Analysing 100 Scandinavian Blue Chip Stocks

Itarle Quants Test

$C++$ Dataset Preprocessing

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Contents

Introduction

This report presents a comprehensive analytical study of statistical metrics derived from a dataset containing 4 days' worth of tick data for 100 Scandinavian blue-chip stocks. The dataset, accessed via AWS and organised into a substantial CSV file, was provided as part of a key recruitment task for Quantitative Analysts at Itarle. This task is designed to simulate the daily responsibilities of the Quantitative Strategies and Development Team.

The preprocessing and extraction of metrics from this dataset were executed using C++, which will be attached at the end of this report. The study focuses on several critical metrics: the time between trades, tick changes, bid-ask spreads, and the round number effect.

By examining these parameters, the study aims to uncover patterns and inefficiencies within the market, thereby contributing valuable insights to both theoretical research and practical applications in algorithmic trading. This task not only provides a clearer understanding of the role but also reflects real-world analytical challenges encountered in the position.

Investigation Outline

Data Overview

The dataset used in this analysis includes several columns that capture various statistical metrics for each stock. To ensure the accuracy of the results, periods with no trading activity are excluded. The columns in the dataset are described as follows:

- **Stock Name**: The stock name for each stock.
- **Mean Time Between Trades**: The average duration, in seconds, between consecutive trades for a specific stock.
- **Median Time Between Trades**: The median value of the time intervals between trades, providing a central tendency measure that is less susceptible to outliers.
- **Mean Time Between Tick Changes**: The average duration, in seconds, between observed changes in tick type for each stock.
- **Median Time Between Tick Changes**: The median interval between tick changes, offering a robust measure of typical market movement.
- **Longest Time Between Trades**: The maximum observed duration between consecutive trades, indicative of periods of low liquidity or market inactivity.
- **Longest Time Between Tick Changes**: The longest recorded interval between tick changes, reflecting periods of market momentum shifts or heightened volatility.
- **Mean Bid-Ask Spread**: The average difference between the bid price (the highest price a buyer is willing to pay) and the ask price (the lowest price a seller will accept), reflecting market liquidity and transaction costs.

- **Median Bid-Ask Spread**: The median bid-ask spread, providing a robust measure of typical spread values, less influenced by extreme fluctuations.

- **Round Number Effect**: A metric designed to capture the influence of round numbers on stock prices, typically reflecting psychological barriers or support levels in market trading behaviour.

Quantitative Techniques

To analyse the dataset, several quantitative techniques are employed to extract meaningful insights:

- **Descriptive Statistics**: Key metrics, including mean, median, and range, are computed for each stock to summarise the dataset. This encompasses measures of central tendency, dispersion, and extreme values to identify patterns, trends, and anomalies.

- **Correlation Analysis**: This technique explores the relationships between different metrics, with particular focus on the interaction between bid-ask spreads and time-based metrics (such as time between trades and tick changes). Correlation coefficients are computed to determine the strength and direction of associations between these variables.

- **Plot Analysis**: Graphical tools such as scatter plots, histograms, and scatter charts are utilised to visually represent data distribution and relationships between variables. These plots assist in detecting trends, clusters, and outliers that may not be immediately evident from descriptive statistics alone.

This methodological approach provides a structured framework for examining the dataset, facilitating a comprehensive understanding of the dynamics of Scandinavian blue-chip stocks, and supporting the development of data-driven trading strategies.

Analysing and Findings

Visualisations of Statistic Metrics

Mean and Median Time between Trade

Histograms are presented below to visualise the distribution of time-related metrics between trade executions.

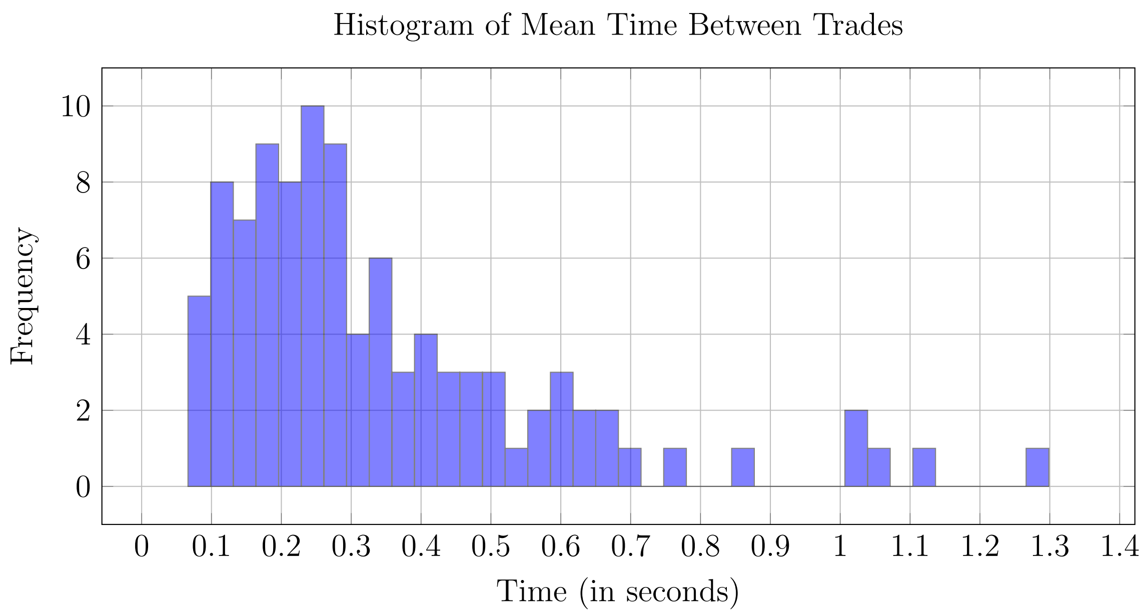

Figure 1: Distribution of Mean Time Between Trades

As shown in Figure 1, the distribution of mean inter-trade times for the 100 analysed stocks peaks around 0.25 seconds, followed by a gradual decay as the time between trades increases. This behaviour closely resembles an exponential decay pattern, which is indicative of the stochastic nature of trade occurrences.

The clustering of trades within short time intervals implies a high frequency of rapid trades, consistent with highly liquid markets. This pattern aligns with the characteristics of high-frequency trading (HFT) environments, where market activity tends to occur in concentrated bursts, driven by algorithms executing trades in rapid succession. Between these bursts, the intervals of reduced trading activity reflect market pauses, possibly due to price discovery processes or traders adjusting to new information.

It is also noteworthy that the median time between trades appears to be zero across all stocks, which may indicate limitations in data resolution of trades at the same timestamp, particularly in HFT environments. This presents challenges in generating informative plots or accurately fitting models.

Additionally, the fact that the mean inter-trade time is influenced by longer trade intervals suggests that the overall distribution is skewed. This indicates that while most trades occur in rapid succession, infrequent longer gaps between trades are pulling the mean higher. As a result, using the mean alone may obscure the true dynamics of trade intensity, and other metrics, such as the mode or percentiles, could offer more informative insights into the typical trading behaviour.

Mean and Median Time between Tick Changes

A tick represents the smallest incremental change in the price of a stock, signifying that the price has either increased or decreased. When a tick change occurs, it reflects movement in the stock price, and the time interval between successive tick changes provides valuable insights into the market's volatility.

