Limitation:

- Liquidity spread across entire price range
- Capital inefficient
- Most liquidity never used

V3 Innovation:

- Concentrated liquidity in price ranges
- LPs choose custom ranges
- Up to 4000x capital efficiency
- Active management required



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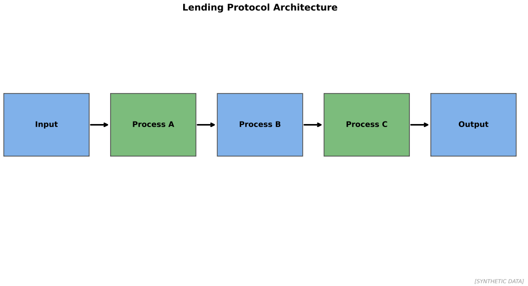
Lending Protocols: Aave and Compound



Mechanism:

- **Lenders:** Deposit assets, earn interest (aTokens/cTokens)
- **Borrowers:** Post collateral, borrow assets, pay interest
- **Interest Rates:** Algorithmically determined by utilization
- **Liquidation:** If collateral drops below threshold, liquidators repay loan, seize collateral at discount

Key concepts from this slide inform practical applications in finance.

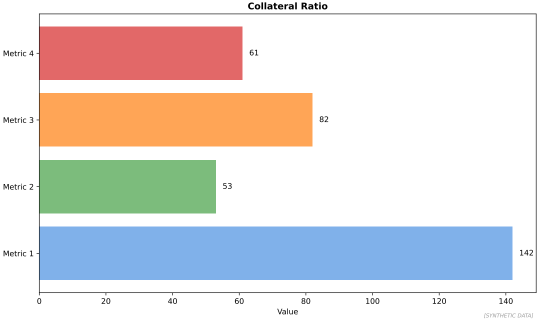
Over-Collateralization Requirement

Why Over-Collateralize?

- No credit checks (permissionless)
- Price volatility protection
- Liquidation buffer

Example (Aave):

- Deposit: 10 ETH ($20K)
- Max LTV: 80%
- Borrow: 16K USDC
- Liquidation threshold: 85%



Risk: If ETH drops >15%, position liquidated

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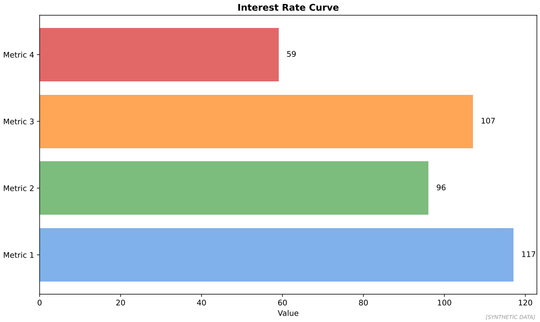
Interest Rate Model



Utilization Rate:

$$U = \frac{\text{Total Borrowed}}{\text{Total Supplied}}$$

Interest Rates:

- Low utilization: Low rates (encourage borrowing)
- High utilization: High rates (incentivize deposits, discourage borrowing)
- Kinked model: Sharp increase near optimal utilization (e.g., 80%)

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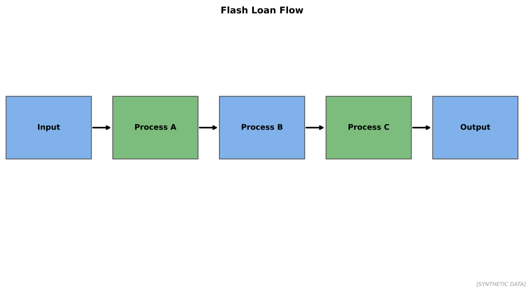
Flash Loans: Zero-Collateral Instant Loans

Concept:

- Borrow any amount
- No collateral required
- Must repay within same transaction
- If not repaid, entire transaction reverts

Use Cases:

- Arbitrage (exploit price differences)
- Collateral swaps
- Liquidations
- Refinancing



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Flash Loan Attack Example

Scenario: Exploit Price Oracle Manipulation (2020, bZx attack)

1. Flash loan 10,000 ETH from dYdX
2. Swap 5,000 ETH for WBTC on Uniswap (moves price)
3. Use manipulated WBTC price to borrow over-collateralized assets on bZx
4. Repay flash loan, keep profit
5. Exploit: $350K profit

Defense:

- Time-weighted average price (TWAP) oracles
- Multiple oracle sources (Chainlink)
- Borrow caps

Note: Flash loans are not inherently bad, but enable rapid exploitation of vulnerabilities

Case studies provide concrete evidence of technology impact and adoption patterns.

