# Designing an Algorithm for Capturing Price Volatility Factors in the Stock Market

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**Abstract**

*The research objective* is to design an algorithm to be used to identify factors influencing price dynamics of shares at the time of publication of quarterly reports.
*Subject of research*: design forecast algorithms for trade platforms for stock exchanges.
*Research methods* used: comparative analysis, business analytics, design of software module, correlation regression analysis, analytical methods.
*Results of the research*: The paper contributes to the empirical studies of the influence of interim disclosures of companies on equity price fluctuation and to the practical design of algorithms for trade forecasting platforms. The key finding is that the highest incidence of price dynamics was observed during the period of quarterly reports. The largest impact on price movements during the quarterly reporting period was made by the number of open short positions and capitalization of companies.

**Keywords**

Algorithm, price forecast, price fluctuations, earning season

## 1. Introduction

The earnings season is a calendar period in which U.S. public companies publish their financial results for the quarter/semi-annual/annual period. Quarterly reports are the main tool utilised to review a company's financial situation and are often used as an indicator of the company's development trends and for predicting the company's performance indicators.

The question of whether the publication of quarterly financial statements is informative for investors has long been investigated. Previous studies have mainly focused on analysing the share price reaction to interim earnings announcements [4]. There have also been many papers investigating price reactions to interim earnings disclosure and the emergence of new firms on regional stock exchanges [4, 19]. Easley et al. (1998) found a significant relationship between option prices and the emergence of new information in the market [8]. Hall, C. M. et al. found that tone of the interim reports, i.e. nature of news announced on the first day of the season, affects the reactions of stock-market players [13].

For investors and traders engaged in active speculation, the earnings season is the most important time in trading, as volatility rises sharply at this time and thus more opportunities for earnings arise. This activity manifests itself in a decrease in the volume of traded shares of companies on stock exchanges, as well as an increase in the range of price movements. Often, such movements determine the price trend for the next quarter. Therefore, the objective of our study is to design an algorithm for the identification of factors influencing the price dynamics of shares at the time of the publication of quarterly reports.

The need for computer-based research of stock price fluctuations in stock exchanges is driven by such factors as: increasing volume of information, increased disclosure of financial statements, emergence of new firms, reputational and corruption risks, accessibility of information and its

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asymmetry, and the need to react quickly to price changes. In fact, improvements are needed in price forecasting systems on trading platforms to provide more accurate information and consider more factors, allowing users of such systems to increase earnings from price fluctuations in the earning season.

Hypothesis. It is assumed that price volatility during quarterly reporting periods can be influenced by such factors as capitalization of companies, number of short positions, change in value of companies during the year, forecasted earnings, forecasted turnover, difference between forecasted and actual earnings, etc.

The paper contributes to the empirical studies of the influence of interim disclosures of companies on equity price fluctuation and to the practical design of algorithms for trade forecasting platforms.

The paper is organized as follows: Part Two describes related literature; Part Three describes sample selection and research methodology; Part Four is devoted to the discussion of the research results; the last part of the paper contains conclusions and prospects for further research.

## 2. Related Literature

Researchers and stock market participants try to identify the factors that have the greatest impact on stock market prices. After the previous research on forecasting prices on stock exchanges [15], it was decided that a deeper study into the determinants of the impact on prices would allow the selection of the more influential factors in prognostic models in the future.

This is particularly relevant during the earnings season. In particular, Sun, Q. (2015), notes that the immediate price reaction to earnings news and post-announcement price drift are more favorable if a news announcement is released at the beginning of earnings season rather than at the end of earnings season ("timing effect") [17].

For their part, the owners of the companies try to " outperform " the good news but avoid the bad. For this purpose, they resort to various tricks, e.g. managers reporting bad news after market hours, on busy days, or reporting bad news on Fridays [5]. Investors and traders should therefore be careful during earnings season. Vieru, M.J. (2002) investigated whether price adjustments are greater in pre-announcement periods than in post-announcement periods. He found that large deals leading to price changes (especially upward trades) before the announcement gave more signals to other investors than similar deals after the announcement. For smaller trades, the results were insignificant [19].