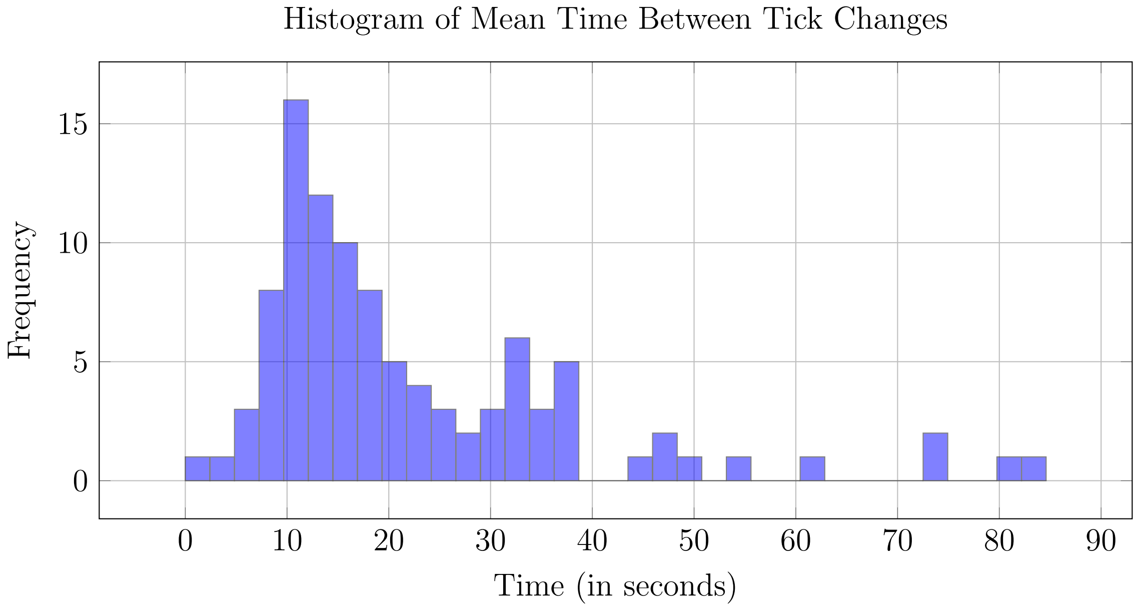

Figure 2: Distribution of Mean Time Between Tick changes

In Figure 2, the mean tick time across the 100 investigated stocks exhibits a peak at approximately 10 seconds before gradually decreasing. This trend is notably similar to the pattern observed in Figure 1, yet with a generally longer time range. This implies that market volatility is usually signified only after successive trades have been computed. Therefore, this may be one reason why average moving trends always lag slightly behind the true stock price trends.

As expected, the alignment between the mean time between tick changes and the time between trades suggests a potential relationship between trade frequency and market volatility, which will be investigated in later sections. Nonetheless, this dynamic is consistent with the general principle that heightened trading activity, driven by rapid buy/sell decisions, often correlates with higher market volatility.

It is also noteworthy that this plot somewhat resembles a Poisson distribution, which is unusual for a complex market environment. This resemblance is intriguing because Poisson processes typically model random events in a homogeneous environment, whereas financial markets are influenced by a variety of factors and exhibit more complexity.

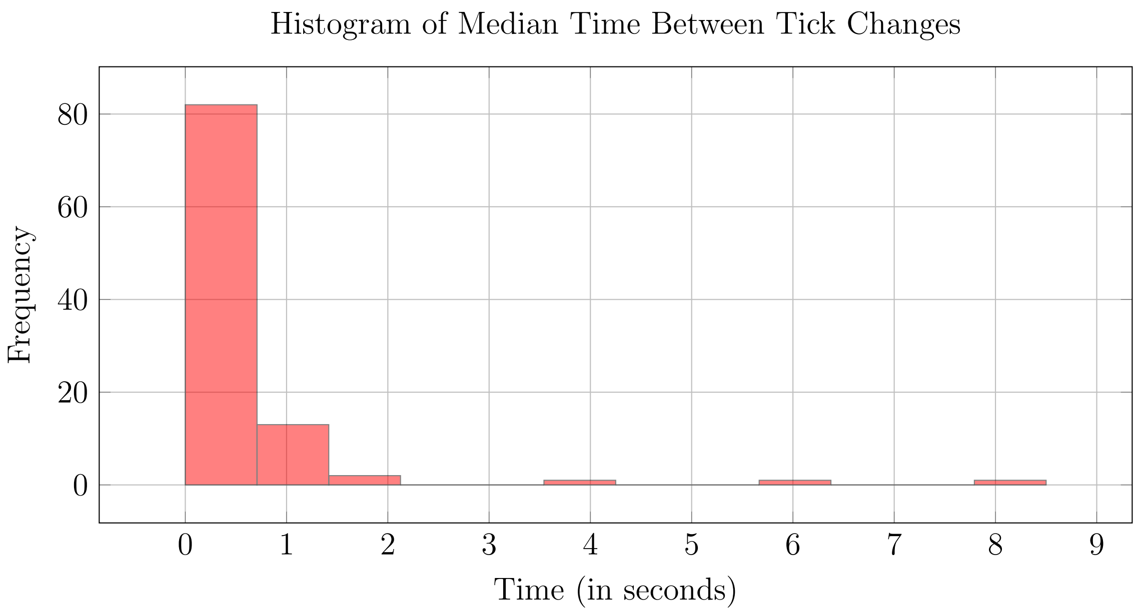

Figure 3: Distribution of Median Time Between Tick Changes

Similar to the pattern observed in trading times, the median time between tick changes is also consistently reported as zero for 80 out of the 100 stocks analysed. This prevalence of zero median tick times suggests that a substantial proportion of tick changes occur in rapid succession, reflecting HFT activity and possibly indicating that many tick changes happen within the same millisecond.

This observation implies that market volatility may be higher than initially expected. The zero median time between tick changes indicates frequent price updates and rapid market movements, which are characteristic of high volatility. In such cases, the market is experiencing constant price adjustments, suggesting heightened trading activity and potentially greater uncertainty or market stress.

Again, the zero median time might point to the limitations of data resolution in capturing the precise intervals between tick changes. To gain a more accurate understanding of volatility, it may be necessary to employ finer-grained data or advanced statistical techniques that can accurately model these high-frequency events.

Longest Time between Trades and between Tick Changes

The two histograms, representing "Longest Time Between Trades" and "Ticks," provide a detailed view of the distribution of outliers. As highlighted in earlier discussions, these histograms reveal the frequency and range of extreme values, offering insights into the causes of anomalies within the data.

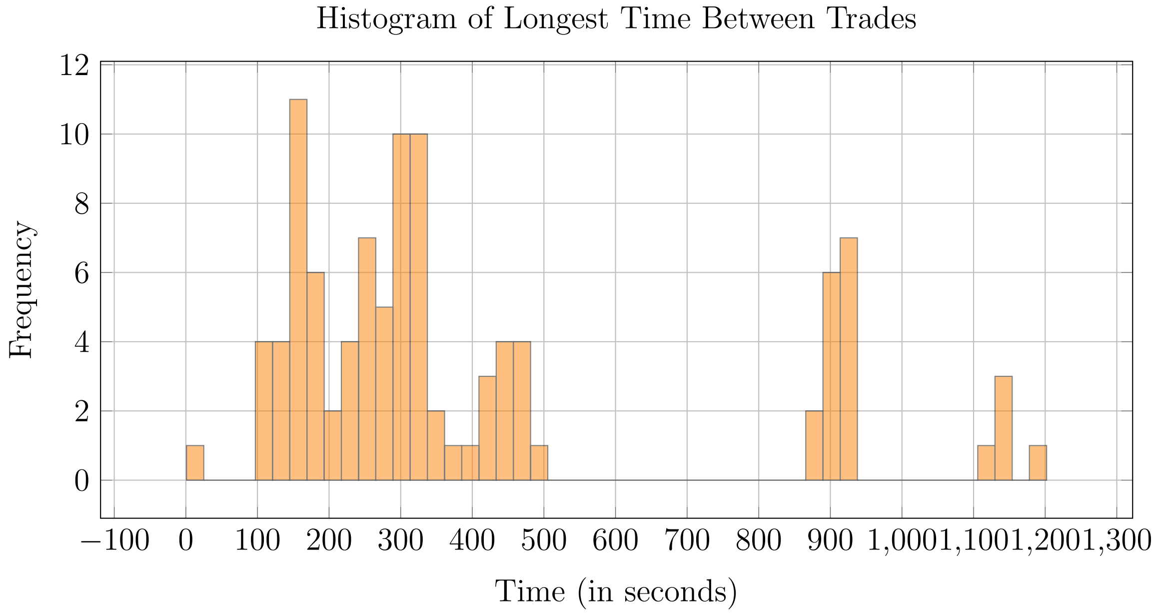

Figure 4: Distribution of Longest Time Between Trades

Observing Figure 4, the distribution of the longest inter-trade times across 100 stocks reveals a concentration primarily within the 100 to 500 seconds range, with a prominent peak at approximately 150 seconds. This aligns with the expected timeframes observed in high-frequency trading (HFT) environments, where the rapid execution of trades leads to relatively short inter-trade durations.

