L37: Lending Protocols

Module E: DeFi Ecosystem

Blockchain & Cryptocurrency

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Learning Objectives

- Understand how DeFi lending protocols work (Aave, Compound)
- Analyze overcollateralization and its necessity
- Calculate health factors and liquidation thresholds
- Explore interest rate models (utilization-based)
- Compare DeFi lending to traditional finance

Traditional Lending vs. DeFi Lending

Traditional Lending

- Credit checks required
- Identity verification (KYC)
- Undercollateralized (borrow more than collateral)
- Long approval process
- Fixed terms and rates
- Geographic restrictions
- Intermediaries (banks)

DeFi Lending

- No credit checks
- Pseudonymous (wallet address)
- Overcollateralized (deposit ¿ borrow)
- Instant approval
- Variable rates (algorithmic)
- Global access
- Smart contracts (no intermediaries)

Key Trade-off: DeFi accessibility vs. capital efficiency (must lock more than you borrow).

How DeFi Lending Works

Core Mechanism:

1. **Lenders (Suppliers)**
   - Deposit assets (ETH, USDC, DAI, etc.) into protocol
   - Earn interest on deposits (APY varies by utilization)
   - Can withdraw anytime (if liquidity available)
2. **Borrowers**
   - Deposit collateral (e.g., ETH)
   - Borrow up to a percentage of collateral value (e.g., 75%)
   - Pay interest to lenders
   - Must maintain health factor above 1
3. **Protocol**
   - Matches lenders and borrowers via smart contracts
   - Sets interest rates algorithmically
   - Manages liquidations

Example: Borrowing on Aave

User Journey:

Step 1: Supply Collateral

- Deposit 10 ETH (worth \$20,000 at \$2,000/ETH)
- Receive aETH tokens (interest-bearing, 1:1 with ETH)

Step 2: Borrow

- ETH has 80% Loan-to-Value (LTV) ratio
- Max borrow: $10 \times \$2{,}000 \times 0.80 = \$16{,}000$
- User borrows \$10,000 USDC (safe margin)

Step 3: Manage Position

- Interest accrues on \$10,000 debt (e.g., 5% APY)
- User earns interest on 10 ETH deposit (e.g., 2% APY)
- Net cost: 5% - 2% = 3% on borrowed amount

Why Overcollateralization?

Problem: No identity means no recourse if borrower defaults.

Solution: Require collateral worth more than loan.

Mechanism:

- If collateral value drops, protocol liquidates automatically
- Liquidators repay debt, seize collateral (with bonus)
- Lenders remain whole

Trade-off:

- **Capital inefficient:** Can't access full collateral value
- **Safe for lenders:** Minimal default risk

Example Use Cases:

- Leverage (borrow USDC, buy more ETH for long exposure)
- Short selling (borrow ETH, sell it, buy back cheaper)
- Liquidity without selling (keep ETH, borrow USDC for expenses)

Loan-to-Value (LTV) Ratio

Definition:

$$\text{LTV} = \frac{\text{Borrowed Value}}{\text{Collateral Value}} \times 100\%$$

Example LTV Limits (Aave):

- ETH: 80% (can borrow up to 80% of ETH value)
- WBTC: 75%
- USDC: 85% (stablecoin, less volatile)
- Low-cap tokens: 40-60% (higher risk)

Why Different LTVs?

- Volatile assets = lower LTV (more buffer for price swings)
- Stable assets = higher LTV (minimal price risk)

Calculation:

- Collateral: 10 ETH at \$2,000 = \$20,000
- Borrowed: \$12,000 USDC
- LTV: $\frac{12{,}000}{20{,}000} = 60\%$ (safe, under 80% max)

Liquidation Threshold

Definition: LTV at which liquidation occurs (always higher than max LTV).

Example (Aave):

- ETH Max LTV: 80%
- ETH Liquidation Threshold: 83%
- Buffer: 3% (gives borrower time to add collateral)

Scenario:

- User borrows at 80% LTV
- ETH price drops 5%
- New LTV: $80\% \times \frac{1}{0.95} \approx 84.2\%$ (exceeds 83% threshold)
- **Liquidation triggered**

Liquidation Penalty:

- Liquidator repays debt, receives collateral + bonus (e.g., 5%)
- Borrower loses penalty amount
- Remaining collateral returned to borrower

Health Factor

Definition: Metric indicating position safety.

