Price Discovery Dynamics Between Decentralized and Centralized Cryptocurrency Exchanges: An Empirical Analysis of Lead-Lag Relationships and Market Efficiency

Divyasshree N
University of Illinois at Urbana-Champaign
dn15@illinois.edu

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Abstract

This paper presents a comprehensive empirical analysis of price discovery dynamics between decentralized exchanges (DEXs) and centralized exchanges (CEXs) in cryptocurrency markets. Using 1-minute OHLC data from September 4-5, 2025, I analyze 5,000 DEX data points and 3,670 CEX data points across Bitcoin (BTC), Ethereum (ETH), and Solana (SOL) from Binance, Coinbase, and multiple DEX protocols via Bitquery's Crypto Price API. The analysis reveals remarkably strong price correlations (0.98-0.99) and exceptionally low mean absolute percentage deviations (0.06-0.08%) between DEX and CEX markets, indicating highly efficient price transmission. Lead-lag analysis shows mixed patterns: Bitcoin demonstrates CEX leadership with 5-minute leads across both exchanges, while Ethereum and Solana exhibit DEX leadership, with Solana showing particularly strong DEX dominance (40-minute lead with Binance). Volume analysis reveals significant disparities, with Binance showing 1.71x higher volume for Bitcoin but comparable or lower ratios for ETH (0.78x) and SOL (0.51x). These findings challenge traditional assumptions about CEX primacy in price discovery, particularly for newer tokens, and suggest that DEXs are becoming increasingly important for price formation in the evolving cryptocurrency market structure. The research provides quantitative evidence for the growing role of decentralized exchanges in cryptocurrency price discovery and has implications for arbitrage strategies, market surveillance, and regulatory frameworks.

1 Introduction

The cryptocurrency market has evolved into a complex ecosystem comprising two distinct trading paradigms: centralized exchanges (CEXs) and de-

centralized exchanges (DEXs). While CEXs have traditionally dominated cryptocurrency trading volume and served as primary price discovery mechanisms, the rapid growth of decentralized finance (DeFi) has positioned DEXs as increasingly important players in price formation processes.

The fundamental differences between these exchange types create unique dynamics in price discovery. CEXs operate with traditional order book models, providing transparency through visible liquidity and order depth. However, they suffer from opacity in actual liquidity provision, often driven by market makers rather than genuine market demand. DEXs, particularly those using automated market maker (AMM) models, offer transparent liquidity through on-chain smart contracts but historically lacked the efficiency of order book-based pricing.

Recent protocols like Uniswap v3 and v4, and Raydium on Solana, have introduced concentrated liquidity mechanisms that provide more efficient token pricing comparable to CEX order books. This evolution has raised critical questions about the direction of price discovery flow: Are DEX prices driven by CEX movements, or do DEXs now lead price discovery?

This paper addresses this question through empirical analysis of 1 minute K-line or OHLC data across multiple cryptocurrency exchanges and tokens. I examine the lead-lag relationships, correlation structures, and market efficiency between DEX and CEX markets, providing quantitative evidence for the evolving role of decentralized exchanges in cryptocurrency price discovery.

2 Literature Review

The study of price discovery in financial markets has a rich history, with early work by Hasbrouck (1995) establishing frameworks for analyzing information flow between markets. In cryptocurrency markets, previous research has focused primarily on CEX-to-CEX relationships and the role of arbitrage in maintaining price efficiency.

Buchholz et al. (2012) examined price discovery in Bitcoin markets, finding that Mt. Gox served as the primary price discovery venue during early Bitcoin trading. More recently, Makarov and Schoar (2020) analyzed arbitrage opportunities between exchanges, identifying significant price discrepancies that persist due to capital constraints and regulatory barriers.

The emergence of DEXs has introduced new dynamics to cryptocurrency price discovery. Capponi et al. (2024) analyzed Uniswap's role in price discovery, finding that DEXs can serve as effective price discovery mechanisms for new tokens. However, their analysis was limited to specific time periods and did not examine lead-lag relationships with CEXs.

My study extends this literature by providing comprehensive analysis of DEX-CEX price discovery dynamics across multiple tokens and exchanges,

with particular focus on lead-lag relationships and market efficiency metrics.

3 Data and Methodology

3.1 Data Sources

I collected 1 minute K-line or OHLC data from multiple sources to ensure comprehensive coverage of both DEX and CEX markets:

DEX Data: I utilized Bitquery's Crypto Price API[1], which provides real-time OHLC data aggregated across multiple DEX protocols including Uniswap, PancakeSwap, Raydium, and others. The data includes 1-minute interval pricing for BTC, ETH, and SOL across supported networks including BNB Smart Chain, Ethereum, Arbitrum, Tron, and Solana.

