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*Distributed
Computing*



Polymarkets Hybrid Exchange System and Prediction Market Arbitrage

Bachelor's Thesis

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Abstract

Polymarket and Kalshi have emerged as leading decentralized prediction market platforms, enabling global speculation on binary outcomes while leveraging blockchain technology for settlement and smart contracts for outcome resolution. This thesis analyzes Polymarket’s hybrid exchange architecture combining an off-chain Central Limit Order Book (CLOB) with on-chain smart contract settlement. We design and implement data collection clients for Polymarket’s and Kalshi’s REST and WebSocket endpoints, addressing poorly documented APIs and discovered inconsistencies. Through on-chain event analysis from November 18, 2025 to January 5, 2026, we examine the market lifecycle, identifying three distinct reporting oracles (MOOV2 Adapter, Negrisk Adapter, and Centralized Adapter), market registration patterns, and outcomes distribution (41.2% YES, 58.6% NO, 0.3% UNKNOWN). For orderbook trading, we measure slippage on 1.44M settlements, finding a convergent slippage rate of 0.7% with 52.2% zero-slippage trades, contrasting favorably with on-chain AMM models that suffer from both mechanical slippage and MEV extraction. Price discrepancy analysis across Polymarket and Kalshi for 15-minute “Bitcoin up or down?” markets reveals lower internal arbitrage spreads on Polymarket, though this may correlate with reported wash trading activity. Key findings highlight the higher implementation barrier for reliable data collection due to Polymarket’s incomplete documentation, undocumented smart contract coordination, and endpoint inconsistencies, yet suggest the platform maintains effective price discovery and arbitrage mechanisms despite these obstacles.

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Introduction

1.1 Speculation

Classifying and regulating speculation on uncertain events has historically been challenging. A common classification hinges on the purpose of the speculation, whether it serves to hedge risk and provide insurance, to enable price discovery for information aggregation and forecasting, or to function as entertainment akin to gambling.

1.1.1 Market Integrity

This regulatory ambiguity can undermine market integrity through two primary risks: direct manipulation and exploitation.

A moral hazard arises when market participants can directly influence an event's outcome. Match-fixing in sports provides an illustrative example: a boxer might have an economic incentive to lose deliberately if betting returns on their defeat exceed the prize for winning.

A related issue is asymmetric information. Not all informational advantages are malicious; some are an unavoidable consequence of information diffusion. However, the asymmetry becomes exploitative, potentially amounting to insider trading, when it arises from privileged access that allows a few actors to profit from unfairly obtained information without altering the outcome.

Both risks extend to more severe scenarios, from corporate managers taking positions that benefit from a project failure they can influence to insiders profiting from foreknowledge of military actions.

1.1.2 Modern Regulation

To mitigate these risks, regulators can prohibit speculation on events that present particularly high moral hazard or exploitation risks. For example, the U.S. Commodity Futures Trading Commission (CFTC) implements 17 C.F.R. § 40.11,

which states that a registered entity "shall not list for trading or accept for clearing" contracts that, among other things, "involve, relate to, or reference terrorism, assassination, war, gaming, or an activity that is unlawful under any State or Federal law" and permits the Commission to identify similar activities it deems contrary to the public interest [1]. This rule was the primary battleground that Kalshi challenged in order to list specific political prediction markets [2] and is a primary reason for Polymarket's restricted access for U.S. users [3].

1.2 Prediction Market Exchanges

Polymarket and Kalshi are two exchanges popularizing prediction markets and making them accessible globally. A prediction market is derived from the outcome of a real-world event. On both exchanges, a prediction market is exclusively designed for binary events with YES and NO outcomes. These outcomes are represented as shares quoted in USD, or on Polymarket specifically, in USDC, a USD-backed ERC-20 token managed by Coinbase through a reserve ensuring its value is identical to USD. An example is the event "Will the Republican Party win the House in 2026?", which is hosted on both exchanges. A position in a prediction market refers to a specific quantity of YES or NO shares held. The process of deciding the outcome of the underlying event and assigning terminal values for a YES and NO share is called resolution; once the values are determined, the market is deemed resolved.

On Kalshi, every YES or NO share is a contract with an expiration date and a central resolution source. Kalshi states, "Each contract is worth \$1 if you're right" [4]. Their legally binding rulebook states that the final outcome is decided at their discretion and that contract modifications are possible [5]. However, for the purpose of this thesis, we assume that markets can only resolve to either YES or NO.

Polymarket uses the Gnosis Conditional Tokens contract (CTF) to define the YES and NO shares as ERC-1155 tokens and to enforce their combined value at 1 USDC. Additionally, it uses UMA's optimistic oracle framework for resolution 4.2. In this system, a prediction can resolve to UNKNOWN, rendering the value of YES and NO shares 0.5 USDC each 4.3.

In both cases, the combined value of a YES and NO share for a prediction is exactly 1 USD at all times, as enforced by the trading contract on Kalshi and by the CTF smart contract on Polymarket 4.1. This does not hold for the market prices of the YES and NO shares on the exchange, which are determined by a Central Limit Order Book (CLOB) on both exchanges 6. This discrepancy is what makes internal market arbitrage possible.

Events with more than two discrete outcomes can be constructed using multiple prediction markets. For example, the event "Which party will win the House

in 2026?” is decomposed into prediction markets for the questions “Will the Democratic Party win the House in 2026?” and “Will the Republican Party win the House in 2026?”. This provides powerful information aggregation capabilities built on top of the information efficiency of markets. A common pattern on both exchanges is to define an event with more than two possible discrete outcomes exhaustively, using a separate prediction market for each mutually exclusive outcome. The event “Which party will win the House in 2026?” is an example of this. Polymarket labels these as *Negrisk* and provides a full suite of smart contracts dedicated to these events, including a distinct settlement smart contract deployment *Negrisk CTFE* and an atomic swap operation for converting a set of mutually exclusive outcome positions into the complementary positions of the alternative outcomes 4.5.

1.2.1 Growth

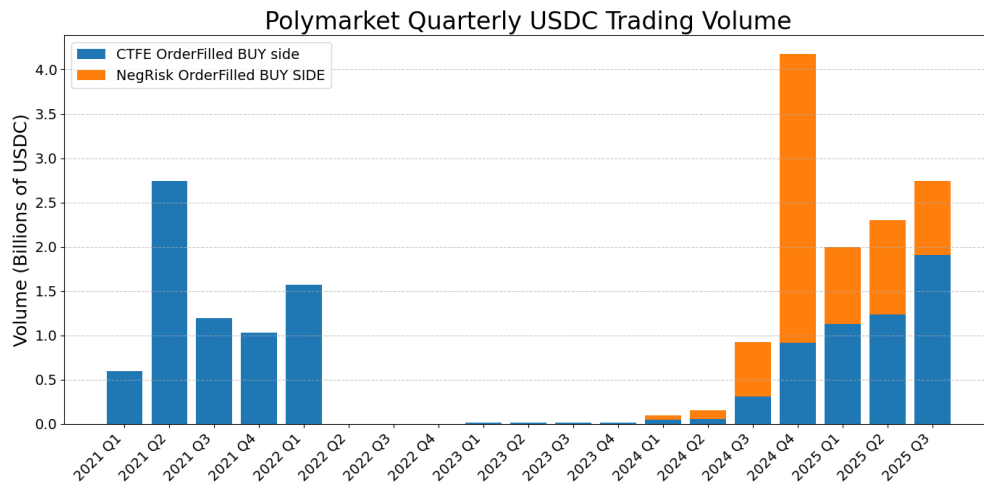


Figure 1.1: Quarterly trade volume on Polymarket. Source: Author’s own compilation using Dune Analytics (<https://dune.com/queries/6298071>).

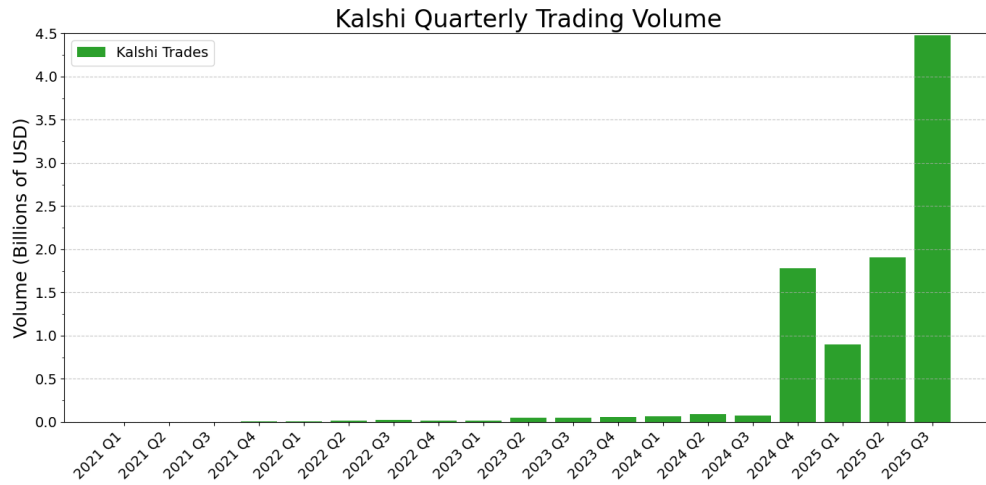


Figure 1.2: Quarterly trade volume on Kalshi. (<https://tokenterminal.com/explorer/projects/kalshi/metrics/trading-volume?interval=max&granularity=quarter>).

Figures 1.1 and 1.2 show the quarterly USD trading volume. For Polymarket, we can also distinguish between trading volume on the Negrisk CTFE and the OOV2 CTFE 4.4.

1.2.2 US Market

The flat line in Polymarket’s trading volume starts right after the CFTC action in January 2022. Kalshi operated only in the U.S. until October 2025, covering the first three quarters of 2025 and the last quarter of 2024 shown in Figure 1.2.

The 47th U.S. presidential election was a major event for both exchanges. Various studies have compared the forecasting ability and information efficiency of Kalshi and Polymarket for this event against other methods like New York Times polls [6, 7]. The volume spike in the fourth quarter of 2024 is also clearly visible. On Kalshi, markets related to politics and the election accounted for roughly 1 billion USD in volume in November alone [8]. On Polymarket, the main market for the presidential election accumulated a total volume of 3.5 billion USDC [9].

However, a recent study using two unsupervised network models suggests that around 18% or less of the volume traded on Polymarket is wash trading, where users trade with themselves to inflate activity. One method reported that approximately 60% of the December 2024 volume was washed [10]. This occurred the month after the U.S. election markets concluded and coincided with a decline

of over 50% in total trading volume [11].

1.2.3 Accessibility

Kalshi expanded to over 140 countries in October 2025 [12], and Polymarket plans to reenter the U.S. market. On July 21, 2025, Polymarket acquired QCX LLC, a company that had registered as a Designated Contract Market (DCM) with the CFTC earlier that month [13]. This entity was subsequently rebranded as “Polymarket US” [14]. As of December 4, 2025, Polymarket was not yet available in the U.S. Both exchanges face regulatory headwinds in many jurisdictions. Gambling authorities in several countries have banned them. This includes Switzerland, where the Swiss Gambling Supervisory Authority (GESPA) has blacklisted their DNS domains, blocking access via Swiss ISPs [15].

Despite CFTC approval, Kalshi faces state-level regulatory issues in the U.S. For example, the Illinois Department of Financial and Professional Regulation (IDFPR) issued a cease-and-desist order preventing Kalshi from operating in Illinois for allegedly defying state gambling regulations. Kalshi argues that national oversight by the CFTC preempts these claims. This ongoing case demonstrates that the regulatory landscape surrounding speculation remains conflicted [16].

Polymarket remains accessible by design, even where banned, because it does not require Know-Your-Customer (KYC) identification on its main platform. Even if KYC were enforced, users could still interact with the underlying smart contracts directly. The ERC-1155 tokens representing YES or NO shares are defined by the Gnosis Conditional Tokens contract. These can be obtained via *splitPosition*, swapped for USDC via *mergePosition*, and redeemed after resolution using *redeemPosition* for the value reported by Polymarket.

Objective and Methodology

The first objective was to design a data collection client for Polymarket’s off-chain endpoints. The second objective was to analyze the market lifecycle on Polymarket. The third objective was to analyze slippage on Polymarket and prediction market arbitrage.

2.1 Methodology

Both Polymarket and Kalshi provide WebSocket endpoints to subscribe to orderbook state changes and trades, as well as HTTP endpoints to request the orderbook state. To use these endpoints, the orderbooks of interest must first be identified. For this, both exchanges define market objects and provide HTTP endpoints to query historical data, as well as WebSocket endpoints to subscribe to market lifecycle events. Both exchanges use JSON for endpoint communication and define rate limits for request throughput.

Due to Polymarket’s sparse documentation, significant information had to be discovered through testing and response analysis. These findings, along with continuous endpoint changes and discovered state inconsistencies, resulted in multiple client iterations. The final clients are tailored for the events “Which party will win the House in 2026?” and the cyclical 15-minute event “Bitcoin up or down?”. This is covered in Chapter 3.

To analyze the market lifecycle, Chapter 4 first examines the statically available information from on-chain smart contracts. This includes essential smart contract control flow, emitted events, and immutable contract storage. These elements allow for establishing links between contracts and their intended use, and they help identify details that can only be deduced from emitted events. For this purpose, a client for the Infura *eth_getLogs* endpoint was implemented. These events and the historical market objects, retrieved through Polymarket’s endpoints, are then used to analyze market lifecycle coordination in Chapter 5.

In Chapter 6, the orderbook for prediction markets is formalized to define how

slippage and arbitrage are measured. Then, data collected from Polymarket's and Kalshi's endpoints, along with emitted events, are used to analyze slippage and arbitrage using these measures.

Finally, Chapter 7 discusses and interprets the findings of this thesis.

Endpoints and Clients

3.1 Polymarket Event and Market Endpoints

Polymarket defines a market object for every prediction market, identified by a unique market ID. Every market is part of an *event*, and every event can be associated with multiple *tags*. The *gamma-api.polymarket.com* domain hosts several HTTP endpoints to query market, event, or tag objects using pagination. The documentation provides only an example use case, a list of query parameters, and a sample request and response.

The most essential query parameters are *offset* and *limit*, which enable batch access. The limit specifies the number of objects in a batch, while the offset determines the starting point. This implicitly assumes an ordered list of objects starting at offset zero. An *order* parameter also exists but lacks detailed specification. Testing revealed that sorting by many attributes fails to order the results correctly, omits markets, or returns duplicates at different offsets. Querying event objects ordered by event ID avoids these anomalies and was recently added as an example in the documentation. However, ordering market objects by ID is not possible.

Testing also revealed an undocumented constraint: the limit parameter is capped at 500. Any value exceeding this simply returns 500 objects starting at the specified offset. Before December 2025, the response behavior for requesting an offset beyond the available range was unspecified. It was eventually clarified in December 2025 that such requests return an empty JSON array.

3.1.1 Event and Market Objects

The market object is listed with over 100 attributes in the documentation. Initial testing showed a mismatch between the attributes in actual responses and those listed in the documentation; furthermore, the attributes vary between responses. For this reason, this analysis covers all event objects (which include associated market and tag objects) obtained from the *events* endpoint.