Formula (Aave):

$$\text{Health Factor} = \frac{\text{Collateral Value} \times \text{Liquidation Threshold}}{\text{Borrowed Value}}$$

Interpretation:

- Health Factor ¿ 1: Safe (no liquidation)
- Health Factor $= 1$: At liquidation threshold
- Health Factor ¡ 1: Liquidation occurs

Example:

- Collateral: \$20,000 (ETH)
- Borrowed: \$12,000 (USDC)
- Liquidation threshold: 83%

$$\text{HF} = \frac{20{,}000 \times 0.83}{12{,}000} = 1.38$$

Safe: 38% buffer before liquidation.

Health Factor Example: Price Drop

Initial State:

- 10 ETH at \$2,000 = \$20,000 collateral
- \$12,000 USDC borrowed
- Liquidation threshold: 83%
- Health Factor: $\frac{20{,}000 \times 0.83}{12{,}000} = 1.38$

ETH drops to \$1,600:

- New collateral value: $10 \times \$1{,}600 = \$16{,}000$
- Borrowed still: \$12,000
- New HF: $\frac{16{,}000 \times 0.83}{12{,}000} = 1.11$ (still safe)

ETH drops to \$1,446:

- New collateral value: $10 \times \$1{,}446 = \$14{,}460$
- New HF: $\frac{14{,}460 \times 0.83}{12{,}000} = 1.00$ (liquidation threshold)
- **Position liquidated**

Liquidation Process

When Health Factor ¡ 1:

1. **Liquidator Bot Detects** unhealthy position
2. **Liquidator Repays** portion of debt (up to 50%)
3. **Liquidator Receives** equivalent collateral + bonus (5-10%)
4. **Borrower Loses** liquidation penalty
5. **Remaining Collateral** returned to borrower

Example:

- Debt: $12,000 USDC
- Collateral: $14,460 ETH (at $1,446/ETH)
- Liquidator repays 50%: $6,000
- Liquidator receives: $6,000 $\times$ 1.05 = $6,300 in ETH
- Borrower left with: $14,460 - $6,300 = $8,160 collateral and $6,000 debt

Penalty: Borrower lost $300 (5% of liquidated amount).

Interest Rate Models

Key Concept: Rates adjust based on utilization.

Utilization Rate:

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

Interest Rates:

- Low utilization (0-60%): Low borrow rates (encourage borrowing)
- Optimal utilization (80%): Moderate rates (balanced)
- High utilization (¿90%): High rates (encourage repayment, discourage borrowing)

Example (USDC on Aave):

- 0% utilization: 1% borrow APY
- 80% utilization: 5% borrow APY
- 95% utilization: 20% borrow APY (sharp increase)

Why? Prevents bank runs (always keep some liquidity for withdrawals).

Supply and Borrow APY Relationship

Lenders earn a portion of what borrowers pay.

Formula:

$$\text{Supply APY} = \text{Borrow APY} \times U \times (1 - \text{Reserve Factor})$$

where Reserve Factor is protocol fee (e.g., 10%).

Example:

- Borrow APY: 5%
- Utilization: 80%
- Reserve Factor: 10%

$$\text{Supply APY} = 5\% \times 0.80 \times 0.90 = 3.6\%$$

Observation: Supply APY always lower than borrow APY (protocol takes cut, not everyone borrows).

Aave Protocol Overview

Key Features:

- **Flash Loans:** Borrow without collateral if repaid in same transaction
- **Rate Switching:** Choose stable or variable interest rates
- **Credit Delegation:** Lend your credit line to others
- **Isolation Mode:** New assets isolated to reduce systemic risk
- **E-Mode:** Higher LTV for correlated assets (e.g., ETH/stETH)

Governance:

- AAVE token holders vote on protocol changes
- Risk parameters (LTV, liquidation thresholds)
- Asset listings
- Treasury management

TVL: $4B (Dec 2024), deployed on Ethereum, Polygon, Avalanche, Arbitrum, Optimism.

Compound Protocol Overview

Key Features:

- **cTokens:** Interest-bearing tokens (cUSDC, cETH)
- **Algorithmic Rates:** Fully automated interest rate model
- **Governance:** COMP token holders control protocol
- **Simplicity:** Fewer features than Aave, easier to understand

cToken Mechanism:

- Supply 100 USDC, receive 5,000 cUSDC
- cUSDC exchange rate increases over time (accrues interest)
- Redeem cUSDC for USDC + interest anytime

Historical Significance:

- Pioneered DeFi lending (launched 2018)
- Introduced COMP governance token (2020)
- Sparked "DeFi Summer" via liquidity mining

TVL: $1.5B (Dec 2024).