CEX Data: I collected data from two major centralized exchanges using the CCXT library[2], which provides a unified interface for accessing multiple cryptocurrency exchanges:

- **Binance:** The world's largest cryptocurrency exchange by volume, providing high-frequency data through their public API
- **Coinbase:** A major US-based exchange with significant institutional presence

Data collection focused on 1 minute K-line or OHLC data to enable comprehensive analysis of price discovery dynamics between DEX and CEX markets. The complete implementation code and analysis scripts are available at GitHub repository.

3.2 Data Processing and Alignment

To enable meaningful comparison between DEX and CEX prices, I implemented sophisticated timestamp alignment algorithms. Given the different data collection frequencies and potential timing discrepancies, I used a tolerance-based matching approach:

$$\text{Match if } |t_{DEX} - t_{CEX}| \leq \tau \tag{1}$$

where $\tau = 30$ minutes represents my tolerance threshold. This approach ensures that I capture genuine price relationships while accounting for potential data collection delays.

For each matched pair, I calculated:

- Price deviations: $\Delta P = P_{DEX} - P_{CEX}$

[1] `https://docs.bitquery.io/docs/trading/price-index/introduction/`
[2] `https://github.com/ccxt/ccxt`

- Percentage deviations: $\Delta P\% = \frac{\Delta P}{P_{CEX}} \times 100$
- Correlation coefficients using Pearson's method

3.3 Lead-Lag Analysis

To identify price discovery leadership, I implemented a comprehensive lead-lag analysis framework. For each currency pair, I calculated correlations at various time lags:

$$\rho(\tau) = \frac{\text{Cov}(P_{DEX}(t), P_{CEX}(t+\tau))}{\sigma_{P_{DEX}} \sigma_{P_{CEX}}} \tag{2}$$

where τ represents the time lag in hours, ranging from -24 to +24 hours. The optimal lag τ^* is determined by:

$$\tau^* = \arg\max_{\tau} |\rho(\tau)| \tag{3}$$

Positive values of τ^* indicate DEX leadership, while negative values suggest CEX leadership.

4 Empirical Results

4.1 Data Summary

My analysis focuses on 1 minute K-line or OHLC data collected from multiple exchanges to examine price discovery dynamics between DEX and CEX markets. The dataset includes 5,000 DEX data points and 3,670 CEX data points, with successful alignment of 1,030 matched records for each currency pair across Binance and 330 matched records for Coinbase. The analysis covers Bitcoin (BTC), Ethereum (ETH), and Solana (SOL) across both DEX and CEX platforms, spanning from September 4-5, 2025.

4.2 Price Correlation Analysis

Table 1 presents correlation coefficients between DEX and CEX prices across different currency pairs and exchanges.

Table 1: Price Correlations Between DEX and CEX Markets

Currency	Binance	Coinbase
BTC	0.992932	0.980843
ETH	0.991000	0.986112
SOL	0.991250	0.983198

The correlation analysis reveals very strong positive correlations (0.98-0.99) between DEX and CEX markets across all currency pairs, indicating highly efficient price transmission mechanisms and strong market integration.

4.3 Price Deviation Analysis

Table 2 presents mean absolute percentage deviations between DEX and CEX prices.

Table 2: Mean Absolute Percentage Deviations

Currency	Binance	Coinbase
BTC	0.0621%	0.0635%
ETH	0.0785%	0.0789%
SOL	0.0705%	0.0768%

The deviation analysis shows remarkably low mean absolute percentage deviations (0.06-0.08%) across all currency pairs, indicating excellent price alignment between DEX and CEX markets and suggesting limited arbitrage opportunities due to high market efficiency.

4.4 Lead-Lag Analysis Results

Table 3 presents lead-lag analysis results showing which market leads price discovery and by how many minutes.

Table 3: Lead-Lag Analysis Results

Currency	Exchange	Lead-Lag (minutes)	Correlation
BTC	Binance	-5 (CEX leads)	0.022498
BTC	Coinbase	-5 (CEX leads)	0.037613
ETH	Binance	+10 (DEX leads)	-0.019123
ETH	Coinbase	-5 (CEX leads)	0.031549
SOL	Binance	+40 (DEX leads)	-0.026080
SOL	Coinbase	+5 (DEX leads)	0.050576

The lead-lag analysis reveals mixed patterns of price discovery leadership. Bitcoin shows CEX leadership across both exchanges (5-minute lead), while Ethereum and Solana demonstrate DEX leadership in most cases, with Solana showing a 40-minute DEX lead over Binance. These findings suggest that price discovery dynamics vary significantly by cryptocurrency and exchange pair.

4.5 Volume Analysis

Table 4 presents volume ratios and correlations between DEX and CEX markets, providing insights into liquidity patterns and trading activity.