Since JSON is specified by a deterministic context-free language, it can be parsed unambiguously into a tree of nodes, where every node has a type. For every event object, a tree is constructed where every node (except the root) is a child of either an object or an array. If a node is a child of an object, it must have an associated string key. A node is a leaf if it is an empty array, an empty object, or a scalar type (number, string, boolean, or null).

For a more representative type analysis, numbers are further categorized as IEEE 754 floating-point values or integers. Strings are classified as empty, whitespace-only, JSON-encoded, standardized timestamps, numeric strings, hexadecimal, case-insensitive literals (“null”, “none”, “nan”, “true”, “false”), or *general* strings. The resulting table showing the type distribution and occurrence frequency for every tree path is available in Appendix D.1.

3.2 Polymarket Orderbook and Trade Endpoints

Polymarket provides a *book* HTTP endpoint to request the current orderbook state under the *clob.polymarket.com* domain. It also provides a *market* WebSocket endpoint to receive state change events under the *ws-subscriptions-clob.polymarket.com* domain, referred to as the *market feed*. Every prediction market is associated with two orderbooks: one for the YES outcome and one for the NO outcome. An orderbook has a side for buying the underlying outcome token (bids) and a side for selling the underlying outcome token (asks). The orderbook’s underlying outcome is uniquely identified by a *token ID*, also referred to as an *asset ID*. Every market object contains two asset IDs within a JSON-encoded string array under the key “clobTokenIds” D.1.

3.2.1 Book Endpoint

The specification for the book endpoint consists only of a list of request and response JSON attributes, along with samples for both. This endpoint returns the orderbook state objects for the requested asset IDs. The documentation does not specify the maximum number of asset IDs that can be requested, the limit on returned orderbooks, or the behavior when requesting the orderbook of an already resolved market. Testing revealed that orderbook states are returned in the order requested. However, any orderbook state object requested for an asset ID whose market is already resolved is omitted from the response. Additionally, the response contains at most 500 orderbook state objects.

The orderbook state object shown in Appendix A.1 is based on the sample provided in Polymarket’s documentation. Notably, the timestamp attribute is described as a string but appears in responses as a string representation of a Unix millisecond timestamp.

3.2.2 Falsely Missing Orderbook State Objects

An initial client making concurrent requests to the book endpoint revealed an anomaly where the endpoint failed to return orderbook state objects for specific asset IDs, only to include them in subsequent responses. This effectively made the orderbook state unavailable, mimicking a resolved market. Crucially, this was not caused by rate limiting, as the endpoint did not return error status codes.

The same setup was run for several hours using strictly serialized requests, and this anomaly was not detected. To investigate further, every asset ID was mapped to a *false miss* counter. This counter incremented whenever the orderbook state object for a requested asset ID was missing from the response; if the object appeared, the counter was reset to 0.

This experiment revealed an initial burst of false misses for many asset IDs, though the counts remained below 13. After this initial burst, the number of asset IDs experiencing false misses decreased significantly, but the reported miss counts showed much larger variance, with some exceeding 1,000 false misses.

3.2.3 Market Feed

The market feed broadcasts event messages for subscribed markets. Prior to December 17, 2025, this endpoint allowed only a single subscription per established WebSocket connection. Consequently, if any markets were resolved or created, a new WebSocket connection had to be established to adapt to the change. This limitation was undocumented; testing simply revealed that sending more than one subscription message stopped all event delivery. Even with a 30-second timeout, the server kept the underlying persistent TCP and WebSocket connection alive without sending further messages, effectively turning it into a zombie connection.

On December 17, dynamic subscription and unsubscription messages were announced via Discord, confirming that this functionality was previously unavailable. This was a significant improvement, as the prior client required a new WebSocket connection whenever new markets were created. Another major improvement occurred around January 5, 2026, when lifecycle updates were added to the market feed. Previously, the market or events endpoint had to be scraped continuously to check for new or resolved markets, introducing unnecessary latency and complexity. Comparing market objects from a long-lived connection (continuously scraped for lifecycle changes) against a separate, one-time exhaustive scrape revealed that some market objects were never returned at any offset on the market endpoint for the long-lived connection. This anomaly was only measurable after three days.

Unlike the book, market, and event endpoints, the market feed's documented response attributes appear in every response and are of the correct type. Sample messages can be found in the Appendix ([A.3](#) for price changes, [A.2](#) for

book events, [A.4](#) for trade events, [A.5](#) for new market events, and [A.6](#) for market resolved events). However, the last trade price event contains an undocumented attribute *tx_hash* of type string, which is always a hexadecimal value with the length of an Ethereum transaction hash. The timestamps for market feed events are string representations of Unix millisecond timestamps, matching those found in the book endpoint responses. However, because timestamps only have millisecond resolution and there are no other attributes to order events, the state becomes ambiguous when multiple conflicting events occur within the same millisecond.

3.2.4 Ambiguous Event Ordering

The most obvious conflict arises between events of the same type occurring at the same millisecond with different resulting states. For price change events, this occurs when two or more events share the same timestamp, side, price, and asset ID, but have different sizes. In such cases, it is unclear what the exact size is at the given price, side, and asset ID at or after that timestamp. Book events conflict if they share the same timestamp and asset ID but list different bids and asks. Similarly, last trade events conflict when they share the same timestamp, asset ID, side, and price, making it impossible to differentiate which trade was filled at which size. Table 3.1 illustrates that this occurs in practice.

Table 3.1: Bitcoin Up or Down - January 7, 11:00AM-11:15AM ET

Message Type	Total	Ambiguous (%)	Duplicate (%)
Asset ID: 113615...8317859			
Last Trade Prices	3,562	24 (0.67%)	0 (0.0%)
Price Changes	158,662	3,228 (2.04%)	1,336 (0.84%)
Books	6,074	0 (0.0%)	0 (0.0%)

If we additionally consider the ambiguity arising when a price change message and a book summary message share the same timestamp (i.e., it is unclear whether the price change applied before or after the book state summary), we find that 7,160 price changes are ambiguous.

3.3 Final Polymarket Client

The initial client was designed to subscribe to the market feed and make order-book state requests for all existing unresolved markets. This involved over 30,000 orderbooks. Since only 500 orderbooks can be requested at once, there is a clear trade-off between the number of orderbooks monitored and the frequency of updates. Additionally, since market feed events cannot be unambiguously ordered,

frequent requests for the actual orderbook state become even more valuable. For these reasons, the final client was designed to monitor fewer than 500 orderbooks and request their states sequentially, with a minimum interval of 500ms between requests. The documentation specifies a rate limit of 500 requests/s, so this setup is very conservative. For the event “Which party will win the House in 2026?”, there are four orderbooks, while the cyclical 15-minute event “Bitcoin up or down?” typically has fewer than 100 active orderbooks.

The final client initially scrapes the events endpoint for all currently available 15-minute cyclical “Bitcoin up or down?” markets. It then subscribes to the market feed using these IDs and the four known orderbooks from “Which party will win the House in 2026?”. It also listens for newly created or resolved “Bitcoin up or down?” markets to dynamically manage subscriptions. The client also initiates the orderbook state requests as specified above and persistently stores the price change, book, last trade price events, and orderbook state objects in a database.

3.4 Kalshi Endpoints

Kalshi provides endpoints similar to those on Polymarket. These include the *events* endpoint for scraping any market ever created and a WebSocket endpoint with different channels, such as *trades*, *orderbook updates*, and *market lifecycle*. Markets are uniquely identified through their *market_ticker*. These tickers allow for dynamic subscription and unsubscription for the channels of interest on the WebSocket endpoint.

However, unlike Polymarket, Kalshi provides a single orderbook for both outcomes of a prediction market. One side represents the YES prices and the other the NO prices, as seen in the documented orderbook delta [A.7](#) and orderbook snapshot [A.8](#) responses. Other documented responses are available in the Appendix ([A.11](#) for event objects, [A.10](#) for market lifecycle events, and [A.9](#) for trade updates).

The JSON objects within the messages sent by the orderbook update and trade channels contain a unique integer sequence identifier. This identifier can be used to unambiguously order the events for a given channel and spot any missing events, as the first event after subscription has sequence identifier zero, and each subsequent event increments the identifier by one. Although Kalshi’s documentation for the trade update message is missing the *seq* attribute, the messages effectively contain it. However, ordering trade events relative to orderbook events remains ambiguous, as it relies on timestamps that are only specified in seconds for trades.

3.5 Kalshi Client

Due to the sequence identifiers provided by Kalshi, there is no need to additionally request the orderbook state, as the identifiers allow for unambiguous maintenance of the orderbook state. The Kalshi client therefore functions similarly to the Polymarket client, but without the need for periodic orderbook state requests.

Smart Contracts

Polymarket maintains a GitHub organization with over 90 repositories. Many individual repositories contain the Solidity source code for smart contracts and their deployment details. They also maintain a dedicated repository listing deployment addresses, associated contracts, and security audits, if available [17]. Although not explicitly labeled as exhaustive, a review of the website documentation and GitHub repositories revealed no undeclared deployments. In the absence of another authoritative source, this list serves as the reference for disclosed deployments.

4.1 Conditional Tokens

The Gnosis Conditional Tokens Framework (CTF) extends the ERC-1155 standard to construct tokens representing the outcomes of an event or condition. This enables the transfer, minting, and burning of multiple outcome tokens within a single transaction.

The contract defines the relationship between the value of the n outcome tokens (O_1, \dots, O_n) for an event and the ERC-20 collateral token Q as:

$$Q = \sum_{i=1}^n O_i \quad (4.1)$$

The *splitPositions* method atomically swaps a specific amount of collateral Q for an equal amount of each outcome token and emits the *PositionSplit* event. The *mergePositions* method performs the reverse atomic swap and emits the *PositionsMerge* event.

Before these methods can be used, the condition must be prepared using the *prepareCondition* method with an oracle address, a question ID, and an outcome count. This emits the *ConditionPreparation* event. Every condition is assigned a unique identifier defined as:

$$condition_{id} := keccak(oracle \parallel question_{id} \parallel outcome\ count) \quad (4.2)$$

Subsequently, only the oracle can report payouts using the *reportPayouts* method by passing an array of unsigned integers *payouts* = (p_1, \dots, p_n) corresponding to the n outcome tokens. This emits the *ConditionResolution* event and assigns each outcome token O_i a new value:

$$O_i := Q \cdot \frac{p_i}{\sum_{k=1}^n p_k} \quad (4.3)$$

After this assignment, Equation (4.1) still holds.

Finally, after the payout is reported, anyone can redeem their outcome tokens for the value assigned in Equation (4.3) using the *redeemPositions* method, which emits the *PayoutRedemption* event.

4.2 UMA Framework

UMA designs oracle protocols and deploys Ethereum-based contracts on various blockchains, such as Polygon. These deployments connect to UMA’s dedicated web application, allowing users to actively participate in resolving price requests.

Polymarket exclusively used UMA’s OptimisticOracleV2 (OOV2) deployment until August 2025, when the UMIP-189 governance proposal passed. Subsequently, UMA deployed a ManagedOptimisticOracleV2 (MOOV2) dedicated exclusively to Polymarket usage. The ManagedOptimisticOracleV2 is based on the same protocol but includes additional access control configurations [18].

Polymarket atomically sets price requests to be event-based within its *UmaCtfAdapter* contract. The process begins with a price request, which emits the *RequestPrice* event. For a price request to be settled, the effective price must first be determined. This requires an initial price proposal suggesting a value for the request, which emits the *ProposePrice* event. Once a price proposal is made, it can be disputed within a liveness period, which defaults to two hours. If the proposal remains undisputed during this period, it becomes the effective price, and the request can be settled.

In OOV2, neither proposals nor disputes have access control restrictions. If the proposal is disputed, the *DisputePrice* event is emitted, initiating a stake-based voting process. The contract governing this process is deployed on the Ethereum blockchain, necessitating an off-chain coordinated message relayer. Once the price is determined, the request is settled. This involves rewarding or slashing the proposer and disputer (if present), depending on the accuracy of their proposals relative to the final outcome. This emits the *Settle* event.

The OOV2 protocol does not inherently specify the semantic meaning of the prices. Therefore, in the context of Polymarket, *ancillary data* must formally specify the semantic meaning of the integer price values. Although Polymarket does not explicitly state this, an analysis of emitted events reveals that virtually

all ancillary data extends the UMIP-107 standard [19]. Specifically, the requested price identifier is *YES_OR_NO_QUERY*, and the ancillary data is a UTF-8 encoded dictionary. This dictionary specifies the question using the *q* key, the associated market via the *marketId* key, and the four possible prices through the *p1*, *p2*, *p3*, and *p4* keys. These keys map specific prices to the outcomes *YES*, *NO*, *UNKNOWN*, and *EARLY_PROPOSAL*.

4.3 UmaCtfAdapter

This is Polymarket’s custom contract, built on top of the CTF and OOV2, whose addresses are stored as immutable references. It provides an *initialize* method that atomically prepares the condition on the CTF and requests the price from the OOV2. When preparing the condition, it uses itself as the oracle and a hardcoded outcome count of two. The *initialize* method is permissionless and emits the *QuestionInitialized* event.

The other permissionless method is *resolve*, which emits the *QuestionResolved* event. It can only be invoked if the market’s requested price has been determined and the contract is not paused. This method calls the OOV2 to settle and retrieve the *int256* price. If the price does not correspond to the *EARLY_PROPOSAL* outcome, it is used to report the payouts on the CTF. The *EARLY_PROPOSAL* outcome is hardcoded as the minimum *int256* value for comparison. A price of 0 is interpreted as *NO*, a price of 0.5 Ether is interpreted as *UNKNOWN*, and any other price is considered *YES*. Based on the outcome, a specific payout array is passed to the CTF: ‘[0,1]’ for *NO*, ‘[1,1]’ for *UNKNOWN*, and ‘[1,0]’ for *YES*.

All other public methods in this contract are restricted to either an *onlyAdmin* or *onlyOracle* role. This includes the *resolveManually* method, which allows an authorized party to report a payout array directly without settling a price request.

4.4 CTFExchange

The CTFExchange is another custom contract by Polymarket that provides the *matchOrders* method. This method is used for settling a match on the CLOB between a taker order and *n* maker orders. It emits one *OrdersMatched* event for the overall match and *n + 1* *OrderFilled* events. One *OrderFilled* event corresponds to the taker’s side of the trade, while the other *n* events correspond to the makers’ sides. There are three types of matches: split, merge, and complementary.

A split match occurs when the taker and makers are both buyers, one for YES shares and the other for NO shares. Analogously, a merge match occurs when the taker and makers are both sellers, one for YES shares and the other for NO shares. A complementary match happens when the taker is selling the shares

that the makers are buying, or vice versa. The match type and the amount of instruments exchanged can be deduced from the ‘OrderFilled’ events.

4.5 Negrisk

The Negrisk framework builds on top of the UmaCtfAdapter to create multiple markets with mutually exclusive outcomes. It provides a *convertPositions* method, which enables atomically swapping a set of YES shares for the complementary set of NO shares, or vice versa. This functionality is implemented in the Negrisk Adapter.

