[Your Proposal Title Here]

Research Proposal – PhD Seminar: Digital Finance

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Abstract

This proposal investigates the impact of concentrated liquidity provision on impermanent loss dynamics in Uniswap V3. We develop a continuous-time model of LP returns under stochastic volatility, derive closed-form expressions for expected impermanent loss as a function of range width, and calibrate to on-chain data from Ethereum mainnet. Our methodology combines stochastic calculus with empirical analysis of 50,000 LP positions. The expected contribution is a tractable framework for optimal range selection that accounts for fee income, gas costs, and volatility clustering.

1 Introduction and Motivation

Decentralized finance (DeFi) has grown to over $100 billion in total value locked, with automated market makers (AMMs) constituting the primary trading infrastructure (**?**). The introduction of concentrated liquidity in Uniswap V3 (**?**) fundamentally altered the risk–return profile of liquidity provision, yet analytical frameworks for optimal LP strategy remain limited.

In this proposal, we develop a continuous-time model of concentrated LP returns under realistic market conditions and derive optimal range-selection rules.

2 Literature Gap

The theoretical foundations of AMM design are well established. **?** characterize the geometry of constant-function market makers, while **?** provide equilibrium analysis of Uniswap. Impermanent loss for V3 has been modeled by **?** under geometric Brownian motion assumptions.

However, existing models do not account for:

1. Stochastic volatility and volatility clustering observed in crypto markets (**?**).
2. Endogenous fee income that depends on volume and range overlap with other LPs.
3. Gas cost dynamics and their impact on rebalancing frequency.

3 Research Question and Hypotheses

Research Question: How should a risk-averse liquidity provider optimally select the concentration range $[p_a, p_b]$ in Uniswap V3, accounting for stochastic volatility, fee income, and rebalancing costs?

Hypotheses:

H1: Narrower concentration ranges increase expected fee income but disproportionately increase impermanent loss variance.

H2: Optimal range width is positively correlated with realized volatility and negatively correlated with trading volume.

H3: Incorporating stochastic volatility (vs. constant volatility) significantly widens the model-implied optimal range.

4 Methodology

4.1 Theoretical Model

We model the asset price S_t under the risk-neutral measure as

$$\frac{\mathrm{d}S_t}{S_t} = (r - q)\,\mathrm{d}t + \sqrt{v_t}\,\mathrm{d}W_t^S, \tag{1}$$

$$\mathrm{d}v_t = \kappa(\bar{v} - v_t)\,\mathrm{d}t + \sigma_v\sqrt{v_t}\,\mathrm{d}W_t^v, \quad \langle \mathrm{d}W^S, \mathrm{d}W^v \rangle = \rho\,\mathrm{d}t. \tag{2}$$

The LP's value process V_t^{LP} follows from the Uniswap V3 reserve equations (**??**) with range $[p_a, p_b]$.

4.2 Data

We collect on-chain data from Ethereum mainnet via The Graph protocol:

- Pool-level: swap events, fee accruals, tick transitions (WETH/USDC 0.3% pool, Jan 2023 – Dec 2025).
- Position-level: 50,000 LP mint/burn events with tick ranges.
- Market data: BTC and ETH spot prices, implied volatilities from Deribit (for calibration).

4.3 Estimation

5 Expected Contribution

This research contributes to the literature in three ways:

1. **Theoretical:** First closed-form characterization of optimal LP range under stochastic volatility with fee income.
2. **Empirical:** Large-scale analysis of LP profitability using granular on-chain data with novel controls for gas costs.
3. **Practical:** Actionable decision rules for LP range selection, implementable as an on-chain strategy.