Many scholars believe that one of the key factors affecting share prices is the discretionary tone in quarterly reporting. For example, Sheehan Rahman (2019) in his study aims to examine the discretionary tone of interim management reports (IMS) in quarterly reporting in the UK. The results of the study showed that the discretionary tone has a different impact depending on the quarter [16]. Akyildirim, E. et. al. (2015) examined the impact of interim disclosures on price fluctuations in terms of their link to liquidity [1]. Chiao, C., et. al. (2017) found that in Taiwan positive (negative) reports move stock prices upwards (downwards) in real time, accompanied by increasing trading volume [3].

Fu, R. et. al (2012) all investigated the effect of financial reporting frequency on information asymmetry and the cost of equity capital [11]. The researchers have shown that the higher frequency of reporting reduces information asymmetry and the cost of equity, from which they conclude that the higher frequency of reporting reduces information asymmetry. Verdi, R. S. (2012) expanded on the research of Fu, R. et. all (2012) and provided suggestions for future research. One of the suggestions was to study the contracting implications of increased reporting frequency [18].

Ernstberger, J. et al (2017) investigated how mandatory quarterly reporting affects managers' business decisions in terms of real activities manipulations [9]. Their results challenge the findings of Fu, R. et. al (2012) because they found that managers were more likely to manipulate the figures in the quarterly reports. Such manipulation puts significant pressure on the market and affects share prices.

Ersan, O. et. al. (2020) studied whether the market reaction speeds in less sophisticated markets are on par with those of developed markets. They have found that market reaction times for positive news are faster than for negative news. When high-frequency traders are more active in the market ahead of announcements, the speed of price corrections slows down [10]. Researchers have proven that it is possible to develop strategies for market participants focused on earning from event-driven price fluctuations.

Jagliński, P. (2021) investigated investors' reactions to quarterly earnings announcements on the Warsaw Stock Exchange. Unlike most other studies on the topic, no evidence of PEAD in the group of companies that reported earnings above market expectations was found. Only anomalies in the group of companies that underperformed earnings forecasts were found. The author believes that this is due to the fact that short selling is not widely available on the Polish stock exchange, and if market participants had the tools necessary to counteract the anomaly, i.e. the ability to take short positions, it would not exist [14].

A review of the existing literature shows that researchers do not consider the difference between disclosure periods. In addition, scholars focus on the impact of earnings information on share price and do not cover most other factors.

## 3. Sample Design and Research Methodology

Empirical studies of stock market fluctuations are based on different models [6,12]. Demski, J.S., Feltham, G.A. analysed two-date rational expectations model [6]. Baber, W. R. et al. are focused on modelling discretionary accrual reversal and the balance sheet as an earnings management constraint [2]. In constructing the models, we have considered the findings of the authors mentioned above as well as in the Literature Review section.

Unlike existing surveys, our sample is based on data from the winter reporting season (14.01.2020 - 14.02.2020), which lasts longer because company reports are not published on the same day, but continuously. Also covered was the last quarter of 2019 (January-June 2019). This is the last quarterly reporting period which was not affected by the COVID-19 crisis and increased price volatility.

To reduce the amount of data and obtain more realistic figures for price movements, companies were selected according to several indicators, first and foremost capitalization. Our data included companies with capitalization exceeding $1 billion. Another filter for the companies was the average volume of traded shares per day, this indicator being more than 200 thousand shares per day.

As a result, 791 companies and 152 types of activity were initially selected belonging to the eight main sectors of the US economy. Even though only 20% of the total volume of shares on the US stock market were sampled, they account for 85% of the aggregate US stock market volume in terms of capitalisation and average trading volume.

At this stage of the research in the sectoral structure of capitalization of our data, the largest share is of financial companies at 25.2%, with technology companies at 23.4%, services companies at 15%, and consumer goods companies at 10.4%. The smallest value is given to companies providing public services, with their share in the total capitalization of our data at 2%.

To identify factors influencing price dynamics, companies that had significant price volatility at the time of the report were first noted. Price dynamics were studied for three days, the first being the reporting day and then the two following days. An investigation of price dynamics was performed based on four types of stock prices: prices on the opening of the trading session, on the closing of the trading session, and the maximum and minimum prices for the day. Significant price change (dP) represents the difference between the opening price (OP) and the closing price (CP), on any of the three surveyed days, and will be twice as large as its average price change range (ATR), (1).

$$|\mathrm{OP} - \mathrm{CP}| > 2 \times \mathrm{ATR}, \mathrm{dP} = 1 \quad (1)$$

Also, the significant price changes can be calculated as the difference between the opening price (OP) and the maximum (MaxP) or minimum (MinP) (the two following days after the statement), when it is three times greater as ATR, as in Formulas 2 and 3.

$$\mathrm{MaxP} - \mathrm{OP} > 3 \times \mathrm{ATR}, \mathrm{dP} = 1 \quad (2)$$

$$\mathrm{OP} - \mathrm{MinP} > 3 \times \mathrm{ATR}, \mathrm{dP} = 1 \quad (3)$$

According to the requirements, our selection of companies was reduced from 791 to the 200 companies which were the most active during the quarterly report. In terms of capitalisation and average trading volume the companies are highly active as they cover close to 70% of the total US equity market.