However, the framework also contains a Negrisk Operator, which the Negrisk UmaCtfAdapter uses as an immutable reference for the conditional tokens contract interface. Notably, the Negrisk Operator’s ‘prepareCondition’ method is empty, and its ‘reportPayouts’ method does not call any other contract. This implies condition preparation and price requests for a Negrisk market are not atomically executed within the same transaction, unless a hidden contract facilitates this.

Additionally, there is a distinct Negrisk CTFExchange deployment. This is simply another instance of the CTFExchange contract that uses the Negrisk Adapter for splitting and merging. It also uses its own collateral token, which is a wrapper around USDC.

Similarly to the UmaCtfAdapter, the Negrisk Operator has a *emergencyResolveQuestion* method to manually report payouts without settling a price request through UMA.

4.6 Polygon Collection

The data collection process uses the Infura *eth_getLogs* endpoint. Infura has a rate limit of 500 credits/s, with a request to the *eth_getLogs* requiring 255 credits according to the documentation. However, testing showed that the actual rate limit between consecutive requests without rate limiting is approximately 1s. The round-trip time (RTT) for a single *eth_getLogs* request can exceed 30s, making it suitable for concurrent requests. Additionally, there is a limit of 10,000 events per request. Requests are specified using a block range. To manage this constraint, we use block density estimation with a margin of 500 blocks to target approximately 9,500 events per request. This seems to be effective as for most events the block density does not seem to have strong variance. But the margin can be increased if some events have a greater block density variance. As a sanity check, the number of events returned was compared against those found in Dune Analytics over the same block range. For consistency, the block

range from 79,172,086 (inclusive) to 81,225,971 (inclusive), spanning November 18, 2025 07:00:03 UTC to January 5, 2026 00:00:01 UTC, was used for all analytics in Chapters 5 and 6. The complete list of collected events is provided in Appendix C.2.

Market Lifecycle

5.1 Market Creation

5.1.1 Reporting Oracles

As explained in Section 4.1, the reporting oracle for a condition is passed as an argument during condition preparation on the CTF. This address is the only one that can report payouts to determine the final YES and NO share values after resolution. This makes it essential to analyze the reporting oracles used by Polymarket.

Out of 128,003 ‘ConditionPreparation’ events, 124,340 have a matching off-chain market object with the same condition ID. These matched events use three distinct reporting oracles, two of which are undocumented: the *MOOV2 Adapter* and the *Centralized Adapter*, detailed in Appendix C.1.

The MOOV2 Adapter is an ‘UmaCtfAdapter’ instance as described in Section 4.3, but it uses the MOOV2 instead of the OOV2. Interestingly, no condition was prepared with the OOV2 Adapter as the reporting oracle. This aligns with the UMIP-189 proposal and suggests that the MOOV2 Adapter has replaced the OOV2 Adapter, although Polymarket has not disclosed this change.

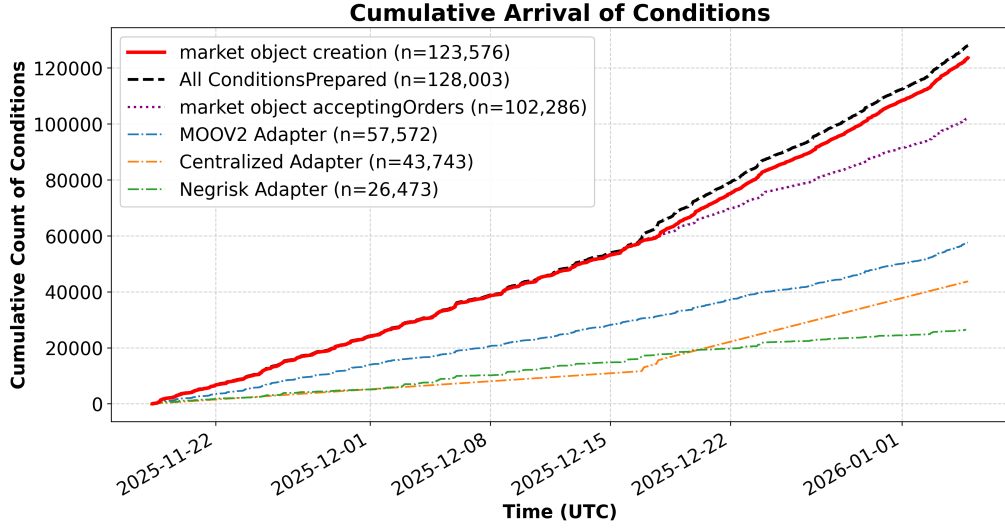


Figure 5.1: Cumulative count of conditions found over time

Figure 5.1 shows that around December 17, 2025, some market objects began to appear without an ‘acceptingOrders’ timestamp, a detail also noted in Appendix D.1. This period coincides with the 3,663 conditions that were prepared on the CTF with no matching off-chain market object. Virtually all of these use the Centralized Adapter as the reporting oracle, and the rate of new conditions prepared with this adapter also changed at this time.

5.1.2 Centralized Adapter

The bytecode for the Centralized Adapter is not recognized by prominent bytecode-to-source indexers like Polygonscan or Etherscan. However, we can still use the matched market objects to analyze this adapter in more detail.

Table 5.1: Label frequency in 41,016 market objects matched with the Centralized Adapter as reporting oracle

Label	Appeared in (%)
Up or Down	41,016 (100%)
Crypto Prices	41,016 (100%)
Hide From New	41,016 (100%)
Recurring	41,016 (100%)
Crypto	41,016 (100%)
5M	21,630 (52.7%)
15M	18,270 (44.5%)
Solana	10,263 (25.0%)
Ethereum	10,257 (25.0%)
XRP	10,256 (25.0%)
Ripple	10,256 (25.0%)
Bitcoin	10,240 (25.0%)
4H	1,116 (2.7%)

Every market object has a set of labels assigned by Polymarket to categorize the event. Table 5.1 shows the label frequency in market objects matched with conditions using the Centralized Adapter. Clearly, all labels are tied to crypto-asset, price-related events. When viewing these matched markets on Polymarket’s web application, none of them link to the UMA resolution status page, which exists for other markets. Instead, they link to a source that tracks the underlying crypto asset price, and this source is used directly as the ground truth for resolution. The cyclical 15-minute “Bitcoin up or down?” markets are an example of this.

5.1.3 Resolution Source

While the MOOV2 Adapter makes a price request atomically with condition preparation, a condition prepared for a Negrisk does not, as explained in Section 4.5. ‘ConditionPreparation’ and ‘RequestPrice’ events have no direct, shared identifier. However, virtually every ancillary data field contains a ‘marketId’ key, which can be used to match price requests to market objects and subsequently to ‘ConditionPreparation’ events. Out of 84,684 ‘RequestPrice’ events, 83,743 have a matching off-chain market object, and 83,652 have a matching ‘ConditionPreparation’ event.

Table 5.2: Resolution Source and Reporting Oracle Pairs

Resolution Source (ids)	Matches	Oracle (Conditions)
MOOV2	57,502	MOOV2 Adapter
OOV2	70	MOOV2 Adapter
OOV2	26,080	Negrisk Adapter

A curious anomaly is that 70 price requests made to the OOV2 matched with conditions using the MOOV2 Adapter as the reporting oracle. Of these, 50 do not share the same transaction hash, indicating they were not executed atomically via the ‘initialize’ method.

The conditions prepared with the Negrisk Adapter as the reporting oracle matched exclusively with price requests made to the OOV2. None of these matches share the same transaction hash, confirming they are not executed atomically. However, 21,672 (83.10%) share the same block number, which demonstrates that while the operations are coordinated through separate transactions, they are typically executed in a timely manner.

5.2 Exchange Registration

For matched orders on the CLOB to be settled on the on-chain exchange, the condition ID and the two token IDs of the prediction market must first be registered, as explained in Section 4.4.

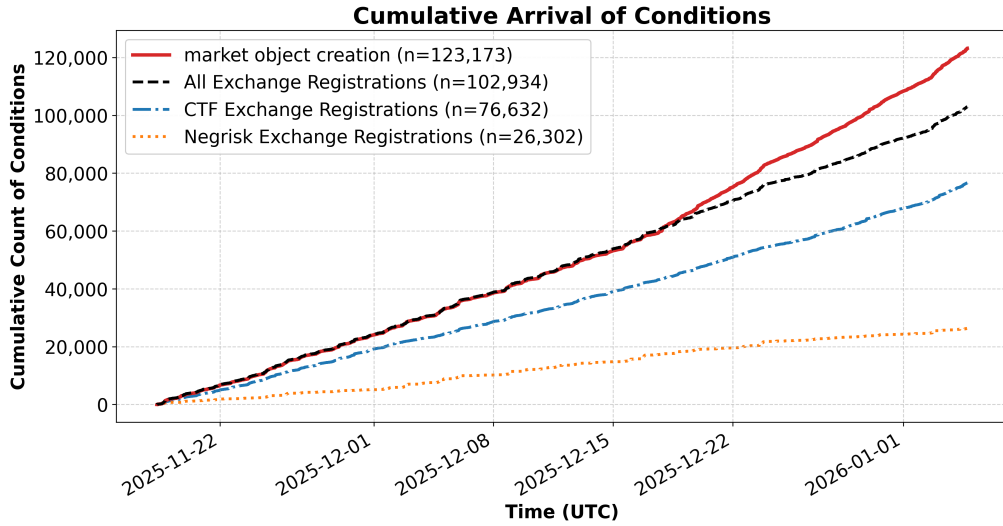


Figure 5.2: CLOB markets and registered tokens unique condition count

Figure 5.2 shows that after a certain point in time, markets are consistently being created without being registered with the on-chain exchange. This trend begins around the same time that market objects start being created without ‘acceptingOrders’ timestamps.

5.2.1 Unregistered Traded Outcomes

When matching the ‘ConditionsPrepared’ events to the ‘RegisteredToken’ events, we find that virtually all unregistered markets were prepared using the Centralized Adapter as the reporting oracle. Overall, less than half of the conditions prepared using the Centralized Adapter as the reporting oracle are registered with an exchange.

Table 5.3: Matched conditions of 134,424 Conditions Prepared and 215,152 TokensRegistered over Nov 18 - Jan 08

Oracle (Conditions)	Matches	Exchange (Conditions)
Centralized Adapter (48,896)	20,425	CTFE (83,262)
MOOV2 Adapter (62,857)	61,439	CTFE (83,262)
Negrisk Adapter (27,728)	23,545	Negrisk CTFE (24,209)

There is a strange anomaly: markets are visible on the Polymarket web application, listed as active in the market object, and show trading activity on the WebSocket market feed, yet they lack any corresponding ‘TokensRegistered’, ‘OrdersMatched’, or ‘OrderFilled’ events emitted from either the CTFE or the Negrisk CTFE. The cyclical 15-minute “Bitcoin up or down?” markets serve as an example of this behavior.

5.3 Resolution

5.3.1 Disputes

As described in Section 4.2, the UMA OOV2 and MOOV2 protocols allow price proposals to be disputed within a liveness period.

There is a total of 74,833 matched proposals and 340 matched disputes. Table B.1 shows the ten most frequent labels assigned to the market objects matched with the disputes. Out of the 340 matched disputes, 145 occurred on the OOV2 and 195 on the MOOV2. This is notable, considering that the MOOV2 was explicitly designed with a proposer whitelist managed by Polymarket under the UMIP-189 proposal. Despite the whitelist, the MOOV2 has a higher raw number of disputes than the OOV2. However, it is important to consider the total volume: the MOOV2 also has 53,818 proposals compared to the OOV2’s 21,015.

5.3.2 Reported Unknown Outcome

The terminal value for the YES and NO shares is determined by the payout array passed from the reporting oracle to the CTF, which then emits a ‘ConditionResolution’ event containing the condition ID and the payout array.

Out of 112,638 ‘ConditionResolution’ events, 283 (0.25%) reported an UNKNOWN outcome, 46,373 (41.17%) reported a YES outcome, and 66,982 (58.58%) reported a NO outcome. If the YES and NO outcomes were uniformly distributed, they would be reported equally. However, most Negrisk events are designed such that one prediction market resolves to YES and the remaining ones to NO. In fact, out of the 19,541 ‘ConditionResolution’ events with a Negrisk Adapter as the reporting oracle, only 2,616 (13.39%) reported a YES outcome, 16,925 (86.61%) reported a NO outcome, and none reported an UNKNOWN outcome. All reported UNKNOWN outcomes were generated by the MOOV2 Adapter.

Table B.2 shows the proportion of labels associated with markets reported to have an UNKNOWN outcome.

5.3.3 Manual Resolutions

Sections 4.3 and 4.5 mentioned that the UmaCtfAdapter and Negrisk Operator contracts include administrative methods that allow for manual market resolution without requiring UMA price requests to be settled. All relevant administrative methods emit events, including the ‘resolveMarketManually’ method in the UmaCtfAdapter and the ‘emergencyResolveQuestion’ method in the Negrisk Operator. However, no events for either of these manual resolution methods were emitted in any of the UmaCtfAdapter instances or the single Negrisk Operator instance during the collection period. This observation does not fully exclude the possibility of manual resolution, but if it occurred, it must have been executed through a delegate call from a hidden proxy contract, which would result in the events being emitted from that proxy contract instead.

Orderbook and Trading

Section 1.2 explained how a prediction market consists of YES and NO shares whose price is denoted in USD. The Central Limit Order Book (CLOB) used by Polymarket and Kalshi captures the intention of traders through market and limit orders. These orders are placed via HTTPS requests to *order* endpoints and are matched based on price-time priority [20, 21]. A limit order allows the trader to specify the price at which they want to buy or sell shares. This price cannot cross other resting limit orders; otherwise, the order becomes marketable. A marketable order is either executed immediately against the best possible resting limit orders by price-time priority or is aborted [22, 23].

6.1 State, Ordering, and Matching

A trader can either buy or sell YES or NO shares, which creates four possible order types: Sell Yes, Sell No, Buy Yes, and Buy No. However, these four types represent only two core intentions: speculating on the YES outcome by buying YES shares or selling NO shares, or speculating on the NO outcome by buying NO shares or selling YES shares.

Kalshi maintains a single orderbook for each prediction market, capturing order intentions through a YES and a NO side. Polymarket, on the other hand, documents and provides separate orderbooks for the YES and NO shares, each with bid and ask sides. However, analyzing the orderbook state reveals that the bid share amount at any given price p for the YES shares is always the same as the ask share amount for the NO shares at price $1 - p$. The analogous relationship also holds for the YES asks and NO bids.

The state of the CLOB is defined by the resting limit orders. A limit order can be defined as a tuple (p, v, s, i) , where $p \in \mathbb{R}^+$ is the price for an outcome share, $v \in \mathbb{R}^+$ is the quantity of shares, $s \in \{\text{YES}, \text{NO}\}$ is the outcome, and $i \in \mathbb{N}$ is the priority for selection when matching with market orders at price p and side s . A lower i indicates a higher priority. This guarantees a unique ordering for both buy and sell limit orders used for matching. Formally, for limit orders, the

ordering is:

$$((p_1, v_1, s_1, i_1) > (p_2, v_2, s_2, i_2)) \iff p_1 < p_2 \vee (p_1 = p_2 \wedge i_1 < i_2) \quad (6.1)$$

Where the best price for the taker is:

$$p_{\text{market}} = \max\{p | (p, v, s, i)\} \quad (6.2)$$

If the quantity for a marketable order cannot be fully filled at the best market price, the taker suffers from ****price slippage**** if the order is executed. If the marketable order cannot be filled by limit orders at any price, the taker order remains partially or fully unfilled. Depending on the market order specification, a partially unfilled market order is either executed or canceled.