Interestingly, the histogram also exhibits significant secondary peaks around the 900 and 1100 seconds intervals. These outliers are likely associated with day traders, whose strategies typically involve holding positions for extended periods within a single trading session. Unlike HFTs, which focus on exploiting minor, short-term price inefficiencies, day traders aim to capitalise on larger price movements throughout the day. The longer inter-trade times observed here may reflect their more deliberate approach, contrasting with the rapid, continuous trading patterns characteristic of HFT strategies.

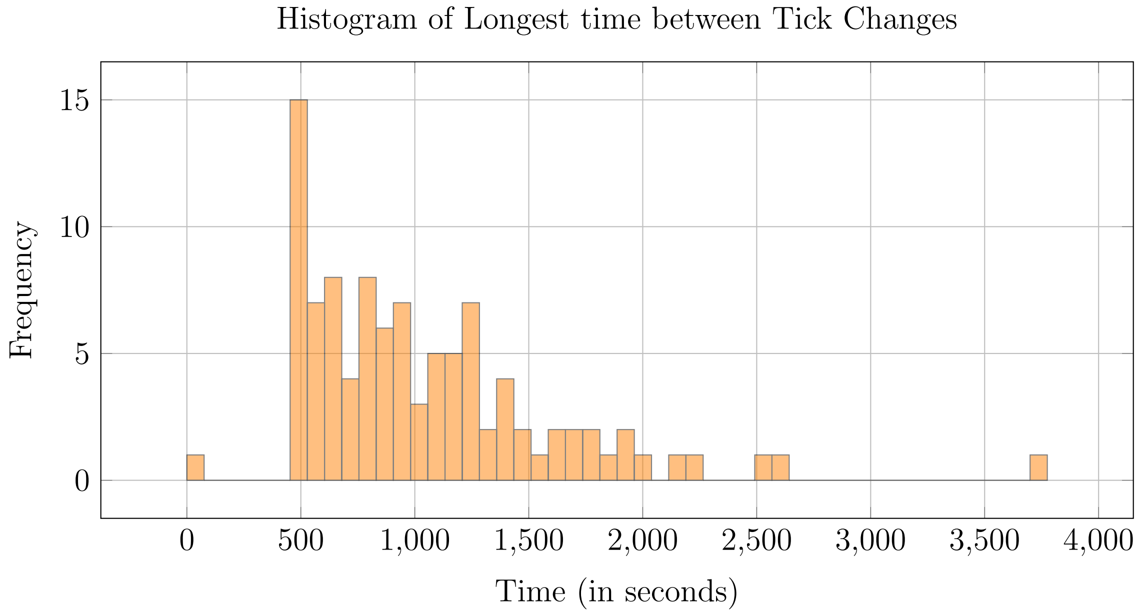

Figure 5: Distribution of Longest Time Between Tick Changes

Figure 5 shows that the distribution of the longest intervals between tick changes follows a characteristic exponential decay, with a peak occurring around 500 seconds, followed by a gradual decline over time. This pattern is notable because the average duration between tick changes tends to be longer than the time between trades, as previously discussed. This distinction underscores how market volatility evolves over time, particularly in periods following active trading.

Further exploration of these inter-tick time distributions can provide deeper insights into market dynamics and trading behaviours. For example, understanding how the time between tick changes is distributed can aid in evaluating the influence of various trading strategies on market liquidity and volatility. Such analysis may also help to assess the market's response to different trading volumes, revealing how quickly price adjustments occur in reaction to trades or external market forces.

Mean and Median of Bid-Ask Spread

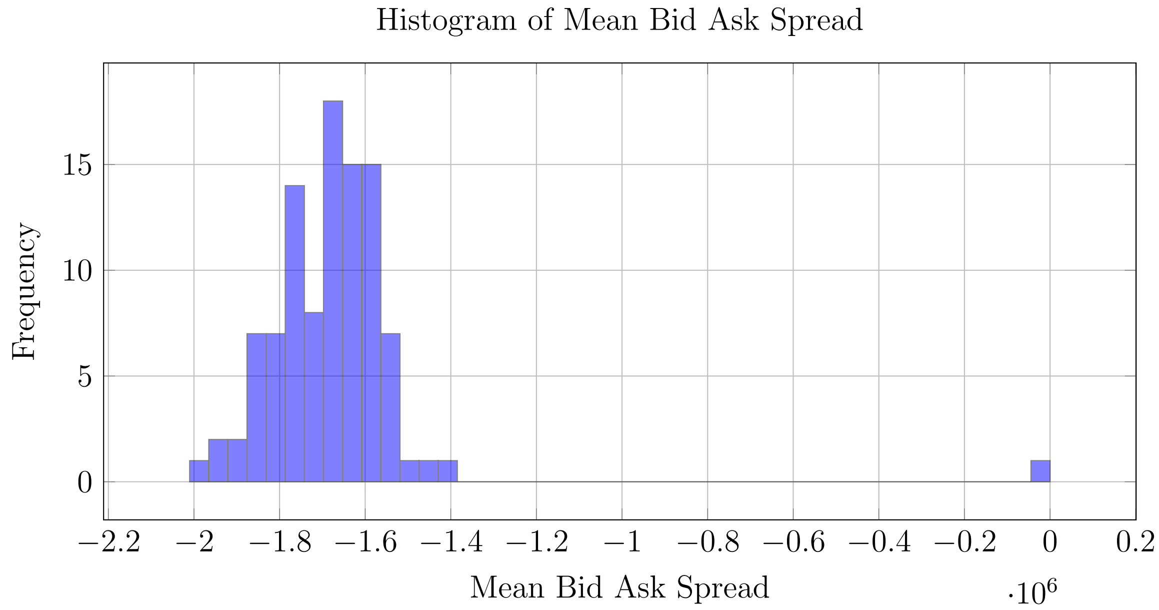

Figure 6: Distribution of Mean Bid Ask Spread

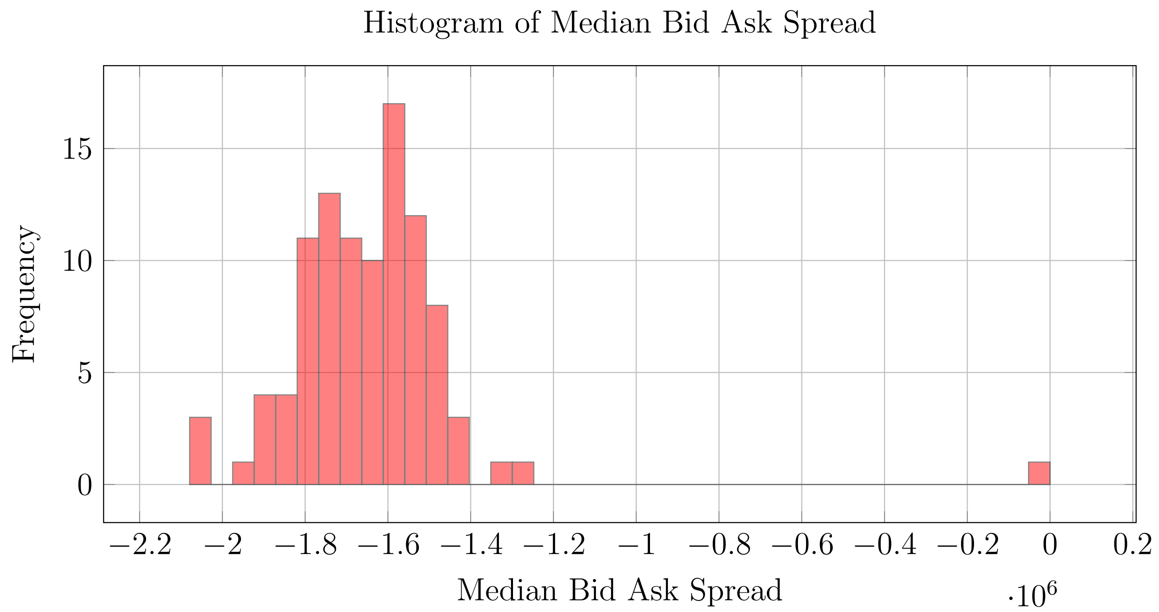

Figure 7: Distribution of Median Bid Ask Spread

To visualise the distribution of the Bid-Ask Spread, histograms of key variables are presented. These histograms are instrumental in assessing market liquidity and the cost of trading.