The activities in which a significant part of companies (more than 30%) showed active price dynamics during the quarterly reports were auto parts, regional banking, application software, trucking etc. (Figure 1).

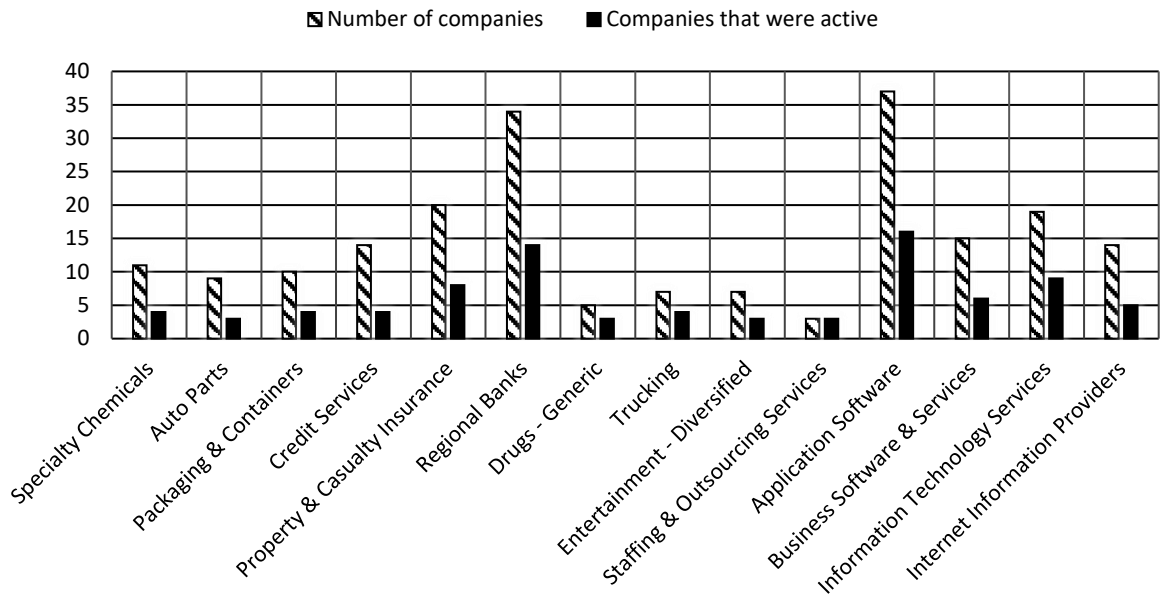


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**Figure 1**: Types of activities in which more than 30% of companies reacted to quarterly reports

After deducting the companies inactive at the time of the quarterly report, the structure of our data was dominated by technology companies, comprising 30% of the total number, financial services companies at 20%, and service companies at 19% (Figure 2).