6.2 Slippage

The CLOB is designed to allow this, with the core principle being that the taker is guaranteed timely order execution but not price, while the maker is guaranteed order price but not timely execution. We can define the slippage for a taker buying or selling x base assets and getting matched with maker orders M as:

$$\text{Slippage}(x, M) = \left| \sum_{(p,v,s,i) \in M} p \cdot v - p_{\text{market}} \cdot x \right| \quad (6.3)$$

The least limit order $(p, v, s, i) = \min\{M\}$ might only be partially consumed. The set M consists of all limit orders (or partial limit orders) used to fill the marketable order. The total quantity executed, x , is the sum of the quantities from all matched maker orders:

$$x = \sum_{(p,v,s,i) \in M} v \quad (6.4)$$

6.2.1 Slippage Rate on Polymarket

Using the ‘OrderFilled’ events emitted by the CTFExchange, we can measure the slippage for all 1,443,953 settlements. We have the USDC amount the taker paid or received from the fill where the taker faces the exchange, and the amount of shares and their price for every fill where the maker faces the taker. We can now construct a set S of tuples (x, y, t) for every settlement, where x is the USDC amount the taker paid or received, y is the slippage, and t is the timestamp of the settlement.

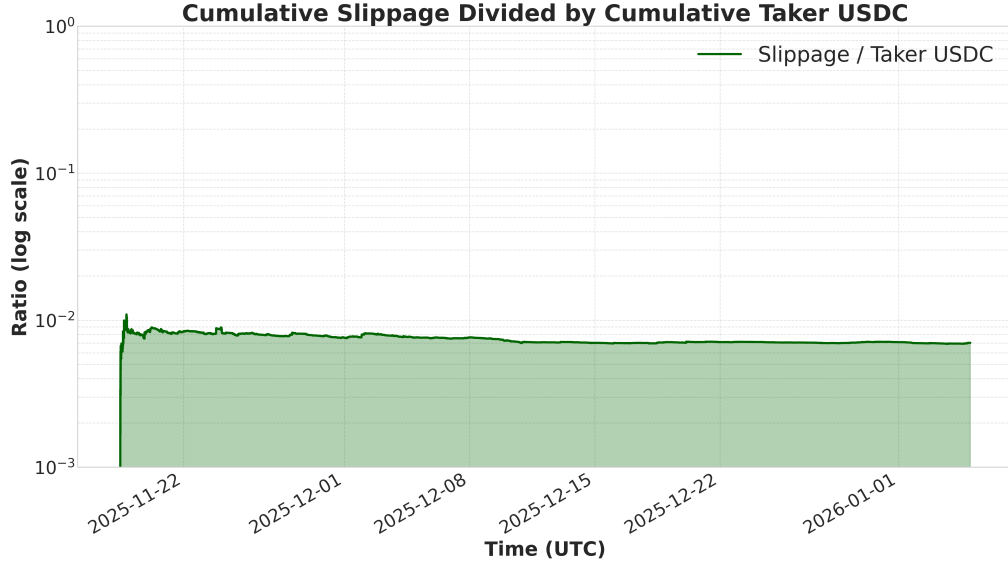


Figure 6.1: Cumulative Taker USDC Divided by Cumulative Slippage

Figure 6.1 shows that the cumulative slippage rate (cumulative USDC divided by cumulative slippage) for all settlements up until time t appears to converge to some value. If we assume that the x and y values in the tuples in S are independent and identically distributed (i.i.d.) random variables X and Y , then we get:

$$\frac{\sum_{(x,y,t) \in S} x}{\sum_{(x,y,t) \in S} y} \xrightarrow{a.s.} \frac{E[X]}{E[Y]} \quad (6.5)$$

With $E[X] = 356.435$ and $E[Y] = 2.491$ computed from S , we get a slippage rate of 0.007, which matches the suggestion in Figure 6.1. However, this ratio is a poor predictor for individual settlements, as $\text{std}(X/Y) = 0.129$ and $X/Y \in [0, 1]$. In fact, 52.176% of settlements have a slippage of 0, with some being in the top 1% of taker amounts.

6.2.2 Comparison with Decentralized AMM Slippage

Polymarket's CLOB differs from decentralized AMMs like Uniswap V2 in slippage behavior. In Uniswap V2, slippage follows the constant product formula $x \cdot y = k$ and scales with trade size relative to liquidity, making price impact unavoidable. Polymarket's CLOB achieves zero slippage for 52.176% of settlements at the best bid-ask prices, though exhibiting high variance ($\text{std}(X/Y) = 0.129$) for larger orders. Additionally, on-chain AMMs suffer from MEV extraction via

sandwich attacks and flashbots, where validators and bots front-run and back-run transactions for profit [24, 25]. Polymarket’s off-chain CLOB with on-chain settlement avoids protocol-level MEV extraction, meaning observed slippage reflects only order book consumption without adversarial extraction.

6.3 Arbitrage

For the 15-minute cyclical “Bitcoin up or down?” markets, there are four shares in total. We can partition these into the YES share partition {YES_Kalshi, YES_Polymarket} and the NO share partition {NO_Kalshi, NO_Polymarket}. Every share within the same partition shares the same value, and the values of any pair of shares from different groups are complementary, summing to 1.

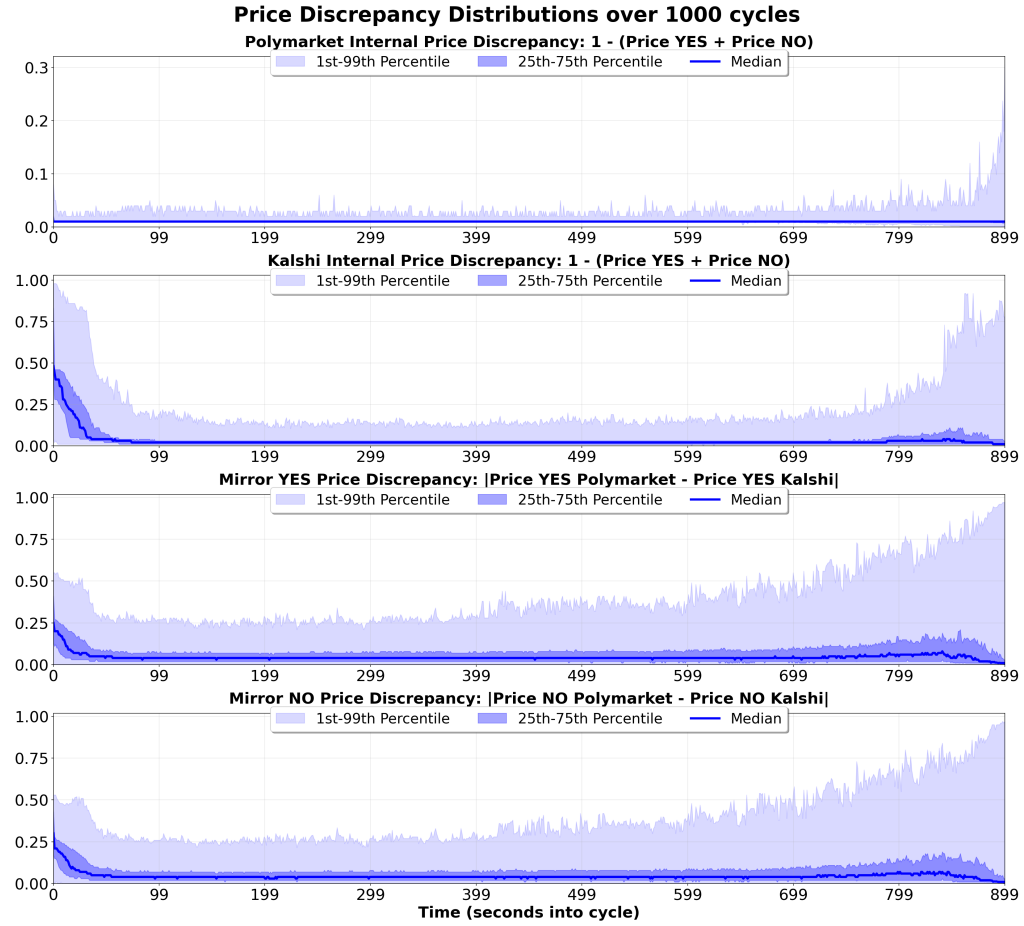


Figure 6.2: Price Discrepancy Distribution for 15-minute cyclical “Bitcoin up or down?” markets

Figure 6.2 shows the distribution of the price discrepancy between four of the six possible pairs of shares. It is important to note that for both Polymarket and Kalshi, the orderbook for a specific 15-minute interval was available before the start of the interval. The price discrepancy is lower when more Polymarket shares are involved, regardless of the point in time, but especially at the start of the interval. In all cases, the median price discrepancy is highest at the start of the interval. Towards the end of the cycle, the median remains relatively low, but the distribution becomes increasingly skewed.

Discussion

7.1 Data Collection Barriers

The barrier for reliable data collection on Polymarket is relatively high as a result of the incomplete, fragmented and even incorrect documentation. This applies to both the off-chain endpoints and the on-chain smart contracts, where the exact coordination is abstracted away. Analyzing the on-chain events and off-chain market objects revealed just how much of the system actually is undocumented, including the transition to the MOOV2 Adapter without public disclosure, the existence of the Centralized Adapter with unrecognized bytecode, and recurring event ambiguities from millisecond-resolution timestamps. Additionally, the off-chain endpoints have demonstrated inconsistent behavior, such as false misses in orderbook requests and zombie connections on the WebSocket feed, which is difficult to assert since there is no specification for expected endpoint behavior in the first place.

7.2 Market Integrity and Effectiveness

Despite these documentation and consistency challenges, the market mechanisms appear effective. Comparing the market internal price discrepancy between Polymarket and Kalshi for the 15-minute cyclical “Bitcoin up or down?” markets suggests that arbitrageurs are maintaining lower price discrepancies on Polymarket compared to Kalshi, indicating tighter and more efficient pricing. However, this efficiency may be partially attributed to wash trading activity, as a recent study suggests approximately 18% or potentially up to 60% of December 2024 volume on Polymarket involved wash trades.

7.3 Slippage and Market Design

The measured slippage rate of 0.7% on Polymarket represents a favorable outcome compared to decentralized AMMs, where slippage is determined by the constant

product formula $x \cdot y = k$ and scales unavoidably with trade size. The finding that 52.2% of settlements incur zero slippage demonstrates a key advantage of the CLOB model: trades can execute at resting prices without consuming deeper liquidity. However, the high variance ($\text{std}(X/Y) = 0.129$) in the slippage-to-volume ratio indicates that large orders face unpredictable price impact from order book depth constraints.

The off-chain CLOB architecture also avoids the protocol-level MEV extraction inherent to on-chain AMMs, where flashbots and sandwich attacks introduce additional adversarial slippage beyond mechanical price impact. This represents a structural advantage of Polymarket’s hybrid model, though application-layer front-running risks remain.

7.4 Unregistered Markets and Emerging Infrastructure

A notable finding is the emergence of unregistered prediction markets on Polymarket around December 2025, primarily using the Centralized Adapter as the reporting oracle. These markets are visible on the web platform, show trading activity, yet lack corresponding smart contract registrations and on-chain trade settlement. This suggests Polymarket is experimenting with markets that may not require on-chain settlement, potentially introducing infrastructure variability that complicates end-to-end analysis.

7.5 Limitations and Future Work

This analysis is limited to a 50-day collection period (November 18, 2025 to January 5, 2026) covering 1.44M on-chain settlements and 144K on-chain events. The wash trading concerns and recent COVID-like volume declines may affect the representativeness of these findings for longer-term market behavior. Future work should examine the role of the Centralized Adapter in market resolution, investigate wash trading detection mechanisms, and analyze longer-term slippage trends following the January 2026 market stabilization.

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Endpoint Documented JSON responses

Listing A.1: Polymarkets Documented Orderbook State Object Sample

```

1 {
2   "market": "0x1b6f76e5b8587ee896c35847e12d
3   11e75290a8c3934c5952e8a9d6e4c6f03cfa",
4   "asset_id": "1234567890",
5   "timestamp": "2023-10-01T12:00:00Z",
6   "hash": "0xabc123def456...",
7   "bids": [
8     {
9       "price": "1800.50",
10      "size": "10.5"
11    }
12  ],
13  "asks": [
14    {
15      "price": "1800.50",
16      "size": "10.5"
17    }
18  ],
19  "min_order_size": "0.001",
20  "tick_size": "0.01",
21  "neg_risk": false
22 }
```

Listing A.2: Polymarkets Documented Book Event

```

1 {
2   "event_type": "book",
3   "asset_id": "65818619657568813474341868652308942079804919
4   287380422192892211131408793125422",
5   "market": "0xbd31dc8a20211944f6b70f31557f1001557
6   b59905b7738480ca09bd4532f84af",
7   "bids": [
8     { "price": ".48", "size": "30" },
9     { "price": ".49", "size": "20" },
10    { "price": ".50", "size": "15" }
```

```

11 ],
12 "asks": [
13   { "price": ".52", "size": "25" },
14   { "price": ".53", "size": "60" },
15   { "price": ".54", "size": "10" }
16 ],
17 "timestamp": "123456789000",
18 "hash": "0x0...."
19 }

```

Listing A.3: Polymarkets Documented Price Change Event

```

1 {
2   "market": "0x5f65177b394277fd294cd75650044e32
3   ba009a95022d88a0c1d565897d72f8f1",
4   "price_changes": [
5     {
6       "asset_id": "71321045679252212594626385532706912
7       750332728571942532289631379312455583992563",
8       "price": "0.5",
9       "size": "200",
10      "side": "BUY",
11      "hash": "56621a121a47ed9333273e21c83b660cff37ae50",
12      "best_bid": "0.5",
13      "best_ask": "1"
14    },
15    {
16      "asset_id": "521143195012459155160551060468842
17      09969926127482827954674443846427813813222426",
18      "price": "0.5",
19      "size": "200",
20      "side": "SELL",
21      "hash": "1895759e4df7a796bf4f1c5a5950b748306923e2",
22      "best_bid": "0",
23      "best_ask": "0.5"
24    }
25  ],
26  "timestamp": "1757908892351",
27  "event_type": "price_change"
28 }

```

Listing A.4: Polymarkets Documented Last Trade Price Event

```

1 {
2   "asset_id": "114122071509644379678018727908709560
3   226618148003371446110114509806601493071694",
4   "event_type": "last_trade_price",
5   "fee_rate_bps": "0",
6   "market": "0x6a67b9d828d53862160e470329ffea5246f3
7   38ecfffd2cab45211ec578b0347",
8   "price": "0.456",
9   "side": "BUY",
10  "size": "219.217767",
11  "timestamp": "1750428146322"