Initially, it is essential to highlight that all stocks in the dataset display a consistently negative bid-ask spread, whether measured by mean or median values. This anomalous finding suggests that bid prices exceed ask prices across the entire dataset.

Several factors could account for this irregularity:

- **Data Error**: There may be inaccuracies or delays in the reporting of bid and ask prices, leading to erroneous spread values.
- **Liquidity Issues**: The market might be experiencing periods of low liquidity, which could result in atypical or unreliable bid and ask prices.
- **Order Book Imbalance**: Temporary discrepancies in the order book could produce misleading bid-ask spreads.

This situation is unusual, as bid prices typically exceed ask prices only during auction periods or in specific market conditions. Since excluding such outliers would distort the dataset and fail to fulfil the task's objectives, no adjustments will be made at this stage. The data will be analysed as is, acknowledging the presence of these anomalies and considering their potential impact on the findings.

The bid-ask spreads tend to follow a normal distribution for both mean and median values. This is demonstrated by the histograms in Figures 6 and 7, which show a central tendency around a negative spread of approximately -1.6×10^6. The full distribution ranges from -2.8×10^6 to 0. This pattern indicates a predominance of negative bid-ask spreads, with data clustering around a central value in a distribution that resembles a normal curve, albeit shifted into the negative range.

Given the validity of these results, further investigation into the causes behind this balanced price spread and the observed normal distribution is warranted, as it is unusual to observe such steady simple models in the trading market. Such exploration could uncover underlying mechanisms driving this phenomenon and enhance our understanding of stock price spreads.

Round Number Effects RNE

The following histograms plot examine the potential effects of the round number effect, when the last digit of trade prices is 0, on both trade prices and volumes. These analyses offer valuable insights into market behavior around psychologically significant price levels, where traders may exhibit biases or preferences. By investigating this phenomenon, we can better understand how round numbers might influence trading patterns and decision-making processes in financial markets.

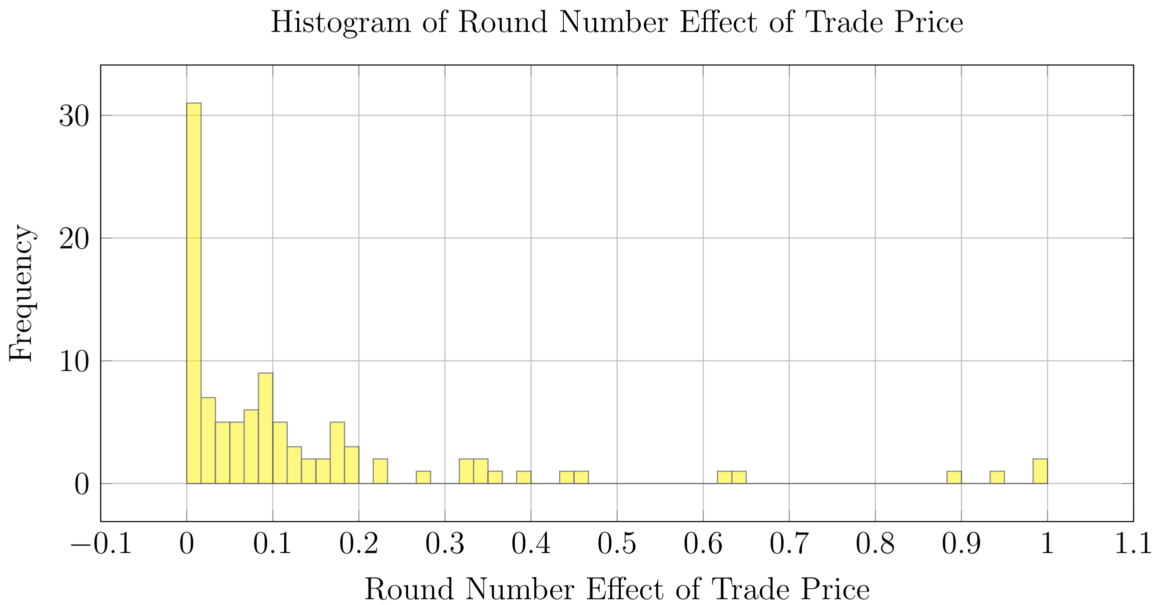

Figure 8: Distribution of RNE of Trade Price

The data presented in Figure 8 reveals that instances of the round number effect as a percentage are relatively low, exhibiting a trend centred around the zero point as percentages increase. This pattern indicates that there is insufficient evidence to support a significant impact of the round number phenomenon on trading prices. Consequently, the analysis suggests that the influence of round numbers on price movements may be weaker than previously assumed.

However, with that said, the round number effect on trading prices should not be neglected when investigating specific stocks. Especially for the instances of the 2 - 3 stocks located in the 90% to 100% tail, which imply that nearly all the trade prices executed are round numbers. Specific studies can be performed to highlight this characteristic in order to maximise returns.

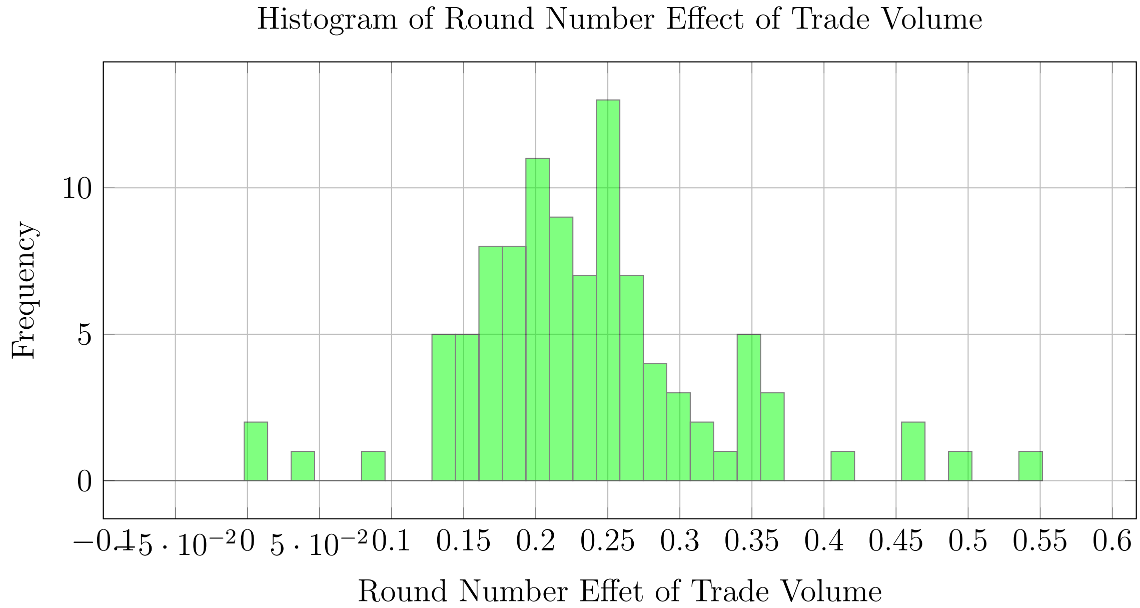

Figure 9: Distribution of RNE of Trade Volume

From Figure 9, it can be observed that the frequency of the round number effect in trade volumes peaks between 20% and 25%. While this effect is not overwhelmingly strong, there appears to be a clearer tendency for most trade volumes to end in round numbers. In contrast to the pattern seen with trade prices, there is still a noticeable occurrence of the round number effect across the board, and even at higher percentage ranges (>0.30%) with 2 to 3 instances.