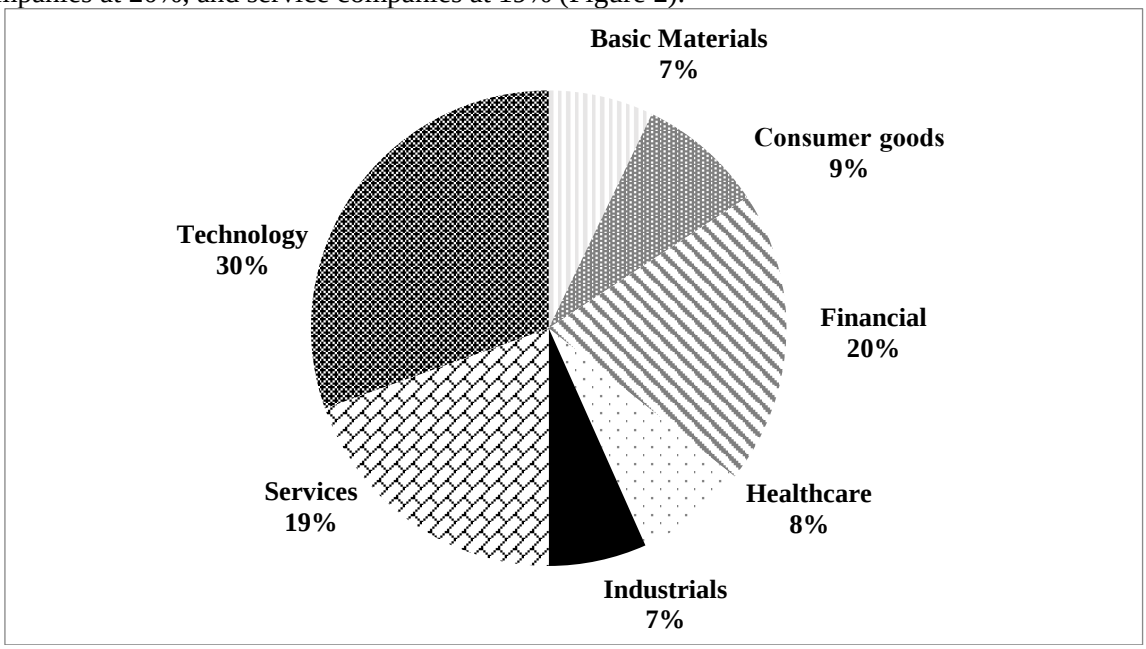


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**Figure 2**: Structure of the quantitative structure of companies active in the last season,%

The survey also revealed that the largest number of companies whose prices were active after the quarterly report was released were small companies with capitalisation of up to USD 5 billion. Their share in the total sample of data was close to 50%. The share of mid-sized companies is 31%. The smallest share of companies, with capitalization over $300 billion, is 1%.

The programming algorithm used for selecting companies and analysing the influence of factors on share prices was developed in RStudio. Fragments of the software code are shown in Fig. 3-5. At the first stage data was taken from the websites of stock exchanges and checked for missing data. In the next step, the data was transformed for further use in the calculations (Figure 3).

```
transform_x <-  function(test_data){
  p.val = 0.00000001
  x = c()
  for ( i in seq(-2,2, by = 0.1)) {
    if (i < 0) {
      q <- -(test_data[,2]^i)
      lm_1 <- lm(test_data[,1]~q)
      p.tv <- summary(lm_1)$r.squared
      if ( p.tv >p.val){
        p.val <- p.tv
        x <- q
      }
    } else { if (i == 0 ){
      q <- log(test_data[,2])
      lm_1 <- lm(test_data[,1]~q)
      p.tv <- summary(lm_1)$r.squared
      if ( p.tv >p.val){
        p.val <- p.tv
        x <- q
      }
    } else {q <- test_data[,2]^i
    lm_1 <- lm(test_data[,1]~q)
    p.tv <- summary(lm_1)$r.squared
    if ( p.tv >p.val){
      p.val <- p.tv
      x <- q }}}}
  print(x)}
```

Source: designed by authors

**Figure 3**: Transformation data according to filters

The factors selected for the model were tested for multicollinearity (Figure 4).

```
is_multicol <- function(d){
  z <- c()
  c_d <- cor(d)
  c_d <- abs(round(c_d, 3))
  for( i in 1:(length(d))){
    if (max(c_d[i,-i])==1){
      z <- append(z, names(d)[i])
    }
  }
  if (length(z) ==0 ){
    z <- "There is no collinearity in the data"
  }
  return(z)
}
#multicollinearity check
```

Source: designed by authors

**Figure 4**: Multicolinearity check

The next step is correlation analysis (Fig. 5).

```
X<-wagesmicrodata[,3,12,13,17]
library(GGally)
ggpairs(X)
#Builds a graph of distribution and correlation between indicators
```

Source: designed by authors

**Figure 5**: Design of graph distribution

## 4. Research Results and Discussions

Price movements during the winter quarterly reports were very unstable. On the first and second days, prices fell for most companies. Prices of consumer good companies fell the most (by 5.3%). On the third day, quotations of all sectors of economy actively increased, which allowed for a positive increase in prices for three days after the reporting day in all types of economic activity, except for

industrial companies. The largest increase in prices for three days after the end of the reporting period was in basic materials (2.6%) and healthcare (2%).