```

12 }

Listing A.5: Polymarkets Documented New Market Event

```

1 {
2   "id": "1031769",
3   "question": "Will NVIDIA (NVDA) close above
4   $240 end of January?",
5   "market": "0x311d0c4b6671ab54af4970c06fcf
6   58662516f5168997bdda209ec3db5aa6b0c1",
7   "slug": "nvda-above-240-on-january-30-2026",
8   "description": "This market will resolve to \"Yes\" if the
   official closing price for NVIDIA (NVDA) on the final
   trading day of January 2026 is higher than the listed price
   . Otherwise, this market will resolve to \"No\".\n\nIf the
   final trading day of the month is shortened (for example,
   due to a market-holiday schedule), the official closing
   price published for that shortened session will still be
   used for resolution.\n\nIf no official closing price is
   published for that session (for example, due to a trading
   halt into the close, system issue, or other disruption),
   the market will use the last valid on-exchange trade price
   of the regular session as the effective closing price.\n\n
   The resolution source for this market is Yahoo Finance
   specifically, the NVIDIA (NVDA) \"Close\" prices available
   at https://finance.yahoo.com/quote/NVDA/history, published
   under \"Historical Prices.\".\n\nIn the event of a stock
   split, reverse stock split, or similar corporate action
   affecting the listed company during the listed time frame,
   this market will resolve based on split-adjusted prices as
   displayed on Yahoo Finance.",
9   "assets_ids": [
10    "76043073756653678226373981964075571318
11    267289248134717369284518995922789326425",
12    "316909342633857276642020992785456880077
13    99199447969475608906331829650099442770"
14  ],
15  "outcomes": [
16    "Yes",
17    "No"
18  ],
19  "event_message": {
20    "id": "125819",
21    "ticker": "nvda-above-in-january-2026",
22    "slug": "nvda-above-in-january-2026",
23    "title": "Will NVIDIA (NVDA) close above ___ end of January
   ?",
24    "description": "This market will resolve to \"Yes\" if the
   official closing price for NVIDIA (NVDA) on the final
   trading day of January 2026 is higher than the listed
   price. Otherwise, this market will resolve to \"No\".\n\n
   If the final trading day of the month is shortened (
   for example, due to a market-holiday schedule), the
   official closing price published for that shortened

```

```

    session will still be used for resolution.\n\nIf no
    official closing price is published for that session (
    for example, due to a trading halt into the close,
    system issue, or other disruption), the market will use
    the last valid on-exchange trade price of the regular
    session as the effective closing price.\n\nThe
    resolution source for this market is Yahoo Finance
    specifically, the NVIDIA (NVDA) \"Close\" prices
    available at https://finance.yahoo.com/quote/NVDA/
    history, published under \"Historical Prices.\".\n\nIn
    the event of a stock split, reverse stock split, or
    similar corporate action affecting the listed company
    during the listed time frame, this market will resolve
    based on split-adjusted prices as displayed on Yahoo
    Finance.\"
25 },
26 \"timestamp\": \"1766790415550\",
27 \"event_type\": \"new_market\"
28 }

```

Listing A.6: Polymarkets Documented Market Resolved Event

```

1 {
2   \"id\": \"1031769\",
3   \"question\": \"Will NVIDIA (NVDA) close above $240
4   end of January?\",
5   \"market\": \"0x311d0c4b6671ab54af4970c06fc
6   f58662516f5168997bdda209ec3db5aa6b0c1\",
7   \"slug\": \"nvda-above-240-on-january-30-2026\",
8   \"description\": \"This market will resolve to \"Yes\" if the
    official closing price for NVIDIA (NVDA) on the final
    trading day of January 2026 is higher than the listed price
    . Otherwise, this market will resolve to \"No\".\n\nIf the
    final trading day of the month is shortened (for example,
    due to a market-holiday schedule), the official closing
    price published for that shortened session will still be
    used for resolution.\n\nIf no official closing price is
    published for that session (for example, due to a trading
    halt into the close, system issue, or other disruption),
    the market will use the last valid on-exchange trade price
    of the regular session as the effective closing price.\n\n
    The resolution source for this market is Yahoo Finance
    specifically, the NVIDIA (NVDA) \"Close\" prices available
    at https://finance.yahoo.com/quote/NVDA/history, published
    under \"Historical Prices.\".\n\nIn the event of a stock
    split, reverse stock split, or similar corporate action
    affecting the listed company during the listed time frame,
    this market will resolve based on split-adjusted prices as
    displayed on Yahoo Finance.\" ,
9   \"assets_ids\": [
10     \"760430737566536782263739819640755713182
11     67289248134717369284518995922789326425\",
12     \"316909342633857276642020992785456880077
13     99199447969475608906331829650099442770\"

```

```

14 ],
15   "winning_asset_id": "7604307375665367822637398196407
16   5571318267289248134717369284518995922789326425",
17   "winning_outcome": "Yes",
18   "event_message": {
19     "id": "125819",
20     "ticker": "nvda-above-in-january-2026",
21     "slug": "nvda-above-in-january-2026",
22     "title": "Will NVIDIA (NVDA) close above ___ end of January
23     ?",
24     "description": "This market will resolve to \"Yes\" if the
25       official closing price for NVIDIA (NVDA) on the final
26       trading day of January 2026 is higher than the listed
27       price. Otherwise, this market will resolve to \"No\".\n
28       \nIf the final trading day of the month is shortened (
29       for example, due to a market-holiday schedule), the
30       official closing price published for that shortened
31       session will still be used for resolution.\n\nIf no
32       official closing price is published for that session (
33       for example, due to a trading halt into the close,
34       system issue, or other disruption), the market will use
35       the last valid on-exchange trade price of the regular
36       session as the effective closing price.\n\nThe
37       resolution source for this market is Yahoo Finance
38       specifically, the NVIDIA (NVDA) \"Close\" prices
39       available at https://finance.yahoo.com/quote/NVDA/
40       history, published under \"Historical Prices.\" \n\nIn
41       the event of a stock split, reverse stock split, or
42       similar corporate action affecting the listed company
43       during the listed time frame, this market will resolve
44       based on split-adjusted prices as displayed on Yahoo
45       Finance."
46   },
47   "timestamp": "1766790415550",
48   "event_type": "new_market"
49 }

```

Listing A.7: Kalshi Documented Orderbook Delta

```

1 {
2   "type": "orderbook_delta",
3   "sid": 2,
4   "seq": 3,
5   "msg": {
6     "market_ticker": "FED-23DEC-T3.00",
7     "market_id": "9b0f6b43-5b68-4f9f-9f02-9a2d1b8ac1a1",
8     "price": 96,
9     "price_dollars": "0.960",
10    "delta": -54,
11    "delta_fp": "-54.00",
12    "side": "yes",
13    "ts": "2022-11-22T20:44:01Z"
14  }
15 }

```

Listing A.8: Kalshi Documented Orderbook Snapshot

```

1  {
2    "type": "orderbook_snapshot",
3    "sid": 2,
4    "seq": 2,
5    "msg": {
6      "market_ticker": "FED-23DEC-T3.00",
7      "market_id": "9b0f6b43-5b68-4f9f-9f02-9a2d1b8ac1a1",
8      "yes": [
9        [
10         8,
11         300
12       ],
13       [
14         22,
15         333
16       ]
17     ],
18     "yes_dollars": [
19       [
20         "0.080",
21         300
22       ],
23       [
24         "0.220",
25         333
26       ]
27     ],
28     "yes_dollars_fp": [
29       [
30         "0.0800",
31         "300.00"
32       ],
33       [
34         "0.2200",
35         "333.00"
36       ]
37     ],
38     "no": [
39       [
40         54,
41         20
42       ],
43       [
44         56,
45         146
46       ]
47     ],
48     "no_dollars": [
49       [
50         "0.540",
51         20
52       ],

```

```

53     [
54         "0.560",
55         146
56     ],
57 ],
58 "no_dollars_fp": [
59     [
60         "0.5400",
61         "20.00"
62     ],
63     [
64         "0.5600",
65         "146.00"
66     ]
67 ]
68 }
69 }

```

Listing A.9: Kalshi Documented Trade Update

```

1  {
2    "type": "trade",
3    "sid": 11,
4    "msg": {
5      "trade_id": "d91bc706-ee49-470d-82d8-11418bda6fed",
6      "market_ticker": "HIGHNY-22DEC23-B53.5",
7      "yes_price": 36,
8      "yes_price_dollars": "0.360",
9      "no_price": 64,
10     "no_price_dollars": "0.640",
11     "count": 136,
12     "count_fp": "136.00",
13     "taker_side": "no",
14     "ts": 1669149841
15   }
16 }

```

Listing A.10: Kalshi Documented Market Lifecycle V2

```

1  {
2    "type": "market_lifecycle_v2",
3    "sid": 13,
4    "msg": {
5      "market_ticker": "INXD-23SEP14-B4487",
6      "event_type": "created",
7      "open_ts": 1694635200,
8      "close_ts": 1694721600,
9      "additional_metadata": {
10        "name": "S&P 500 daily return on Sep 14",
11        "title": "S&P 500 closes up by 0.02% or more",
12        "yes_sub_title": "S&P 500 closes up 0.02%+",
13        "no_sub_title": "S&P 500 closes up <0.02%",
14        "rules_primary": "The S&P 500 index level at 4:00 PM ET...",
15        "rules_secondary": "",

```

```

16     "can_close_early": true,
17     "event_ticker": "INXD-23SEP14",
18     "expected_expiration_ts": 1694721600,
19     "strike_type": "greater",
20     "floor_strike": 4487
21   }
22 }
23 }

```

Listing A.11: Kalshi Documented Event Object

```

1 {
2   "event": {
3     "event_ticker": "<string>",
4     "series_ticker": "<string>",
5     "sub_title": "<string>",
6     "title": "<string>",
7     "collateral_return_type": "<string>",
8     "mutually_exclusive": true,
9     "category": "<string>",
10    "available_on_brokers": true,
11    "product_metadata": {},
12    "strike_date": "2023-11-07T05:31:56Z",
13    "strike_period": "<string>",
14    "markets": [
15      {
16        "ticker": "<string>",
17        "event_ticker": "<string>",
18        "market_type": "binary",
19        "title": "<string>",
20        "subtitle": "<string>",
21        "yes_sub_title": "<string>",
22        "no_sub_title": "<string>",
23        "created_time": "2023-11-07T05:31:56Z",
24        "updated_time": "2023-11-07T05:31:56Z",
25        "open_time": "2023-11-07T05:31:56Z",
26        "close_time": "2023-11-07T05:31:56Z",
27        "expiration_time": "2023-11-07T05:31:56Z",
28        "latest_expiration_time": "2023-11-07T05:31:56Z",
29        "settlement_timer_seconds": 123,
30        "status": "initialized",
31        "response_price_units": "usd_cent",
32        "yes_bid": 123,
33        "yes_bid_dollars": "0.5600",
34        "yes_ask": 123,
35        "yes_ask_dollars": "0.5600",
36        "no_bid": 123,
37        "no_bid_dollars": "0.5600",
38        "no_ask": 123,
39        "no_ask_dollars": "0.5600",
40        "last_price": 123,
41        "last_price_dollars": "0.5600",
42        "volume": 123,
43        "volume_fp": "10.00",

```



```

44     "volume_24h": 123,
45     "volume_24h_fp": "10.00",
46     "result": "yes",
47     "can_close_early": true,
48     "open_interest": 123,
49     "open_interest_fp": "10.00",
50     "notional_value": 123,
51     "notional_value_dollars": "0.5600",
52     "previous_yes_bid": 123,
53     "previous_yes_bid_dollars": "0.5600",
54     "previous_yes_ask": 123,
55     "previous_yes_ask_dollars": "0.5600",
56     "previous_price": 123,
57     "previous_price_dollars": "0.5600",
58     "liquidity": 123,
59     "liquidity_dollars": "0.5600",
60     "expiration_value": "<string>",
61     "tick_size": 123,
62     "rules_primary": "<string>",
63     "rules_secondary": "<string>",
64     "price_level_structure": "<string>",
65     "price_ranges": [
66         {
67             "start": "<string>",
68             "end": "<string>",
69             "step": "<string>"
70         }
71     ],
72     "expected_expiration_time": "2023-11-07T05:31:56Z",
73     "settlement_value": 123,
74     "settlement_value_dollars": "0.5600",
75     "settlement_ts": "2023-11-07T05:31:56Z",
76     "fee_waiver_expiration_time": "2023-11-07T05:31:56Z",
77     "early_close_condition": "<string>",
78     "strike_type": "greater",
79     "floor_strike": 123,
80     "cap_strike": 123,
81     "functional_strike": "<string>",
82     "custom_strike": {},
83     "mve_collection_ticker": "<string>",
84     "mve_selected_legs": [
85         {
86             "event_ticker": "<string>",
87             "market_ticker": "<string>",
88             "side": "<string>",
89             "yes_settlement_value_dollars": "0.5600"
90         }
91     ],
92     "primary_participant_key": "<string>",
93     "is_provisional": true
94 }
95 ]
96 },
97 "markets": [

```

```

98  {
99      "ticker": "<string>",
100      "event_ticker": "<string>",
101      "market_type": "binary",
102      "title": "<string>",
103      "subtitle": "<string>",
104      "yes_sub_title": "<string>",
105      "no_sub_title": "<string>",
106      "created_time": "2023-11-07T05:31:56Z",
107      "updated_time": "2023-11-07T05:31:56Z",
108      "open_time": "2023-11-07T05:31:56Z",
109      "close_time": "2023-11-07T05:31:56Z",
110      "expiration_time": "2023-11-07T05:31:56Z",
111      "latest_expiration_time": "2023-11-07T05:31:56Z",
112      "settlement_timer_seconds": 123,
113      "status": "initialized",
114      "response_price_units": "usd_cent",
115      "yes_bid": 123,
116      "yes_bid_dollars": "0.5600",
117      "yes_ask": 123,
118      "yes_ask_dollars": "0.5600",
119      "no_bid": 123,
120      "no_bid_dollars": "0.5600",
121      "no_ask": 123,
122      "no_ask_dollars": "0.5600",
123      "last_price": 123,
124      "last_price_dollars": "0.5600",
125      "volume": 123,
126      "volume_fp": "10.00",
127      "volume_24h": 123,
128      "volume_24h_fp": "10.00",
129      "result": "yes",
130      "can_close_early": true,
131      "open_interest": 123,
132      "open_interest_fp": "10.00",
133      "notional_value": 123,
134      "notional_value_dollars": "0.5600",
135      "previous_yes_bid": 123,
136      "previous_yes_bid_dollars": "0.5600",
137      "previous_yes_ask": 123,
138      "previous_yes_ask_dollars": "0.5600",
139      "previous_price": 123,
140      "previous_price_dollars": "0.5600",
141      "liquidity": 123,
142      "liquidity_dollars": "0.5600",
143      "expiration_value": "<string>",
144      "tick_size": 123,
145      "rules_primary": "<string>",
146      "rules_secondary": "<string>",
147      "price_level_structure": "<string>",
148      "price_ranges": [
149          {
150              "start": "<string>",
151              "end": "<string>",