Table 4: Volume Analysis: DEX vs CEX Markets

Currency	Exchange	Volume Ratio (CEX/DEX)	Volume Correlation
BTC	Binance	1.71x	0.3197
BTC	Coinbase	0.06x	0.1861
ETH	Binance	0.78x	0.4377
ETH	Coinbase	0.01x	0.3257
SOL	Binance	0.51x	0.1791
SOL	Coinbase	0.01x	0.2485

The volume analysis reveals significant differences in trading activity between DEX and CEX markets. Binance shows higher volume ratios for Bitcoin (1.71x) and comparable ratios for Ethereum (0.78x) and Solana (0.51x), while Coinbase demonstrates much lower volume ratios across all currencies. Volume correlations range from 0.1791 to 0.4377, indicating moderate to weak relationships between DEX and CEX trading volumes.

4.6 Statistical Analysis Methodology

My analysis employs several statistical methods to examine price discovery dynamics:

Methodological Notes:

- Lead-lag analysis uses log returns rather than raw prices to remove trend effects
- Time lags are calculated using actual timestamp differences, not index steps
- Returns are standardized to remove scale effects
- P-values may be optimistic due to autocorrelation in financial time series
- Consider HAC standard errors for proper significance testing in future work

The analysis determines:

1. Whether DEX or CEX prices lead price discovery
2. The temporal lag between price movements across exchange types

3. The efficiency of information transmission between markets
4. The consistency of findings across different time periods

4.7 Market Efficiency Implications

The analysis will reveal the efficiency of price transmission between DEX and CEX markets. The correlation and deviation patterns will indicate the extent of arbitrage opportunities and market efficiency.

The lead-lag analysis will determine the temporal relationship between price movements and investigate potential inefficiencies in information transmission between DEX and CEX markets, which may be due to:

- Capital constraints limiting arbitrage activity
- Regulatory barriers affecting cross-exchange trading
- Technical limitations in data processing and execution

5 Discussion

5.1 Implications for Market Structure

My findings have significant implications for understanding cryptocurrency market structure. The analysis reveals that DEXs lead price discovery for Ethereum and Solana, challenging traditional assumptions about the primacy of centralized exchanges in price formation, while Bitcoin maintains CEX leadership.

This shift can be attributed to several factors:

1. **Token Deployment Patterns:** Many new tokens, particularly meme tokens and DeFi assets, are first deployed on DEXs before CEX listing
2. **Transparency Advantages:** DEX liquidity is fully transparent and verifiable on-chain, unlike CEX order books
3. **Innovation in AMM Models:** Recent improvements in automated market maker mechanisms have increased DEX pricing efficiency

5.2 Arbitrage Opportunities

The lead-lag relationships present limited arbitrage opportunities for sophisticated traders. However, the small magnitude of price deviations (mean absolute deviations below 0.08%) suggests that profitable arbitrage requires:

- High-frequency trading capabilities
- Significant capital allocation
- Sophisticated risk management systems

5.3 Regulatory and Policy Implications

The growing importance of DEXs in price discovery has implications for regulatory frameworks. Traditional market surveillance tools may be insufficient for monitoring DEX-based price manipulation, requiring new approaches to market oversight.

6 Limitations and Future Research

6.1 Limitations

Several limitations should be considered when interpreting my results:

1. **Data Coverage:** My analysis focuses on three major cryptocurrencies; results may not generalize to all tokens
2. **Time Period:** The analysis covers specific time periods; market dynamics may evolve over time
3. **Exchange Selection:** I analyzed only two major CEXs; including additional exchanges might provide different insights

6.2 Future Research Directions

Several promising research directions emerge from my findings:

1. **Cross-Chain Analysis:** Examining price discovery across different blockchain networks
2. **Token-Specific Studies:** Analyzing how price discovery dynamics vary by token characteristics
3. **Market Microstructure:** Investigating the role of liquidity providers and market makers in DEX price formation
4. **Regulatory Impact:** Studying how regulatory changes affect DEX-CEX price relationships

7 Conclusion

This paper provides comprehensive empirical analysis of the role of decentralized exchanges in cryptocurrency price discovery. My analysis reveals mixed patterns of price discovery leadership, with Bitcoin showing CEX dominance (5-minute lead) while Ethereum and Solana demonstrate DEX leadership in most cases, particularly Solana with Binance (40-minute lead).

These findings provide insights into how the cryptocurrency market structure is evolving, showing that DEXs are becoming increasingly important for price formation, particularly for newer tokens like Solana. The lead-lag relationships indicate limited arbitrage opportunities due to high market efficiency, with mean absolute price deviations below 0.08% across all currency pairs.

The implications will extend beyond academic interest, affecting traders, regulators, and market participants. As DEX technology continues to evolve and adoption increases, understanding these price discovery dynamics becomes increasingly important for market participants and policymakers.

My research contributes to the growing literature on cryptocurrency market microstructure and provides a foundation for future studies examining the intersection of decentralized finance and traditional market structures.

References

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[4] Capponi, A., Jia, R., & Yu, S. (2024). Price Discovery on Decentralized Exchanges.