Below is an overview of the impact of certain factors on the activity of companies during the reporting period. It should be noted that we assessed the activity of companies in accordance with the proposed methodology (formulas 1-3). Changes in the value of shares of companies during the year affect the volatility of stock quotes during the quarterly reports (Figure 6). As can be seen, the greater the growth over the previous year, the greater is the likelihood that a company's price will be active at the time of the quarterly report. More than 60% of the companies whose shares fell by more than 50% over the year were active at the time of the report; on the other hand, nearly 40% of the companies whose value grew by more than 50% over the year were unusually active at the time of the report.

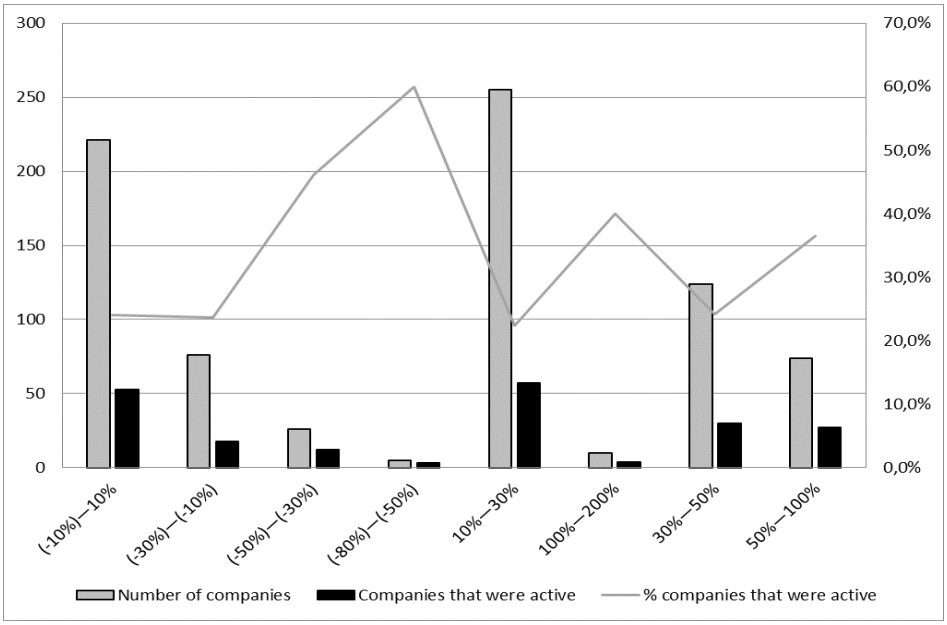


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**Figure 6**: Dependence of volatility of share quotations during the quarterly reports on changes in the value of companies over the last year, %

Also, an important factor is the ratio of short positions to price activity at the time of the report (Figure 7). Figure 7 shows the number of short positions opened ranked as follows: Group A (over 30%), Group B (20% to 30%), Group C (10% to 20%), Group D (5% to 10%), Group E (under 5%). As we can see, a linear relationship between the number of short positions and price volatility at the time of the report is evidenced. In the smallest group of companies (Group A) with a remarkably high level of short positions (>35% short in float) the highest proportion of companies were active at the time of the report (up to 40%).

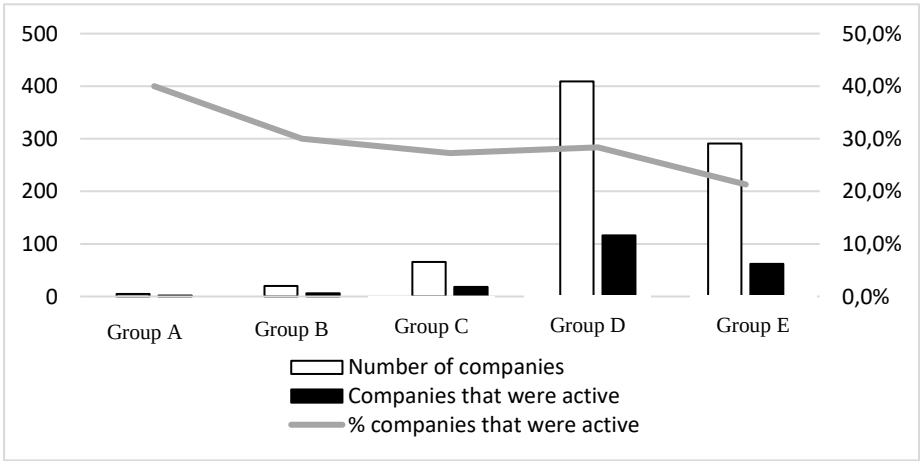

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**Figure 7**: Dependence of share price volatility on last year's value changes during the quarterly reports, %

Therefore, during the quarterly reporting period, the shares of those companies are active, (1) the value of which has significantly decreased or increased during the year (2), which have many open short positions in the total number of shares available for trading (3) less capitalised companies, the higher the volatility of prices during the quarterly reporting period.