```

```
152     "step": "<string>"
153   }
154 ],
155 "expected_expiration_time": "2023-11-07T05:31:56Z",
156 "settlement_value": 123,
157 "settlement_value_dollars": "0.5600",
158 "settlement_ts": "2023-11-07T05:31:56Z",
159 "fee_waiver_expiration_time": "2023-11-07T05:31:56Z",
160 "early_close_condition": "<string>",
161 "strike_type": "greater",
162 "floor_strike": 123,
163 "cap_strike": 123,
164 "functional_strike": "<string>",
165 "custom_strike": {},
166 "mve_collection_ticker": "<string>",
167 "mve_selected_legs": [
168   {
169     "event_ticker": "<string>",
170     "market_ticker": "<string>",
171     "side": "<string>",
172     "yes_settlement_value_dollars": "0.5600"
173   }
174 ],
175 "primary_participant_key": "<string>",
176 "is_provisional": true
177 }
178 ]
179 }
```

Resolution Tables

Table B.1: Ten Most Frequent Tags in Matched Disputes

Label	Appeared In (%)
Politics	104 (32.00%)
Culture	99 (30.46%)
Sports	74 (22.77%)
Games	72 (22.15%)
Hide From New	49 (15.08%)
Recurring	45 (13.85%)
Weather	44 (13.54%)
Best of 2025	41 (12.62%)
Trump	40 (12.31%)
Geopolitics	39 (12.00%)

Table B.2: Ten Most Frequent Tags For Markets resolved to UNKNOWN

Label	Appeared In (%)
Games	272 (96.11%)
Sports	259 (91.52%)
Esports	102 (36.04%)
Basketball	51 (18.02%)
NCAA	42 (14.84%)
UFC	39 (13.78%)
Dota 2	35 (12.37%)
NCAA Basketball	31 (10.95%)
Rocket League	30 (10.60%)
Tennis	29 (10.25%)

APPENDIX C

Smart Contracts

Table C.1: Contract Aliases, Deployment Addresses, and Event Tables

Alias	Deployment Address	Contract Table Name
CTFE	0x4bfb41d5b3570defd03c39a9a4d8de6bd8b8982e	CTFExchange
Negrisk CTFE	0xC5d563A36AE78145C45a50134d48A1215220f80a	CTFExchange
CTF	0x4d97dcd97ec945f40cf65f87097ace5ea0476045	(Gnosis) Conditional Tokens
Negrisk Operator	0x71523d0f655b41e805cec45b17163f528b59b820	Negrisk Operator
Negrisk Adapter	0xd91e80cf2e7be2e162c6513ced06f1dd0da35296	Negrisk Adapter
Negrisk UmaCtfAdapter	0x2F5e3684cb1F318ec51b00Edba38d79Ac2c0aA9d	UmaCtfAdapter
OOV2 UmaCtfAdapter	0x6A9D222616C90FcA5754cd1333cFD9b7fb6a4F74	UmaCtfAdapter
MOOV2 Adapter	0x65070BE91477460D8A7AeEb94ef92fe056C2f2A7	UmaCtfAdapter
MOOV2	0x2C0367a9DB231dDeBd88a94b4f6461a6e47C58B1	(UMA) Managed Optimistic Oracle V2
Oracle Child Tunnel	0xac60353a54873c446101216829a6A98cDbbC3f3D	Oracle Child Tunnel
FxTunnel	0x8397259c983751DAf40400790063935a11afa28a	FxTunnel
OOV2	0xE3Afe347D5C74317041E2618C49534dAf887c24	(UMA) Optimistic Oracle V2

Table C.2: Contract Event Signatures

Contract / Event Signatures
CTFExchange

Table C.2 – continued from previous page

Contract / Event Signatures

```

    FeeCharged(receiver(address), tokenId(uint256), fee(uint256))
    NewAdmin(admin(address), newAdmin(address))
    NewOperator(operator(address), newOperator(address))
    OrderCancelled(orderHash(bytes32))
    OrderFilled(orderHash(bytes32), maker(address), taker(address),
makerAssetId(uint256), takerAssetId(uint256), making(uint256),
taking(uint256), fee(uint256))
    OrdersMatched(orderHash(bytes32), maker(address),
makerAssetId(uint256), takerAssetId(uint256), making(uint256),
taking(uint256))
    ProxyFactoryUpdated(oldProxyFactory(address),
newProxyFactory(address))
    RemovedAdmin(admin(address), oldAdmin(address))
    RemovedOperator(operator(address), oldOperator(address))
    SafeFactoryUpdated(oldSafeFactory(address),
newSafeFactory(address))
    TokenRegistered(token0(uint256), token1(uint256),
conditionId(bytes32))
    TradingPaused(trader(address))
    TradingUnpaused(trader(address))

```

Conditional Tokens

```

    ConditionPreparation(conditionId(bytes32), oracle(address),
questionId(bytes32), outcomeSlotCount(uint256))
    ConditionResolution(conditionId(bytes32), oracle(address),
questionId(bytes32), outcomeSlotCount(uint256),
payoutNumerators(uint256[]))
    PositionSplit(stakeholder(address), collateralToken(address),
parentCollectionId(bytes32), conditionId(bytes32),
partition(uint256[]), amount(uint256))
    PositionsMerge(stakeholder(address), collateralToken(address),
parentCollectionId(bytes32), conditionId(bytes32),
partition(uint256[]), amount(uint256))
    PayoutRedemption(redeemer(address), collateralToken(address),
parentCollectionId(bytes32), conditionId(bytes32),
indexSets(uint256[]), payout(uint256))
    URI(value(string), id(uint256))

```

Neg Risk Operator

```

    MarketPrepared(marketId(bytes32), feeBips(uint256), data(bytes))

```

Table C.2 – continued from previous page

Contract / Event Signatures

```

NewAdmin(admin(address), newAdmin(address))
QuestionEmergencyResolved(questionId(bytes32), result(bool))
QuestionFlagged(questionId(bytes32))
QuestionPrepared(marketId(bytes32), questionId(bytes32),
requestId(bytes32), questionIndex(uint256), data(bytes))
QuestionReported(questionId(bytes32), requestId(bytes32),
result(bool))
QuestionResolved(questionId(bytes32), result(bool))
QuestionUnflagged(questionId(bytes32))
RemovedAdmin(admin(address), oldAdmin(address))

```

Neg Risk Adapter

```

MarketPrepared(marketId(bytes32), oracle(address),
feeBips(uint256), data(bytes))
NewAdmin(admin(address), newAdmin(address))
OutcomeReported(marketId(bytes32), questionId(bytes32),
outcome(bool))
PayoutRedemption(redeemer(address), conditionId(bytes32),
amounts(uint256[]), payout(uint256))
PositionSplit(stakeholder(address), conditionId(bytes32),
amount(uint256))
PositionsConverted(stakeholder(address), marketId(bytes32),
indexSet(uint256), amount(uint256))
PositionsMerge(stakeholder(address), conditionId(bytes32),
amount(uint256))
QuestionPrepared(marketId(bytes32), questionId(bytes32),
index(uint256), data(bytes))
RemovedAdmin(admin(address), oldAdmin(address))

```

UmaCtfadapter

```

AncillaryDataUpdated(questionId(bytes32), creator(address),
ancillaryData(bytes))
NewAdmin(admin(address), newAdmin(address))
QuestionFlagged(questionId(bytes32))
QuestionInitialized(questionId(bytes32), timestamp(uint256),
creator(address), ancillaryData(bytes), rewardToken(address),
reward(uint256), proposalBond(uint256))
QuestionManuallyResolved(questionId(bytes32), payouts(uint256[]))
QuestionPaused(questionId(bytes32))
QuestionReset(questionId(bytes32))

```

Table C.2 – continued from previous page

Contract / Event Signatures

QuestionResolved(questionId(bytes32), price(int256),
 payouts(uint256[]))
 QuestionUnflagged(questionId(bytes32))
 QuestionUnpaused(questionId(bytes32))
 RemovedAdmin(admin(address), oldAdmin(address))

Managed Optimistic Oracle V2

MessageSent(data(bytes))
 PriceRequestAdded(identifier(bytes32), timestamp(uint256),
 ancillaryData(bytes), childRequestId(bytes32))
 PriceRequestBridged(requester(address), identifier(bytes32),
 time(uint256), ancillaryData(bytes), childRequestId(bytes32),
 parentRequestId(bytes32))
 PushedPrice(identifier(bytes32), timestamp(uint256),
 ancillaryData(bytes), price(int256), childRequestId(bytes32))
 ResolvedLegacyRequest(identifier(bytes32), timestamp(uint256),
 ancillaryData(bytes), price(int256), childRequestId(bytes32),
 parentRequestId(bytes32))
 AllowedBondRangeUpdated(proposer(address), minBond(uint256),
 maxBond(uint256))
 CustomBondSet(identifier(bytes32), proposer(address),
 ancillaryData(bytes32), data(bytes), currency(address),
 bond(uint256))
 CustomLivenessSet(identifier(bytes32), proposer(address),
 ancillaryData(bytes32), data(bytes), liveness(uint256))
 CustomProposerWhitelistSet(identifier(bytes32),
 proposer(address), ancillaryData(bytes32), data(bytes),
 newProposer(address))
 DefaultAdminDelayChangeCanceled()
 DefaultAdminDelayChangeScheduled(delay(uint48), newDelay(uint48))
 DefaultAdminTransferCanceled()
 DefaultAdminTransferScheduled(newAdmin(address), time(uint48))
 DefaultProposerWhitelistUpdated(newWhitelist(address))
 DisputePrice(requester(address), proposer(address),
 disputer(address), identifier(bytes32), timestamp(uint256),
 ancillaryData(bytes), proposedPrice(int256))
 Initialized(version(uint64))
 MinimumLivenessUpdated(minimumLiveness(uint256))

Table C.2 – continued from previous page

Contract / Event Signatures

```

    ProposePrice(requester(address), proposer(address),
    identifier(bytes32), timestamp(uint256), ancillaryData(bytes),
    proposedPrice(int256), expirationTime(uint256), currency(address))
    RequestManagerAdded(requestManager(address))
    RequestManagerRemoved(requestManager(address))
    RequestPrice(requester(address), identifier(bytes32),
    timestamp(uint256), ancillaryData(bytes), currency(address),
    reward(uint256), finalFee(uint256))
    RequesterWhitelistUpdated(newWhitelist(address))
    RoleAdminChanged(role(bytes32), previousAdminRole(bytes32),
    newAdminRole(bytes32))
    RoleGranted(role(bytes32), account(address), adminRole(bytes32))
    RoleRevoked(role(bytes32), account(address), adminRole(bytes32))
    Settle(requester(address), proposer(address), disputer(address),
    identifier(bytes32), timestamp(uint256), ancillaryData(bytes),
    resolvedPrice(int256), payout(uint256))
    Upgraded(implementation(address))

```

Oracle Child Tunnel

```

    PriceRequestBridged(requester(address), identifier(bytes32),
    time(uint256), ancillaryData(bytes), childRequestId(bytes32),
    parentRequestId(bytes32))
    ResolvedLegacyRequest(identifier(bytes32), timestamp(uint256),
    ancillaryData(bytes), price(int256), childRequestId(bytes32),
    parentRequestId(bytes32))
    PriceRequestAdded(identifier(bytes32), timestamp(uint256),
    ancillaryData(bytes), childRequestId(bytes32))
    PushedPrice(identifier(bytes32), timestamp(uint256),
    ancillaryData(bytes), price(int256), childRequestId(bytes32))
    MessageSent(data(bytes))

```

FxTunnel

```

    NewFxMessage(rootMessageSender(address), receiver(address),
    data(bytes))

```

Optimistic Oracle V2

```

    RequestPrice(requester(address), identifier(bytes32),
    timestamp(uint256), ancillaryData(bytes), currency(address),
    reward(uint256), finalFee(uint256))

```

Table C.2 – continued from previous page

Contract / Event Signatures
<pre> ProposePrice(requester(address), proposer(address), identifier(bytes32), timestamp(uint256), ancillaryData(bytes), proposedPrice(int256), expirationTime(uint256), currency(address)) DisputePrice(requester(address), proposer(address), disputer(address), identifier(bytes32), timestamp(uint256), ancillaryData(bytes), proposedPrice(int256)) Settle(requester(address), proposer(address), disputer(address), identifier(bytes32), timestamp(uint256), ancillaryData(bytes), resolvedPrice(int256), payout(uint256)) </pre>

Polymarket Event Object JSON Tree Analysis

Table D.1: JSON Tree Structure Analysis of `/events` Endpoint Responses. For each entry, the Path and Total Count are on the first line, with Presence and Type Makeup on the indented second line.

Path	Total Count
ROOT	126558
<i>Presence: 100.0% Type: Object (100.0)</i>	
ROOT.tags	126555
<i>Presence: 100.0% Type: Object (100.0)</i>	
ROOT.tags.[]	126555
<i>Presence: 100.0% Type: Array (100.0)</i>	
ROOT.markets	126523
<i>Presence: 100.0% Type: Object (100.0)</i>	
ROOT.markets.[]	126523
<i>Presence: 100.0% Type: Array (100.0)</i>	
ROOT.series	105820
<i>Presence: 83.6% Type: Object (100.0)</i>	
ROOT.series.[]	105820
<i>Presence: 83.6% Type: Array (100.0)</i>	
ROOT.markets.[] .clobRewards	9805
<i>Presence: 7.7% Type: Object (100.0)</i>	
ROOT.markets.[] .clobRewards.[]	9805
<i>Presence: 7.7% Type: Array (100.0)</i>	

Table D.1 – continued from previous page

Path	Total Count
ROOT.eventCreators <i>Presence: 0.1% Type: Object (100.0)</i>	87
ROOT.eventCreators.[] <i>Presence: 0.1% Type: Array (100.0)</i>	87
ROOT.tags.[] .slug <i>Presence: 100.0% Type: str:general (100.0), str:integer (0.0)</i>	740323
ROOT.tags.[] .requiresTranslation <i>Presence: 100.0% Type: bool (100.0)</i>	740323
ROOT.tags.[] .label <i>Presence: 100.0% Type: str:general (100.0), str:integer (0.0)</i>	740323
ROOT.tags.[] .id <i>Presence: 100.0% Type: str:integer (100.0)</i>	740323
ROOT.tags.[] .updatedAt <i>Presence: 100.0% Type: str:timestamp (100.0)</i>	740162
ROOT.tags.[] .createdAt <i>Presence: 98.8% Type: str:timestamp (100.0)</i>	731578
ROOT.tags.[] .forceShow <i>Presence: 88.6% Type: bool (100.0)</i>	655610
ROOT.tags.[] .publishedAt <i>Presence: 40.7% Type: str:general (100.0)</i>	301036
ROOT.markets.[] .approved <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .active <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .clearBookOnStart <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .createdAt <i>Presence: 100.0% Type: str:timestamp (100.0)</i>	294240
ROOT.markets.[] .cyom <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .feesEnabled <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .umaResolutionStatuses <i>Presence: 100.0% Type: str:json_encoded (100.0)</i>	294240