Flash Loans (Aave)

Definition: Borrow any amount without collateral, repay in same transaction.

How It Works:

1. Borrow $1M USDC from Aave
2. Use $1M for arbitrage, collateral swap, or liquidation
3. Repay $1M + 0.09% fee
4. All in one atomic transaction (either all succeeds or all reverts)

Use Cases:

- **Arbitrage:** Exploit price differences across DEXs
- **Collateral Swap:** Switch collateral without closing position
- **Self-Liquidation:** Repay debt before liquidation penalty
- **Exploits:** Unfortunately, used in many DeFi hacks

Fee: 0.09% of borrowed amount.
Risk: If transaction fails, borrow is reversed (no loss to lenders).

Flash Loan Attack Example

Historical Attack: bZx (2020)

Attack Steps:

1. Flash loan 10,000 ETH from dYdX
2. Deposit 5,500 ETH into Compound as collateral
3. Borrow 112 WBTC from Compound
4. Swap 112 WBTC on Uniswap for 6,871 ETH (manipulating price)
5. Use pumped ETH price to borrow max from bZx
6. Repay flash loan, keep profit ($350k)

Root Cause: bZx used Uniswap as sole price oracle (manipulable).

Lesson: Flash loans amplify oracle manipulation attacks. Protocols must use decentralized, manipulation-resistant oracles.

Stable vs. Variable Interest Rates

Aave offers borrowers a choice:

Variable Rate

- Changes with utilization
- Usually lower (on average)
- Unpredictable
- Can spike during high demand

Best for:

- Short-term borrowing
- Users who monitor actively

Stable Rate

- Fixed for duration
- Higher than variable (premium for stability)
- Predictable
- Can be rebalanced by protocol if too far from market

Best for:

- Long-term borrowing
- Risk-averse users

Switching: Borrowers can switch between rate types anytime.

Risks in DeFi Lending

1. **Smart Contract Risk**
   - Bugs or exploits in protocol code
   - Historical hacks: Rari Capital, Cream Finance
2. **Liquidation Risk**
   - Volatile markets can trigger liquidations
   - Network congestion may prevent adding collateral
3. **Oracle Risk**
   - Price feed manipulation
   - Stale prices during network issues
4. **Governance Risk**
   - Malicious proposals changing parameters
   - Low voter participation
5. **Liquidity Risk**
   - High utilization prevents withdrawals
   - Bank run scenarios (rare but possible)

DeFi Lending vs. CeFi Lending

DeFi (Aave, Compound)

- Non-custodial
- Transparent reserves
- Overcollateralized
- Instant settlement
- Smart contract risk
- No insurance (usually)
- Permissionless

CeFi (BlockFi, Celsius)

- Custodial
- Opaque reserves
- Can be undercollateralized
- T+1 settlement
- Counterparty risk
- Some insurance
- KYC required

2022 Lesson: CeFi lenders (Celsius, Voyager, BlockFi) collapsed. DeFi protocols (Aave, Compound) survived intact, demonstrating transparency advantage.

Future: Undercollateralized Lending

Current Limitation: DeFi lending is capital inefficient (overcollateralization).

Emerging Solutions:

1. **On-Chain Credit Scores**
   - Track repayment history, wallet activity
   - Examples: Credora, ARCx
2. **Real-World Identity**
   - Link wallet to verified identity (KYC)
   - Legal recourse if default
   - Examples: Goldfinch, TrueFi
3. **Social Collateral**
   - Community vouching, reputation staking
   - Example: Teller Protocol

Trade-off: Undercollateralization requires identity or trust, reducing permissionlessness.

Summary

Key Takeaways:

- DeFi lending is permissionless but requires overcollateralization
- LTV ratios vary by asset risk (ETH 80%, low-cap tokens 40%)
- Health factor must stay above 1 to avoid liquidation
- Interest rates adjust algorithmically based on utilization
- Flash loans enable zero-collateral borrowing within one transaction
- Aave and Compound dominate DeFi lending ($5.5B+ combined TVL)
- Risks: smart contract bugs, liquidations, oracle manipulation
- Future: undercollateralized lending via on-chain credit scoring

Next Lecture: Stablecoin Mechanisms - How stablecoins maintain price stability.

Questions for Reflection

1. Calculate health factor for: $30k collateral, $20k borrowed, 85% liquidation threshold.
2. Why is overcollateralization necessary in DeFi lending?
3. How do interest rates adjust to prevent bank runs?
4. What risks do flash loans pose to DeFi protocols?
5. Would you prefer variable or stable interest rates for a 1-year borrow?