Correlation analysis to determine which of the above-mentioned factors have the greatest impact on price movements during the quarterly report period (dAll_) was also used. First examined are those that impact non-financial factors (Figure 8-9), and then those that impact financial factors (Figure 10-11).

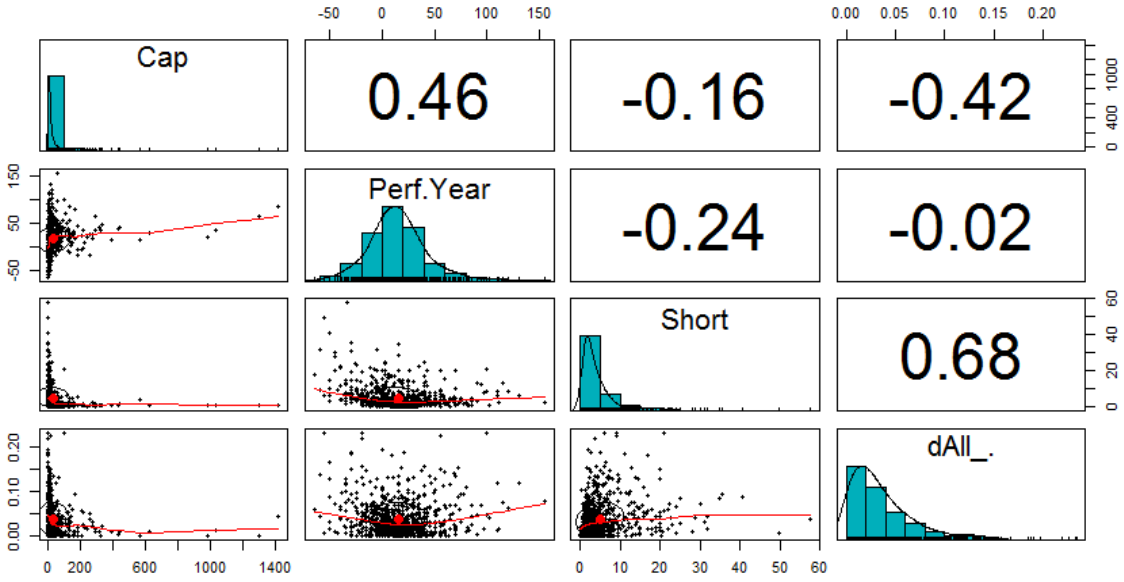


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**Figure 8**: Correlation coefficients, scatterplots and histograms of the breakdown between financial performance and price changes at the time of the companies' reports

| | | | |
|---|---|---|---|
| Histogram of companies' capitalisation | Correlation coefficient between capitalisation and price change over the year | Correlation coefficient between capitalisation and % of short positions | Correlation coefficient between capitalisation and price change over 3 reporting days |
| Scatter chart of values and average value (red line) between capitalisation and price change over the year | Histogram of price movements over the rest of the year | Correlation coefficient between price change over the last year and % of short positions | Correlation coefficient between price change over the rest of the year and price change over 3 successive reporting days |
| Scatter chart of values and average value (red line) between capitalisation and % of short positions | Scatter chart of values and average value (red line) of price change over the last year and % of short positions | Histogram of the distribution % of short positions | Correlation coefficient between % of short positions and price change over 3 reporting days |

| | | | |
|---|---|---|---|
| Scatter chart of values, and the average value (red line) between capitalisation and price change over 3 reporting days | Scatter chart of values and the average value (red line) of the price change over the last year and the price change over the 3 days after the reporting period | Scatter chart of values and average value (red line) between % of short positions and price change over 3 reporting days | Histogram of the price distribution over the 3 days after the reporting period |