Table D.1 – continued from previous page

Path	Total Count
ROOT.markets.[] .deploying <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .description <i>Presence: 100.0% Type: str:general (100.0)</i>	294240
ROOT.markets.[] .funded <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .archived <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .bestAsk <i>Presence: 100.0% Type: float (59.7), int (40.3)</i>	294240
ROOT.markets.[] .manualActivation <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .id <i>Presence: 100.0% Type: str:integer (100.0)</i>	294240
ROOT.markets.[] .holdingRewardsEnabled <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .pagerDutyNotificationEnabled <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .pendingDeployment <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .question <i>Presence: 100.0% Type: str:general (100.0)</i>	294240
ROOT.markets.[] .ready <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .rewardsMaxSpread <i>Presence: 100.0% Type: int (82.9), float (17.1)</i>	294240
ROOT.markets.[] .outcomes <i>Presence: 100.0% Type: str:json_encoded (100.0)</i>	294240
ROOT.markets.[] .rfqEnabled <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .rewardsMinSize <i>Presence: 100.0% Type: int (100.0), float (0.0)</i>	294240
ROOT.markets.[] .spread <i>Presence: 100.0% Type: float (83.4), int (16.6)</i>	294240

Table D.1 – continued from previous page

Path	Total Count
ROOT.markets.[] .requiresTranslation <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .restricted <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .slug <i>Presence: 100.0% Type: str:general (100.0)</i>	294240
ROOT.markets.[] .conditionId <i>Presence: 100.0% Type: str:hexadecimal (99.97), str:empty (0.03)</i>	294240
ROOT.markets.[] .closed <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .negRiskOther <i>Presence: 100.0% Type: bool (100.0)</i>	294240
ROOT.markets.[] .marketMakerAddress <i>Presence: 100.0% Type: str:empty (91.1), str:hexadecimal (8.9)</i>	294240
ROOT.markets.[] .new <i>Presence: 100.0% Type: bool (100.0)</i>	294209
ROOT.markets.[] .clobTokenIds <i>Presence: 99.9% Type: str:json_encoded (100.0)</i>	294080
ROOT.markets.[] .image <i>Presence: 99.8% Type: str:general (99.6), str:empty (0.4)</i>	293596
ROOT.markets.[] .icon <i>Presence: 99.7% Type: str:general (99.6), str:empty (0.4)</i>	293371
ROOT.markets.[] .updatedAt <i>Presence: 99.6% Type: str:timestamp (100.0)</i>	293018
ROOT.markets.[] .hasReviewedDates <i>Presence: 99.3% Type: bool (100.0)</i>	292264
ROOT.markets.[] .questionID <i>Presence: 99.3% Type: str:hexadecimal (100.0)</i>	292192
ROOT.markets.[] .enableOrderBook <i>Presence: 99.1% Type: bool (100.0)</i>	291620
ROOT.markets.[] .endDate <i>Presence: 99.0% Type: str:timestamp (100.0)</i>	291388
ROOT.markets.[] .startDate <i>Presence: 98.7% Type: str:timestamp (100.0)</i>	290272

Table D.1 – continued from previous page

Path	Total Count
ROOT.markets.[] .orderMinSize <i>Presence: 98.4% Type: int (100.0), float (0.0)</i>	289522
ROOT.markets.[] .orderPriceMinTickSize <i>Presence: 98.4% Type: float (100.0), int (0.0)</i>	289520
ROOT.markets.[] .endDateIso <i>Presence: 98.2% Type: str:timestamp (100.0)</i>	288839
ROOT.markets.[] .acceptingOrders <i>Presence: 97.0% Type: bool (100.0)</i>	285530
ROOT.markets.[] .negRisk <i>Presence: 96.8% Type: bool (100.0)</i>	284707
ROOT.markets.[] .outcomePrices <i>Presence: 95.5% Type: str:json_encoded (100.0)</i>	280947
ROOT.markets.[] .automaticallyActive <i>Presence: 95.4% Type: bool (100.0)</i>	280826
ROOT.markets.[] .featured <i>Presence: 94.7% Type: bool (100.0)</i>	278588
ROOT.markets.[] .startDateIso <i>Presence: 91.5% Type: str:timestamp (100.0)</i>	269084
ROOT.markets.[] .volume <i>Presence: 91.4% Type: str:float (77.1), str:integer (22.9)</i>	268901
ROOT.markets.[] .volumeNum <i>Presence: 91.4% Type: float (77.0), int (23.0)</i>	268901
ROOT.markets.[] .acceptingOrdersTimestamp <i>Presence: 90.4% Type: str:timestamp (100.0)</i>	266051
ROOT.markets.[] .volumeClob <i>Presence: 89.8% Type: float (76.6), int (23.4)</i>	264197
ROOT.markets.[] .groupItemThreshold <i>Presence: 89.6% Type: str:integer (100.0)</i>	263602
ROOT.markets.[] .closedTime <i>Presence: 88.3% Type: str:general (100.0)</i>	259848
ROOT.markets.[] .lastTradePrice <i>Presence: 88.0% Type: int (78.0), float (22.0)</i>	258812
ROOT.markets.[] .umaResolutionStatus <i>Presence: 87.6% Type: str:general (100.0)</i>	257686

Table D.1 – continued from previous page

Path	Total Count
ROOT.markets.[] .umaEndDate <i>Presence: 87.4% Type: str:timestamp (96.9), str:general (3.1)</i>	257309
ROOT.markets.[] .automaticallyResolved <i>Presence: 84.7% Type: bool (100.0)</i>	249301
ROOT.tags.[] .updatedBy <i>Presence: 32.7% Type: int (100.0)</i>	241730
ROOT.markets.[] .resolvedBy <i>Presence: 81.8% Type: str:hexadecimal (100.0)</i>	240654
ROOT.markets.[] .resolutionSource <i>Presence: 80.4% Type: str:general (74.5), str:empty (25.5)</i>	236453
ROOT.tags.[] .isCarousel <i>Presence: 31.2% Type: bool (100.0)</i>	231335
ROOT.markets.[] .volume1yrClob <i>Presence: 77.1% Type: float (61.6), int (38.4)</i>	226919
ROOT.markets.[] .volume1yr <i>Presence: 77.1% Type: float (61.6), int (38.4)</i>	226919
ROOT.markets.[] .volume1moClob <i>Presence: 77.0% Type: float (61.5), int (38.5)</i>	226441
ROOT.markets.[] .volume1mo <i>Presence: 77.0% Type: float (61.5), int (38.5)</i>	226441
ROOT.markets.[] .submitted_by <i>Presence: 76.7% Type: str:hexadecimal (99.7), others (0.3)</i>	225800
ROOT.markets.[] .volume1wkClob <i>Presence: 76.0% Type: float (60.6), int (39.4)</i>	223602
ROOT.markets.[] .volume1wk <i>Presence: 76.0% Type: float (60.6), int (39.4)</i>	223602
ROOT.markets.[] .umaBond <i>Presence: 74.5% Type: str:integer (98.7), str:float (1.3)</i>	219274
ROOT.markets.[] .umaReward <i>Presence: 74.5% Type: str:integer (98.6), str:float (1.4)</i>	219274
ROOT.markets.[] .negRiskRequestID <i>Presence: 70.9% Type: str:empty (54.9), str:hexadecimal (45.1)</i>	208566
ROOT.markets.[] .groupItemTitle <i>Presence: 69.9% Type: str:general (91.6), others (8.4)</i>	205672

Table D.1 – continued from previous page

Path	Total Count
ROOT.markets.[] .oneDayPriceChange <i>Presence: 68.4% Type: float (75.7), int (24.3)</i>	201115
ROOT.markets.[] .deployingTimestamp <i>Presence: 64.6% Type: str:timestamp (100.0)</i>	189939
ROOT.markets.[] .customLiveness <i>Presence: 61.3% Type: int (100.0)</i>	180461
ROOT.markets.[] .bestBid <i>Presence: 58.7% Type: float (71.6), int (28.4)</i>	172631
ROOT.markets.[] .oneHourPriceChange <i>Presence: 53.9% Type: float (52.6), int (47.4)</i>	158604
ROOT.markets.[] .competitive <i>Presence: 47.1% Type: int (85.3), float (14.7)</i>	138520
ROOT.markets.[] .liquidity <i>Presence: 47.1% Type: str:integer (80.6), str:float (19.4)</i>	138485
ROOT.markets.[] .liquidityNum <i>Presence: 47.1% Type: int (82.3), float (17.7)</i>	138485
ROOT.markets.[] .showGmpOutcome <i>Presence: 46.8% Type: bool (100.0)</i>	137594
ROOT.markets.[] .showGmpSeries <i>Presence: 46.8% Type: bool (100.0)</i>	137593
ROOT.markets.[] .liquidityClob <i>Presence: 45.4% Type: int (84.3), float (15.7)</i>	133631
ROOT.markets.[] .oneWeekPriceChange <i>Presence: 42.4% Type: int (60.2), float (39.8)</i>	124819
ROOT.active <i>Presence: 100.0% Type: bool (100.0)</i>	126558
ROOT.title <i>Presence: 100.0% Type: str:general (100.0)</i>	126558
ROOT.pendingDeployment <i>Presence: 100.0% Type: bool (100.0)</i>	126558
ROOT.requiresTranslation <i>Presence: 100.0% Type: bool (100.0)</i>	126558
ROOT.negRiskAugmented <i>Presence: 100.0% Type: bool (100.0)</i>	126558

Table D.1 – continued from previous page

Path	Total Count
ROOT.image <i>Presence: 100.0% Type: str:general (99.8), str:empty (0.2)</i>	126558
ROOT.icon <i>Presence: 100.0% Type: str:general (99.8), str:empty (0.2)</i>	126558
ROOT.id <i>Presence: 100.0% Type: str:integer (100.0)</i>	126558
ROOT.deploying <i>Presence: 100.0% Type: bool (100.0)</i>	126558
ROOT.closed <i>Presence: 100.0% Type: bool (100.0)</i>	126558
ROOT.cyom <i>Presence: 100.0% Type: bool (100.0)</i>	126558
ROOT.createdAt <i>Presence: 100.0% Type: str:timestamp (100.0)</i>	126558
ROOT.enableNegRisk <i>Presence: 100.0% Type: bool (100.0)</i>	126558
ROOT.showAllOutcomes <i>Presence: 100.0% Type: bool (100.0)</i>	126558
ROOT.showMarketImages <i>Presence: 100.0% Type: bool (100.0)</i>	126558
ROOT.slug <i>Presence: 100.0% Type: str:general (100.0)</i>	126558
ROOT.ticker <i>Presence: 100.0% Type: str:general (100.0)</i>	126556
ROOT.archived <i>Presence: 100.0% Type: bool (100.0)</i>	126550
ROOT.restricted <i>Presence: 100.0% Type: bool (100.0)</i>	126550
ROOT.featured <i>Presence: 100.0% Type: bool (100.0)</i>	126534
ROOT.startDate <i>Presence: 100.0% Type: str:timestamp (100.0)</i>	126529
ROOT.new <i>Presence: 100.0% Type: bool (100.0)</i>	126520

Table D.1 – continued from previous page

Path	Total Count
ROOT.updatedAt <i>Presence: 100.0% Type: str:timestamp (100.0)</i>	126495
ROOT.creationDate <i>Presence: 99.9% Type: str:timestamp (100.0)</i>	126461
ROOT.endDate <i>Presence: 99.9% Type: str:timestamp (100.0)</i>	126388
ROOT.description <i>Presence: 99.5% Type: str:general (100.0), others (0.0)</i>	125876
ROOT.commentCount <i>Presence: 99.3% Type: int (100.0)</i>	125633
ROOT.openInterest <i>Presence: 98.7% Type: int (100.0)</i>	124935
ROOT.enableOrderBook <i>Presence: 97.5% Type: bool (100.0)</i>	123449
ROOT.closedTime <i>Presence: 94.8% Type: str:timestamp (100.0)</i>	119928
ROOT.automaticallyResolved <i>Presence: 90.5% Type: bool (100.0)</i>	114539
ROOT.negRisk <i>Presence: 89.2% Type: bool (100.0)</i>	112947
ROOT.resolutionSource <i>Presence: 88.3% Type: str:general (87.2), str:empty (12.8)</i>	111781
ROOT.seriesSlug <i>Presence: 83.7% Type: str:general (100.0)</i>	105868
ROOT.series.[].id <i>Presence: 100.0% Type: str:integer (100.0)</i>	105820
ROOT.series.[].closed <i>Presence: 100.0% Type: bool (100.0)</i>	105820
ROOT.series.[].createdAt <i>Presence: 100.0% Type: str:timestamp (100.0)</i>	105820
ROOT.series.[].requiresTranslation <i>Presence: 100.0% Type: bool (100.0)</i>	105820
ROOT.series.[].commentCount <i>Presence: 100.0% Type: int (100.0)</i>	105820

Table D.1 – continued from previous page

Path	Total Count
ROOT.series.[] .active <i>Presence: 100.0% Type: bool (100.0)</i>	105820
ROOT.series.[] .archived <i>Presence: 100.0% Type: bool (100.0)</i>	105820
ROOT.series.[] .ticker <i>Presence: 100.0% Type: str:general (100.0)</i>	105820
ROOT.series.[] .slug <i>Presence: 100.0% Type: str:general (100.0)</i>	105820
ROOT.series.[] .title <i>Presence: 100.0% Type: str:general (100.0)</i>	105820
ROOT.series.[] .updatedAt <i>Presence: 100.0% Type: str:timestamp (100.0)</i>	105820
ROOT.series.[] .seriesType <i>Presence: 99.9% Type: str:general (100.0)</i>	105750
ROOT.series.[] .recurrence <i>Presence: 99.9% Type: str:general (99.9), str:empty (0.1)</i>	105750
ROOT.volume <i>Presence: 82.8% Type: float (95.9), int (4.1)</i>	104840
ROOT.automaticallyActive <i>Presence: 81.5% Type: bool (100.0)</i>	103195
ROOT.markets.[] .secondsDelay <i>Presence: 34.2% Type: int (100.0)</i>	100673
ROOT.markets.[] .gameStartTime <i>Presence: 33.4% Type: str:general (100.0)</i>	98324
ROOT.markets.[] .negRiskMarketID <i>Presence: 32.0% Type: str:hexadecimal (100.0)</i>	94024
ROOT.markets.[] .oneMonthPriceChange <i>Presence: 30.5% Type: int (83.6), float (16.4)</i>	89813
ROOT.startTime <i>Presence: 69.7% Type: str:timestamp (100.0)</i>	88272
ROOT.series.[] .featured <i>Presence: 79.2% Type: bool (100.0)</i>	83843
ROOT.series.[] .restricted <i>Presence: 78.7% Type: bool (100.0)</i>	83242