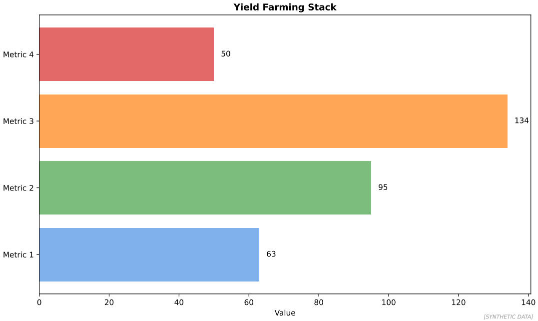
Yield Farming: Chasing Returns

Strategy:

- Provide liquidity or lend assets
- Earn fees + protocol token rewards
- Compound yields (reinvest)
- Move capital to highest APY

Yield Sources:

- Trading fees (0.3% on Uniswap)
- Borrow interest (Aave, Compound)
- Token incentives (governance tokens)
- Staking rewards



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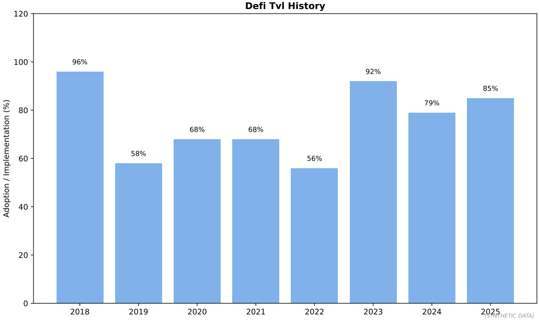
DeFi Summer 2020: Liquidity Mining Explosion



Catalyst: Compound launches COMP token distribution (June 2020)

Result:

- Total Value Locked (TVL): \$1B $\rightarrow$ \$100B+ (2021 peak)
- APYs: 100–1000%+ (unsustainable, token inflation)
- Copycat protocols, "DeFi Degen" culture

DeFi recreates traditional financial services in a permissionless, programmable way.

Risks in DeFi

- **Smart Contract Risk:** Bugs, exploits (e.g., The DAO, bZx)
- **Impermanent Loss:** Price divergence reduces LP returns
- **Oracle Manipulation:** Flash loan attacks on price feeds
- **Liquidation Risk:** Volatile collateral leads to forced sales
- **Rug Pulls:** Developers drain liquidity (unaudited projects)
- **Regulatory Risk:** Securities classification, AML/KYC future requirements
- **Composability Risk:** Cascading failures (one protocol exploited affects others)

Mitigation: Use audited protocols, diversify, understand risks, start small

DeFi recreates traditional financial services in a permissionless, programmable way.

DeFi vs CeFi: Trade-offs

Aspect	DeFi	CeFi
Custody	Self-custody (your keys)	Custodial (exchange holds)
Access	Permissionless (anyone)	KYC/AML required
Transparency	Open-source, on-chain	Opaque (trust exchange)
Execution	Slower (block time), higher fees	Instant, low fees
Risk	Smart contract risk	Counterparty risk (FTX)
Liquidity	Fragmented across DEXs	Concentrated on CEX

Comparative analysis helps identify the right tool for specific requirements.

Summary

- **DeFi:** Permissionless financial services via smart contracts
- **AMMs:** Constant product formula ($x \times y = k$), liquidity pools replace order books
- **Impermanent Loss:** LPs lose vs holding when prices diverge
- **Lending:** Over-collateralized loans, algorithmic interest rates, liquidations
- **Flash Loans:** Uncollateralized loans repaid in same transaction
- **Risks:** Smart contract bugs, IL, oracle manipulation, liquidations

Next Lesson: Stablecoins and Terra/Luna collapse case study