Furthermore, it is noteworthy that only 3 out of the 100 stocks exhibit no round number effect in their trade volumes, indicating that this phenomenon is relatively widespread across the dataset. This suggests that round numbers play a non-negligible role in shaping the trade volume patterns of most stocks.

Extra Visualisations

This section is an additional area for further investigation, which is not included in the original task. Analysis in this section is based on the condition where trades during the auction period with an empty condition code are excluded. As a result, only eCross trades are analysed for this period. This approach was discovered after several trials to improve the representativeness of the data by eliminating potential distortions caused by auction trades.

Mean and Median Time between Type Changes

Given that trading action types reflect underlying market behaviour, analysing the time between changes in these types can offer significant insights into shifts in market pressure.

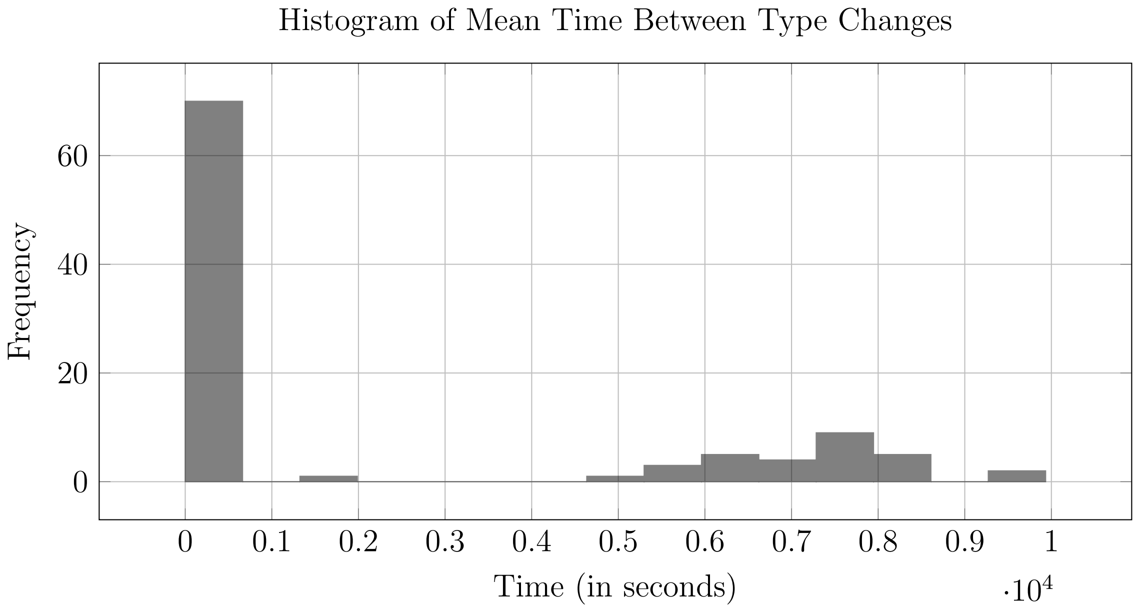

Figure 10: Distribution of Mean Time Between Type changes

From Figure 10, we observe a significant clustering of the mean time between type changes around 0 to 500 seconds. This indicates that trading type, or shifts in market pressure, is highly dynamic and subject to frequent fluctuations, which aligns with our previous analyses.

However, we also observe smaller peaks in the 5000 to 9000 seconds range. This is particularly interesting, as it suggests that during these intervals, market trends are more uniform and less subject to rapid changes. One plausible explanation for this phenomenon could be iceberg trading, where large trade orders are broken into smaller segments and executed over a period of 1-2 hours, resulting in a prolonged, steady directional shift in the market. Another possible explanation might be a "black swan" event, where unforeseen factors, such as the sudden merger of two companies, cause a sharp and sustained movement in the market in a single direction.

It is important to note that the median time between type changes for all observed stocks is zero, which complicates the generation of meaningful plots based on the median. This outcome is, however, expected given the mean time graph. Nonetheless, the deviations marked by the smaller peaks in the time series warrant further investigation. These anomalies could represent outliers and are likely related to the suggested mechanisms, underscoring the need for additional analysis.

Visualisation of Correlation Analysis

The following section will focus on exploring correlations between various statistical metrics. Analysing these relationships will provide valuable insights into how pricing dynamics interact within the market. By uncovering underlying patterns and correlations, we can enhance our understanding of market behaviour and pricing mechanisms.

Mean inter-Trade and inter-Tick Time Correlations

As discussed in previous sections, we can analyse the relationship between inter-trade and inter-tick times to examine the correlation between trading frequency and market volatility.

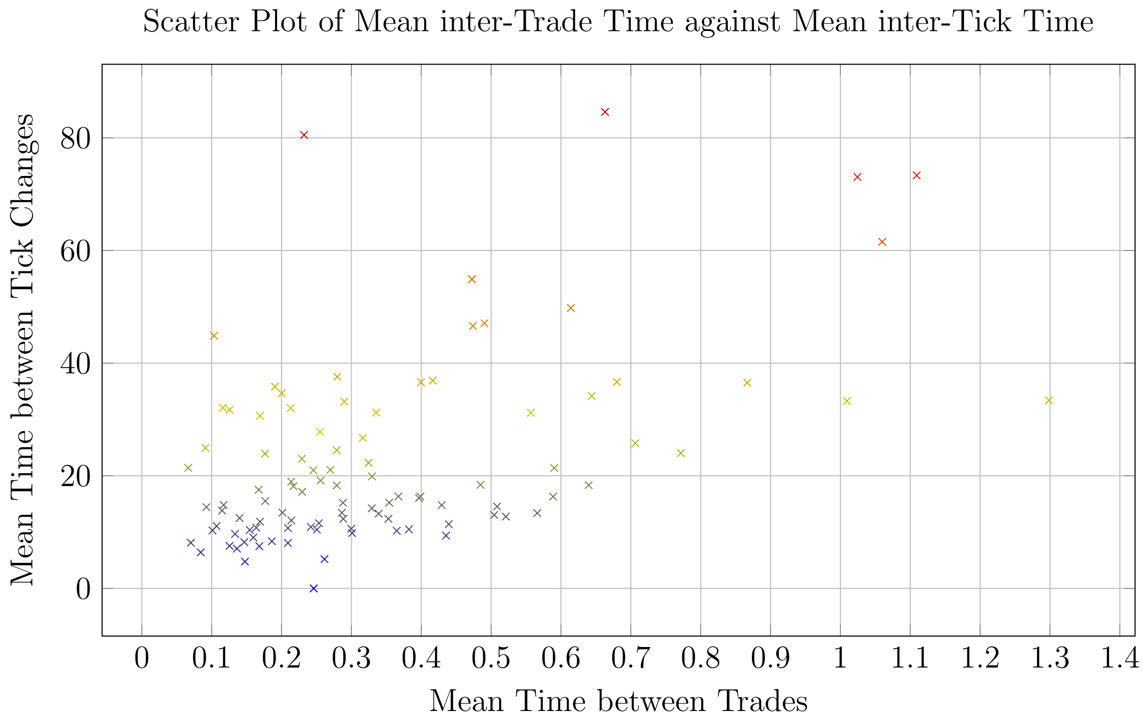

Figure 11: Mean inter-Trade and inter-Tick Time Relation

In Figure 11, a clear linear trend is observed, supporting our assumption of a positive correlation between inter-trade time and inter-tick-change time. This suggests that higher trade frequency often coincides with shorter intervals between price changes, indicating a relationship between trade frequency and market volatility. It would be optimal to apply a simple linear regression line to illustrate a more intuitive plot, but this will be done when time allows.