Table D.1 – continued from previous page

Path	Total Count
ROOT.series.[] .image <i>Presence: 76.6% Type: str:empty (58.4), str:general (41.6)</i>	81104
ROOT.series.[] .icon <i>Presence: 76.6% Type: str:empty (58.4), str:general (41.6)</i>	81104
ROOT.markets.[] .eventStartTime <i>Presence: 26.5% Type: str:timestamp (100.0)</i>	78103
ROOT.tags.[] .createdBy <i>Presence: 10.4% Type: int (100.0)</i>	76858
ROOT.series.[] .liquidity <i>Presence: 71.8% Type: float (100.0)</i>	75989
ROOT.series.[] .volume <i>Presence: 71.6% Type: float (98.6), int (1.4)</i>	75775
ROOT.markets.[] .oneYearPriceChange <i>Presence: 25.6% Type: int (99.9), float (0.1)</i>	75186
ROOT.markets.[] .volume1wkAmm <i>Presence: 25.5% Type: int (100.0)</i>	75118
ROOT.markets.[] .volume1yrAmm <i>Presence: 25.5% Type: int (100.0)</i>	75118
ROOT.markets.[] .volume1moAmm <i>Presence: 25.5% Type: int (100.0)</i>	75118
ROOT.volume1yr <i>Presence: 58.7% Type: float (77.3), int (22.7)</i>	74284
ROOT.volume1mo <i>Presence: 58.7% Type: float (77.3), int (22.7)</i>	74274
ROOT.volume1wk <i>Presence: 58.5% Type: float (77.1), int (22.9)</i>	74043
ROOT.markets.[] .sportsMarketType <i>Presence: 22.9% Type: str:general (100.0)</i>	67474
ROOT.tags.[] .forceHide <i>Presence: 8.2% Type: bool (100.0)</i>	60671
ROOT.competitive <i>Presence: 47.9% Type: int (92.0), float (8.0)</i>	60616
ROOT.liquidity <i>Presence: 47.8% Type: int (91.0), float (9.0)</i>	60435

Table D.1 – continued from previous page

Path	Total Count
ROOT.liquidityClob <i>Presence: 47.7% Type: int (91.1), float (8.9)</i>	60431
ROOT.markets.[] .volume24hr <i>Presence: 18.9% Type: int (85.6), float (14.4)</i>	55570
ROOT.liquidityAmm <i>Presence: 43.5% Type: int (99.9), float (0.1)</i>	55028
ROOT.markets.[] .volume24hrClob <i>Presence: 17.3% Type: int (84.3), float (15.7)</i>	50866
ROOT.markets.[] .line <i>Presence: 14.8% Type: float (98.3), int (1.7)</i>	43542
ROOT.markets.[] .seriesColor <i>Presence: 14.1% Type: str:empty (99.0), str:general (1.0)</i>	41612
ROOT.markets.[] .volumeAmm <i>Presence: 14.1% Type: int (98.7), float (1.3)</i>	41454
ROOT.markets.[] .volume24hrAmm <i>Presence: 14.0% Type: int (100.0)</i>	41306
ROOT.markets.[] .clobRewards.[] .rewardsAmount <i>Presence: 100.0% Type: int (100.0)</i>	32054
ROOT.markets.[] .clobRewards.[] .id <i>Presence: 100.0% Type: str:integer (100.0)</i>	32054
ROOT.markets.[] .clobRewards.[] .endDate <i>Presence: 100.0% Type: str:timestamp (100.0)</i>	32054
ROOT.markets.[] .clobRewards.[] .conditionId <i>Presence: 100.0% Type: str:hexadecimal (100.0)</i>	32054
ROOT.markets.[] .clobRewards.[] .assetAddress <i>Presence: 100.0% Type: str:hexadecimal (100.0)</i>	32054
ROOT.markets.[] .clobRewards.[] .startDate <i>Presence: 100.0% Type: str:timestamp (100.0)</i>	32054
ROOT.markets.[] .clobRewards.[] .rewardsDailyRate <i>Presence: 100.0% Type: int (100.0), float (0.0)</i>	32054
ROOT.eventDate <i>Presence: 21.4% Type: str:timestamp (100.0)</i>	27116
ROOT.markets.[] .fpmmLive <i>Presence: 9.0% Type: bool (100.0)</i>	26535

Table D.1 – continued from previous page

Path	Total Count
ROOT.markets.[] .wideFormat <i>Presence: 8.8% Type: bool (100.0)</i>	25839
ROOT.markets.[] .fee <i>Presence: 8.8% Type: str:integer (100.0), str:float (0.0)</i>	25829
ROOT.eventWeek <i>Presence: 18.6% Type: int (100.0)</i>	23516
ROOT.markets.[] .readyForCron <i>Presence: 7.8% Type: bool (100.0)</i>	22819
ROOT.period <i>Presence: 16.6% Type: str:general (94.1), str:empty (5.9)</i>	20964
ROOT.markets.[] .sentDiscord <i>Presence: 7.0% Type: bool (100.0)</i>	20529
ROOT.ended <i>Presence: 16.1% Type: bool (100.0)</i>	20316
ROOT.live <i>Presence: 16.0% Type: bool (100.0)</i>	20290
ROOT.score <i>Presence: 15.1% Type: str:general (99.6), str:empty (0.4)</i>	19084
ROOT.markets.[] .notificationsEnabled <i>Presence: 6.2% Type: bool (100.0)</i>	18372
ROOT.sortBy <i>Presence: 14.4% Type: str:general (100.0)</i>	18208
ROOT.gameId <i>Presence: 13.5% Type: int (100.0)</i>	17121
ROOT.elapsed <i>Presence: 13.4% Type: str:empty (96.5), others (3.5)</i>	16898
ROOT.finishedTimestamp <i>Presence: 10.9% Type: str:timestamp (100.0)</i>	13752
ROOT.negRiskMarketID <i>Presence: 9.2% Type: str:hexadecimal (99.9), str:empty (0.1)</i>	11614
ROOT.series.[] .new <i>Presence: 10.1% Type: bool (100.0)</i>	10705
ROOT.markets.[] .gameId <i>Presence: 3.5% Type: str:hexadecimal (55.1), str:integer (44.9)</i>	10354

Table D.1 – continued from previous page

Path	Total Count
ROOT.markets.[] .marketType <i>Presence: 3.4% Type: str:general (100.0)</i>	10072
ROOT.markets.[] .creator <i>Presence: 3.4% Type: str:empty (100.0)</i>	10072
ROOT.deployingTimestamp <i>Presence: 6.7% Type: str:timestamp (100.0)</i>	8511
ROOT.volume24hr <i>Presence: 6.2% Type: int (65.4), float (34.6)</i>	7886
ROOT.series.[] .layout <i>Presence: 7.4% Type: str:general (100.0)</i>	7868
ROOT.series.[] .volume24hr <i>Presence: 7.4% Type: int (100.0)</i>	7816
ROOT.series.[] .publishedAt <i>Presence: 7.4% Type: str:general (100.0)</i>	7816
ROOT.series.[] .competitive <i>Presence: 7.4% Type: str:integer (100.0)</i>	7816
ROOT.series.[] .commentsEnabled <i>Presence: 7.4% Type: bool (100.0)</i>	7816
ROOT.series.[] .updatedBy <i>Presence: 7.3% Type: str:integer (100.0)</i>	7710
ROOT.series.[] .createdBy <i>Presence: 7.3% Type: str:integer (100.0)</i>	7710
ROOT.series.[] .startDate <i>Presence: 6.6% Type: str:timestamp (100.0)</i>	7013
ROOT.gmpChartMode <i>Presence: 5.4% Type: str:general (100.0)</i>	6866
ROOT.homeTeamName <i>Presence: 4.6% Type: str:general (100.0)</i>	5770
ROOT.awayTeamName <i>Presence: 4.6% Type: str:general (100.0)</i>	5770
ROOT.markets.[] .commentsEnabled <i>Presence: 2.0% Type: bool (100.0)</i>	5772
ROOT.markets.[] .updatedBy <i>Presence: 1.9% Type: int (100.0)</i>	5544

Table D.1 – continued from previous page

Path	Total Count
ROOT.markets.[] .umaEndDateIso <i>Presence: 1.7% Type: str:timestamp (100.0)</i>	5124
ROOT.published_at <i>Presence: 4.0% Type: str:general (100.0)</i>	5089
ROOT.markets.[] .category <i>Presence: 1.5% Type: str:general (99.9), str:empty (0.1)</i>	4353
ROOT.markets.[] .takerBaseFee <i>Presence: 1.1% Type: int (100.0)</i>	3313
ROOT.markets.[] .makerBaseFee <i>Presence: 1.1% Type: int (100.0)</i>	3312
ROOT.markets.[] .twitterCardLocation <i>Presence: 1.0% Type: str:general (100.0)</i>	3026
ROOT.markets.[] .twitterCardLastRefreshed <i>Presence: 1.0% Type: str:integer (100.0)</i>	3003
ROOT.category <i>Presence: 2.2% Type: str:general (100.0)</i>	2837
ROOT.markets.[] .mailchimpTag <i>Presence: 0.9% Type: str:integer (90.0), str:null_like (10.0)</i>	2668
ROOT.commentsEnabled <i>Presence: 1.8% Type: bool (100.0)</i>	2246
ROOT.markets.[] .marketGroup <i>Presence: 0.7% Type: int (100.0)</i>	2092
ROOT.parentEventId <i>Presence: 1.3% Type: int (100.0)</i>	1603
ROOT.markets.[] .twitterCardLastValidated <i>Presence: 0.5% Type: str:float (100.0)</i>	1435
ROOT.negRiskFeeBips <i>Presence: 0.8% Type: int (100.0)</i>	999
ROOT.series.[] .description <i>Presence: 0.6% Type: str:general (100.0)</i>	628
ROOT.updatedBy <i>Presence: 0.4% Type: str:integer (100.0)</i>	530
ROOT.featuredImage <i>Presence: 0.4% Type: str:general (66.2), str:empty (33.8)</i>	518

Table D.1 – continued from previous page

Path	Total Count
ROOT.series.[] .cgAssetName <i>Presence: 0.5% Type: str:general (100.0)</i>	512
ROOT.series.[] .pythTokenID <i>Presence: 0.5% Type: str:hexadecimal (100.0)</i>	512
ROOT.series.[] .subtitle <i>Presence: 0.5% Type: str:general (100.0)</i>	512
ROOT.featuredOrder <i>Presence: 0.3% Type: int (100.0)</i>	373
ROOT.markets.[] .categoryMailchimpTag <i>Presence: 0.1% Type: str:null_like (83.1), str:integer (16.9)</i>	308
ROOT.createdBy <i>Presence: 0.1% Type: str:integer (100.0)</i>	182
ROOT.countryName <i>Presence: 0.1% Type: str:general (99.3), str:empty (0.7)</i>	140
ROOT.electionType <i>Presence: 0.1% Type: str:general (100.0)</i>	137
ROOT.tweetCount <i>Presence: 0.1% Type: int (100.0)</i>	134
ROOT.totalsMainLine <i>Presence: 0.1% Type: float (100.0)</i>	99
ROOT.spreadsMainLine <i>Presence: 0.1% Type: float (100.0)</i>	99
ROOT.eventCreators.[] .id <i>Presence: 100.0% Type: str:integer (100.0)</i>	87
ROOT.eventCreators.[] .creatorImage <i>Presence: 100.0% Type: str:general (100.0)</i>	87
ROOT.eventCreators.[] .creatorHandle <i>Presence: 100.0% Type: str:general (100.0)</i>	87
ROOT.eventCreators.[] .creatorUrl <i>Presence: 100.0% Type: str:general (100.0)</i>	87
ROOT.eventCreators.[] .creatorName <i>Presence: 100.0% Type: str:general (100.0)</i>	87
ROOT.eventCreators.[] .createdAt <i>Presence: 100.0% Type: str:timestamp (100.0)</i>	87

Table D.1 – continued from previous page

Path	Total Count
ROOT.markets.[] .subcategory <i>Presence: 0.0% Type: str:general (89.2), str:empty (10.8)</i>	74
ROOT.markets.[] .lowerBound <i>Presence: 0.0% Type: str:integer (78.1), str:float (19.2), others (2.7)</i>	73
ROOT.markets.[] .upperBound <i>Presence: 0.0% Type: str:integer (79.2), str:float (19.4), others (1.4)</i>	72
ROOT.markets.[] .disqusThread <i>Presence: 0.0% Type: str:general (100.0)</i>	68
ROOT.subcategory <i>Presence: 0.1% Type: str:general (98.5), str:empty (1.5)</i>	68
ROOT.markets.[] .formatType <i>Presence: 0.0% Type: str:general (100.0)</i>	66
ROOT.markets.[] .twitterCardImage <i>Presence: 0.0% Type: str:general (100.0)</i>	62
ROOT.sportsradarMatchId <i>Presence: 0.0% Type: str:general (100.0)</i>	47
ROOT.turnProviderId <i>Presence: 0.0% Type: str:integer (100.0)</i>	35
ROOT.disqusThread <i>Presence: 0.0% Type: str:general (100.0)</i>	28
ROOT.gameStatus <i>Presence: 0.0% Type: str:general (100.0)</i>	23
ROOT.markets.[] .groupItemRange <i>Presence: 0.0% Type: str:json_encoded (100.0)</i>	22
ROOT.color <i>Presence: 0.0% Type: str:general (95.2), str:integer (4.8)</i>	21
ROOT.estimateValue <i>Presence: 0.0% Type: bool (100.0)</i>	4
ROOT.cantEstimate <i>Presence: 0.0% Type: bool (100.0)</i>	4
ROOT.carouselMap <i>Presence: 0.0% Type: str:json_encoded (100.0)</i>	4
ROOT.markets.[] .teamBID <i>Presence: 0.0% Type: str:integer (100.0)</i>	4

Table D.1 – continued from previous page

Path	Total Count
ROOT.markets.[] .teamAID <i>Presence: 0.0% Type: str:integer (100.0)</i>	4
ROOT.estimatedValue <i>Presence: 0.0% Type: str:float (100.0)</i>	3
ROOT.markets.[] .sponsorImage <i>Presence: 0.0% Type: str:empty (100.0)</i>	2
ROOT.markets.[] .createdBy <i>Presence: 0.0% Type: int (100.0)</i>	1
ROOT.markets.[] .denominationToken <i>Presence: 0.0% Type: str:empty (100.0)</i>	1

Table D.2: Raw Pairwise Comparison Statistics for CLOB Market Timestamps

T_1	T_2	Pairs (N)	$P(T_1 < T_2)$	$P(T_1 = T_2)$	$P(T_1 > T_2)$
acceptingOrdersTimestamp	closedTime	233 087	100.00	0.00	0.00
acceptingOrdersTimestamp	createdAt	266 051	0.00	0.00	100.00
acceptingOrdersTimestamp	endDate	263 251	98.36	0.00	1.64
acceptingOrdersTimestamp	startDate	263 888	99.69	0.00	0.31
acceptingOrdersTimestamp	umaEndDate	233 022	100.00	0.00	0.00
acceptingOrdersTimestamp	updatedAt	266 051	100.00	0.00	0.00
closedTime	createdAt	259 848	0.00	0.00	100.00
closedTime	endDate	258 742	16.98	0.00	83.02
closedTime	startDate	256 120	0.02	0.00	99.98
closedTime	umaEndDate	257 286	1.06	98.07	0.87
closedTime	updatedAt	259 848	99.99	0.01	0.00
createdAt	endDate	291 388	97.87	0.00	2.13
createdAt	startDate	290 272	93.83	0.19	5.98
createdAt	umaEndDate	257 297	99.90	0.00	0.10
createdAt	updatedAt	293 018	100.00	0.00	0.00
endDate	startDate	287 460	2.24	0.72	97.04
endDate	umaEndDate	256 223	82.24	0.88	16.89
endDate	updatedAt	290 166	77.45	0.00	22.55
startDate	umaEndDate	254 373	99.21	0.77	0.02
startDate	updatedAt	289 086	99.58	0.42	0.00
umaEndDate	updatedAt	257 297	99.91	0.00	0.09