This correlation can be understood within the context of market microstructure theory, where increased trading activity tends to reflect greater information flow or shifts in market sentiment, both of which contribute to heightened volatility. In such cases, traders react to new information more rapidly, causing frequent price adjustments and, in turn, amplifying market fluctuations.

It is important to note, however, that trade frequency is not the only factor affecting market volatility. Other significant drivers include liquidity conditions, order book depth, and external market events such as macroeconomic news releases or geopolitical developments.

Mean inter-Time Metrics and Bid-Ask Spread Correlations

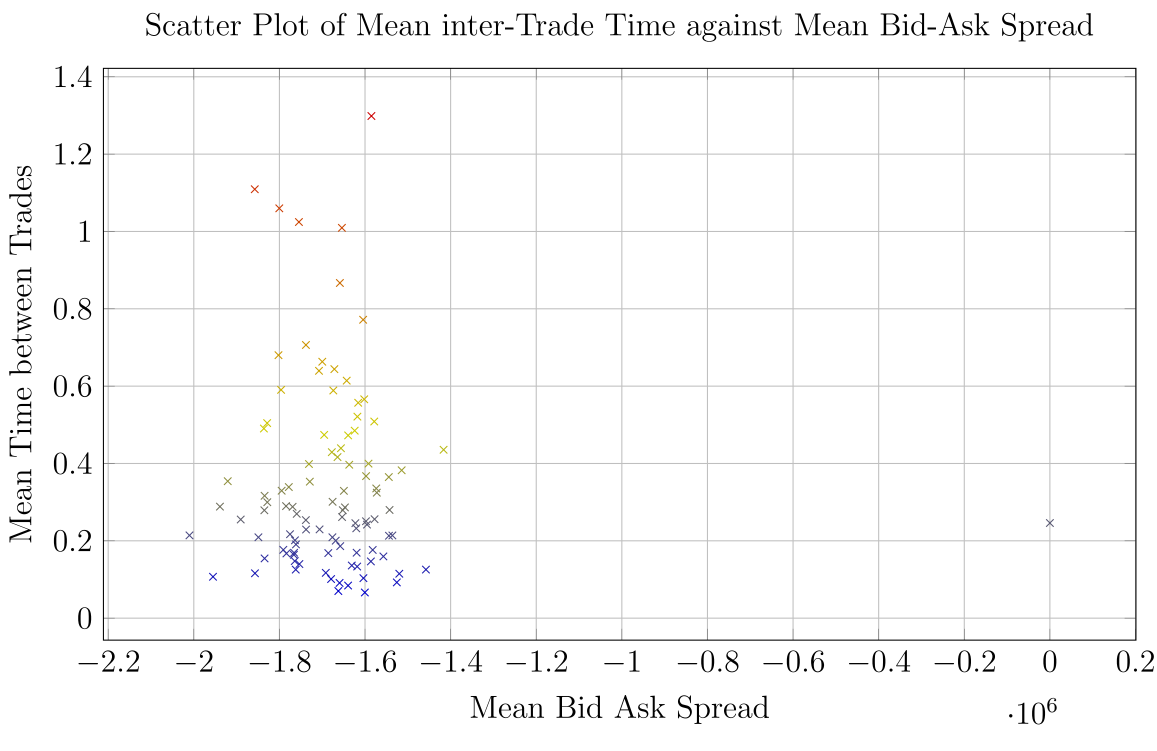

Figure 12: Mean inter-Trade Time against Mean Bid-Ask Spread Relation

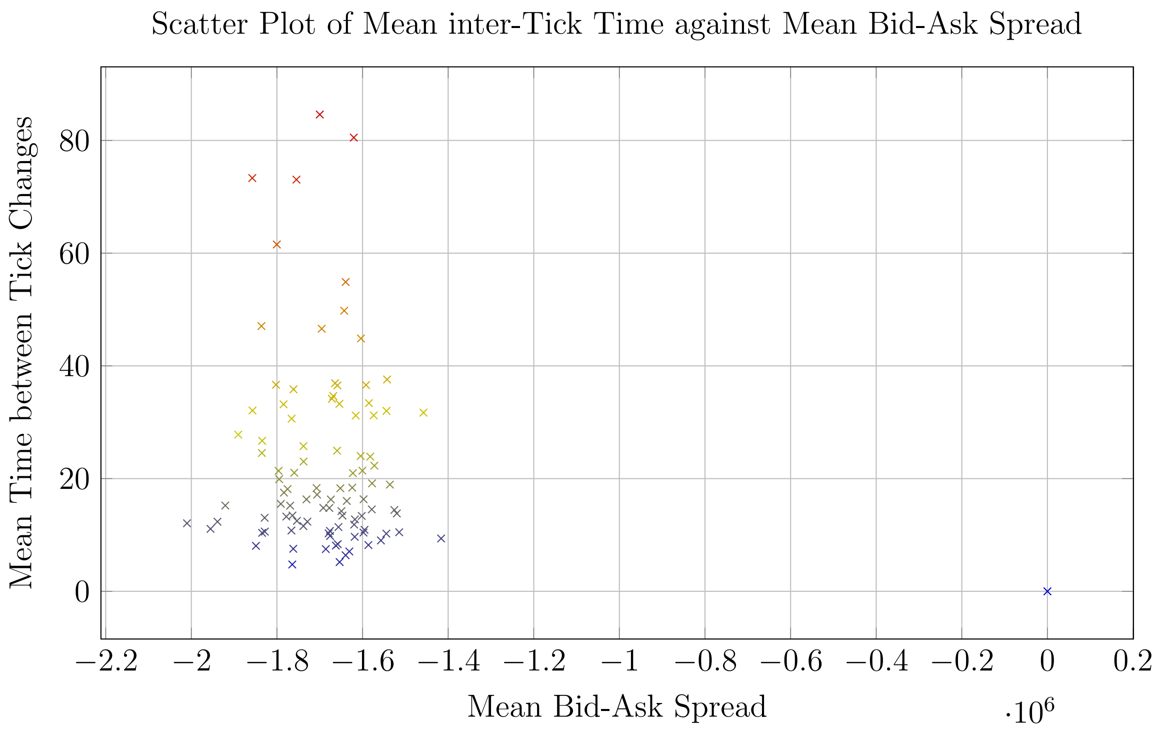

Figure 13: Mean inter-Tick Time against Mean Bid-Ask Spread Relation

Based on the analysis of Figures 12 and 13, there is no discernible correlation between the time intervals between trades or tick changes and the mean bid-ask spread. The scatter plots exhibit a predominantly vertical dispersion of data points, indicating that variations in the mean bid-ask spread are independent of the time elapsed between trades or tick changes. This pattern suggests that fluctuations in the bid-ask spread do not show a significant correlation with the frequency or timing of trading activity or tick updates.

This lack of correlation is surprising, given that one might expect a positive correlation between trading activity and bid-ask spread, as increased liquidity is often associated with higher trading frequencies. However, the observed Figure 6, where bid-ask spreads are entirely negative, could imply some specific special cases. Therefore, this situation might obscure potential correlations between the bid-ask spread and trading or tick update frequencies, leading to the observed lack of correlation.

Mean inter-Time Metrics and Round Number Effect (RNE) Correlations

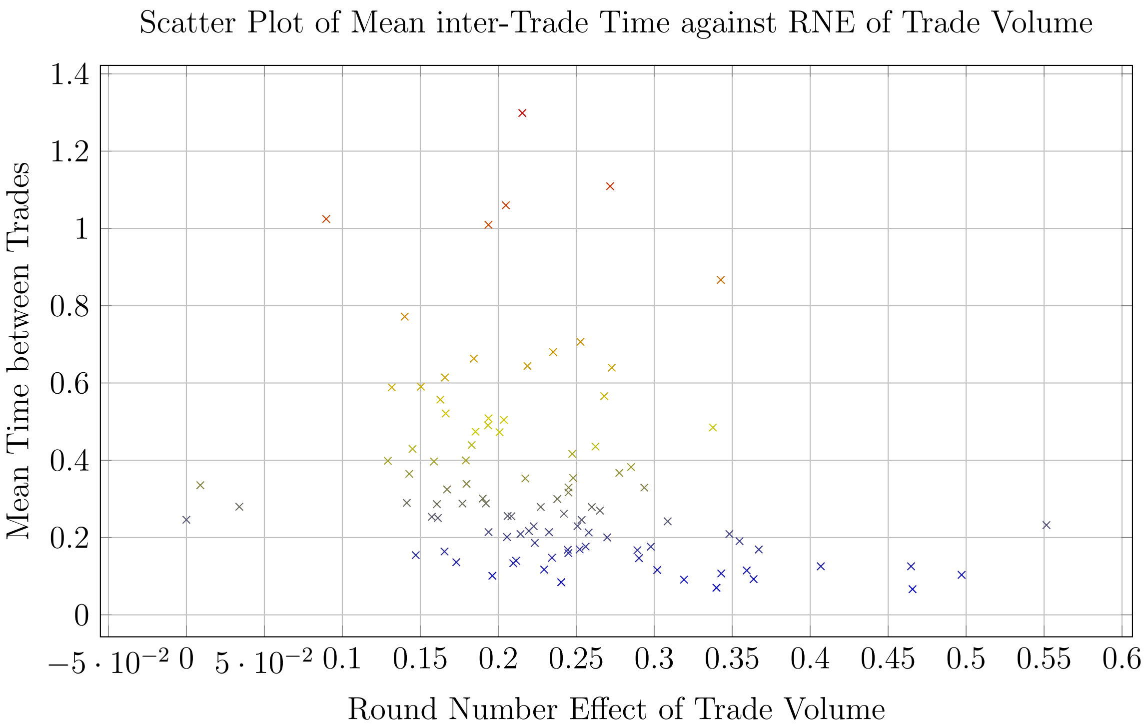

Figure 14: Mean inter-Trade Time against RNE of Trade Volume Relation

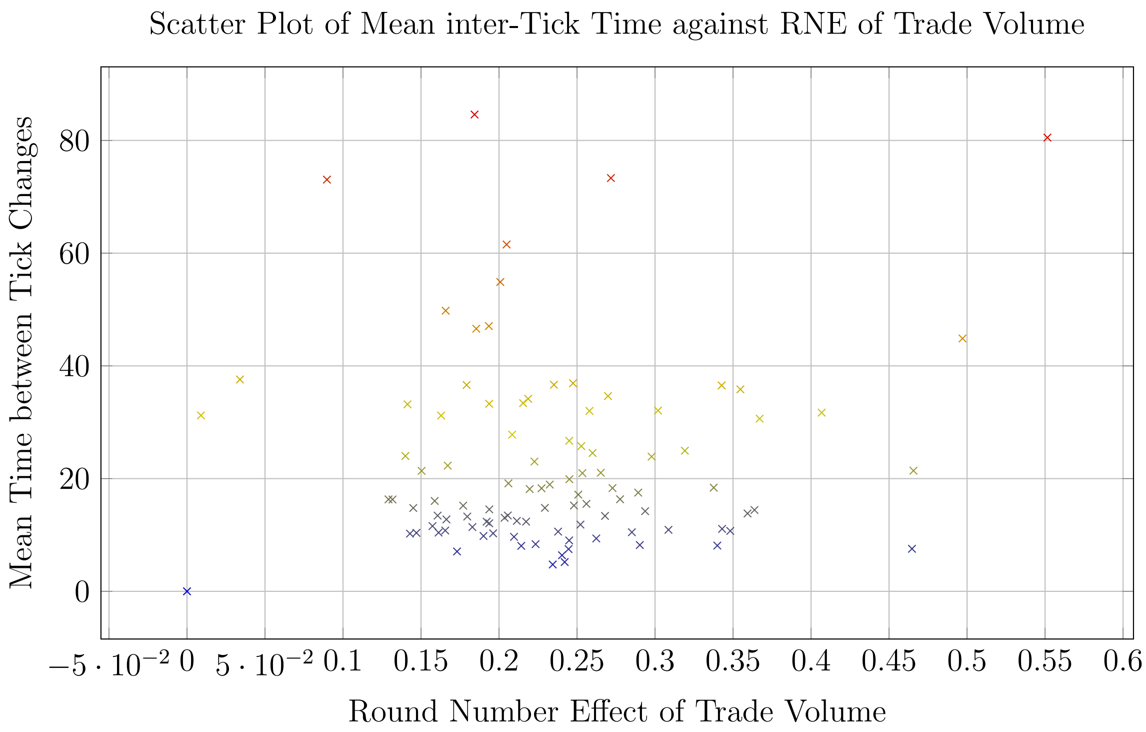

Figure 15: Mean inter-Tick Time against RNE of Trade Volume

Analysing Figures 14 and 15 reveals that there is no significant correlation between the relative number of events (RNE) in trade volume and the time intervals between trades or tick changes. This lack of correlation indicates that the presence of round numbers does not influence either the timing of trades or the frequency of tick changes in the observed data.

This finding implies that round numbers may not play a critical role in affecting trading patterns or market microstructure as previously hypothesised. It is surprising because one might expect that psychological factors associated with round numbers could influence trading behaviour, potentially impacting the timing and frequency of trades. However, the absence of this effect in the data suggests that other factors may be more influential in driving these trading metrics.

Conclusion

Overall, these findings provide a comprehensive overview of trading metrics, highlighting the complexity of market dynamics and the need for refined datasets or techniques to capture the true nature of trading behaviours and volatility. The analysis of trading metrics across 100 stocks reveals several key findings:

Inter-Trade Times:
The distribution of mean inter-trade times peaks around 0.25 seconds, resembling an exponential decay, indicative of high-frequency trading (HFT) environments where trades occur in rapid bursts. The median time between trades is consistently zero, suggesting potential data resolution limitations. The mean inter-trade time is skewed by infrequent longer intervals, highlighting that alternative metrics such as the mode or percentiles may better represent typical trading behaviour.

Tick Times:
The mean tick time peaks at approximately 10 seconds and exhibits a similar exponential decay pattern to the inter-trade times, but with generally longer durations. This suggests that market volatility becomes evident only after several trades have been executed, leading to a lag in average trends relative to actual price changes. The median tick time is also zero for 80 out of 100 stocks, indicating rapid tick changes and possibly high volatility. This zero median time reflects challenges in data resolution, suggesting the need for finer-grained data for accurate volatility analysis.

Longest Inter-Trade Times:
The distribution of the longest inter-trade times shows a concentration between 100 and 500 seconds, with significant secondary peaks around 900 and 1100 seconds. This pattern indicates the presence of day traders who hold positions longer, contrasting with the rapid trading typical of HFT strategies.

Longest Inter-Tick Times:
The distribution follows an exponential decay with a peak around 500 seconds. This

longer duration between tick changes compared to trades underscores evolving market volatility, especially following periods of active trading.

Bid-Ask Spread:
All stocks in the dataset show a negative bid-ask spread, which is unusual and may result from data errors, liquidity issues, or order book imbalances. The spread follows a normal distribution with a central tendency around -1.6×10^6, suggesting a predominance of negative values and warranting further investigation into the causes of this anomaly.

Round Number Effect:
The analysis of round number effects shows a low incidence in trade prices but a noticeable frequency in trade volumes, peaking between 20% and 25%. This effect is present in most stocks, indicating that round numbers influence trade volumes more than prices. Specific stocks exhibiting strong round number effects should be further investigated to understand their impact on trading strategies.

Time Between Type Changes:
The mean time between type changes clusters around 0 to 500 seconds, with smaller peaks at 5000 to 9000 seconds. This suggests that market trends are subject to rapid fluctuations but also exhibit prolonged steady shifts during certain intervals, possibly due to iceberg trading or significant market events.

Correlation Insights:
The analysis shows a positive correlation between inter-trade and inter-tick-change times, indicating that higher trade frequency is associated with shorter intervals between price changes. However, there is no significant correlation between bid-ask spread and trade or tick timings, suggesting that the spread does not vary with trading activity. Additionally, there is no significant correlation between the relative number of round number events and the timing of trades or tick changes.

Appendix: C++ Code

```
#include <iostream>
#include <fstream>
#include <string>
#include <sstream>
#include <map>
#include <vector>
#include <cmath>
#include <algorithm>
#include <tuple>
#include <iomanip>

using namespace std;

// Function to split a string by a specific delimiter
vector<string> split(const string &line, char delimiter) {
    vector<string> tokens;
    stringstream ss(line);
    string token;
    while (getline(ss, token, delimiter)) {
        tokens.push_back(token);
    }
    return tokens;
}

// Function to compute the mean of a vector of doubles
double mean(const vector<double> &values) {
    if (values.empty()) return 0.0;
    double sum = 0.0;
    for (double v : values) sum += v;
    return sum / values.size();
}

// Function to compute the median of a vector of doubles
double median(vector<double> values) {
    if (values.empty()) return 0.0;
```

```
    nth_element(values.begin(), values.begin() + values.size() / 2, values.end());
    if (values.size() % 2 == 0) {
        nth_element(values.begin(), values.begin() + values.size() / 2 - 1, values.end());
        return (values[values.size() / 2 - 1] + values[values.size() / 2]) / 2.0;
    }
    return values[values.size() / 2];
}

// Function to compute the bid-ask spread
inline double computeBidAskSpread(double askPrice, double bidPrice) {
    return askPrice - bidPrice;
}

// Function to check if the condition indicates an auction period
bool exclusionPeriods(const double &bidPrice, const double &askPrice, const int &tradeVolume, const string &conditionCode) {
    return (tradeVolume == 0 || (bidPrice > askPrice && conditionCode != "XT" && conditionCode != ""));
}

int main() {
    // Open input CSV file containing tick data
    ifstream infile("scandi/scandi.csv");

    // Map to store stock data (keyed by stock ID)
    map<string, vector<tuple<double, double, double, int, int, string, int>>> stockData;
    // Dummy item
    string line;

    // Read and process CSV data line by line
    while (getline(infile, line)) {
        auto tokens = split(line, ',');

        double bidPrice = stod(tokens[1]);
        double askPrice = stod(tokens[2]);
        int tradeVolume = stoi(tokens[7]);
        string conditionCode = tokens[14];

        if (exclusionPeriods(bidPrice, askPrice, tradeVolume, conditionCode)) {
            continue;
        }

```

```
        string stockId = tokens[0];
        double tradePrice = stod(tokens[3]);
        int updateType = stoi(tokens[8]);
        int time = stoi(tokens[11]); // Timestamp

        stockData[stockId].emplace_back(bidPrice, askPrice,
           tradePrice, tradeVolume, time, conditionCode, updateType)
           ;
    }
    infile.close();

    // Open output CSV file
    ofstream outfile("output2.csv");

    // Write header to output file
    outfile << "Stock ID,Mean Time Between Trades,Median Time
       Between Trades,Mean Time Between Tick Changes,Median Time
       Between Tick Changes,"
               "Longest Time Between Trades,Longest Time Between
                  Tick Changes,Mean Bid Ask Spread,Median Bid Ask
                  Spread,"
               "Price Round Number Effect,Volume Round Number Effect
                  ,Mean Time Between Type Changes,Median between
                  Type Changes\n";

    // Process each stock's data for analysis
    for (const auto &entry : stockData) {
        const string &stockId = entry.first;
        const vector<tuple<double, double, double, int, int, string,
            int>> &data = entry.second;

        vector<double> tradeTimes, tickTimes, bidAskSpreads,
           typeTimes, tradePrice;
        double zeroAsPriceLastDigit_Count = 0.0,
           nonzeroAsPriceLastDigit_Count = 0.0;
        double zeroAsVolumeLastDigit_Count = 0.0,
           nonzeroAsVolumeLastDigit_Count = 0.0;
        double timePassTickChange = 0.0;
        double timePassTypeChange = 0.0;

        // Process the data for the current stock
        for (size_t i = 1; i < data.size(); ++i) {
            // Extract current and previous data for comparison
            const auto &prev = data[i - 1];
            const auto &curr = data[i];

            // Time difference between trades
```

```
        double tradeTimeDiff = static_cast<double>(get<4>(curr) - get<4>(prev));
        tradeTimes.push_back(tradeTimeDiff);

        // Time difference between tick changes
        if (get<2>(curr) == get<2>(prev)) {
            timePassTickChange += tradeTimeDiff;
        } else {
            tickTimes.push_back(timePassTickChange);
            timePassTickChange = 0.0;
        }

        // Time difference between type changes
        if (get<6>(curr) == get<6>(prev)) {
            timePassTypeChange += tradeTimeDiff;
        } else {
            typeTimes.push_back(timePassTypeChange);
            timePassTypeChange = 0.0;
        }

        // Calculate bid-ask spread
        bidAskSpreads.push_back(computeBidAskSpread(get<1>(curr), get<0>(curr)));


        // Accumulate round number events (last digit being zero)
        double currTradePrice = get<2>(curr);
        int currTradeVolume = get<3>(curr);
        // Check if round number
        if (static_cast<int>(currTradePrice) % 10 == 0) {
            zeroAsPriceLastDigit_Count++;
        } else {
            nonzeroAsPriceLastDigit_Count++;
        }

        if (currTradeVolume % 10 == 0) {
            zeroAsVolumeLastDigit_Count++;
        } else {
            nonzeroAsVolumeLastDigit_Count++;
        }

    }

    // Calculate metrics
    double meanTradeTime = mean(tradeTimes);
    double medianTradeTime = median(tradeTimes);
    double meanTickTime = mean(tickTimes);
```

```
        double medianTickTime = median(tickTimes);
        double longestTradeTime = tradeTimes.empty() ? 0.0 : *max_element(tradeTimes.begin(), tradeTimes.end());
        double longestTickTime = tickTimes.empty() ? 0.0 : *max_element(tickTimes.begin(), tickTimes.end());
        double meanBidAskSpread = mean(bidAskSpreads);
        double medianBidAskSpread = median(bidAskSpreads);
        double meanTypeTime = mean(typeTimes);
        double medianTypeTime = median(typeTimes);

        // Round number effect (percentage of times the last digit is zero)
        double totalTradeCount = zeroAsPriceLastDigit_Count + nonzeroAsPriceLastDigit_Count;
        double priceRoundNumberEffect = totalTradeCount == 0 ? 0.0 : zeroAsPriceLastDigit_Count / totalTradeCount;

        double volumeRoundNumberEffect = totalTradeCount == 0 ? 0.0 : zeroAsVolumeLastDigit_Count / totalTradeCount;

        // Write to output file
        outfile << stockId << ","
                << meanTradeTime << "," << medianTradeTime << ","
                << meanTickTime << "," << medianTickTime << ","
                << longestTradeTime << "," << longestTickTime << ","
                << meanBidAskSpread << "," << medianBidAskSpread << ","
                << priceRoundNumberEffect << "," << volumeRoundNumberEffect << ","
                << meanTypeTime << "," << medianTypeTime << "\n";
    }

    outfile.close();
    cout << "Processing complete. Output file closed.\n";
    return 0;
}
```

itarle_task.cpp