Source: designed by authors

**Figure 9**: Figure 8 Explanations by sections

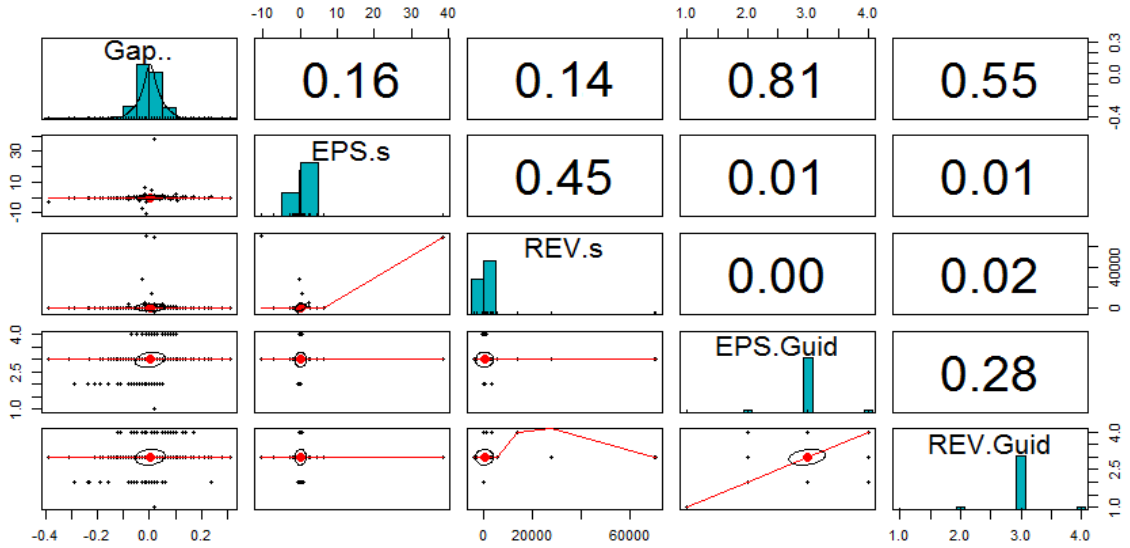
As evidenced by the data, there is a strong correlation between certain oil and gas indicators (Overview indicators) and price change during the quarterly reporting period. The greatest influence on price movements during the period of the quarterly reports is the indicator - % of short positions for the share (r = 0.68). This can be explained by the fact that shares are a long-term value driver which is mostly used by investors for long-term strategies. Short positions in equities are mainly used by speculators in companies that ran into problems, thus increasing the risk and volatility of these equities. Accordingly, at the time of the report, the management of the company may present a record of strong performance or say that one is expected, which may be a significant motive for exit from a short position.

Short squeezes often arise when there are many bear stocks in open positions, which on the average were selling at low prices, and on good news some start to buy, others cover short positions (also buy). This is a situation when almost nobody sells, so there is a liquidity deficit, and the share price rises sharply, forcing other market players, even those convinced of the lack of the company's future, to exit the company as the balance runs out of cash. That is why, in companies with many short positions, share prices can be very volatile at the time of the report.

Another non-financial indicator influencing price movement during the three days after the reporting period (dAll_) is its capitalization (r=0.42), and here everything is more predictable in that the larger the company is, the less volatile is its price movement. This is explained by the fact that such companies have high float, i.e., there is constant liquidity, and by the fact that it is very important to go beyond forecasts at the time of the report.

The remaining non-financial indicator is the value of companies during the year. According to the results, there is no correlation between this indicator and the price change over three days. This situation can be explained by the fact that the opposite directions of price movements do not influence the correlation, with some companies in the sector falling in price, and others increasing during this period. However, an important role in this case belongs to extreme fluctuations in stock prices, for which the correlation coefficient can reach 0.46.

Below, the impact of the main financial factors on the share price performance in the pre-market and post-market, i.e. the gap (Figку 10-11) is examined.




Source: designed by authors

**Figure 10**: Correlation coefficients, scatter graphs and histograms of the distribution between financial indicators and % of the gap at the time of the report

The following legend is used in the figure:

**Gap** is the difference between the closing prices prior to the statement and the opening price after the statement was published as well as the difference between the closing price in the period when the statement was published and the opening price in the post-market period.

**EPS.s** is the difference between the earnings per share that market participants (banks, investment funds) expect and the actual earnings per share. Average market expectations are published in various publications (Reuters, Briefing, Bloomberg, etc.).

**REV.s** is the difference between the revenue expected by market participants (banks, investment funds) and the actual revenue reported in the statement.

**EPS.guid** is earnings per share value forecasted by the company for the next quarter or year.

**REV.guid** is revenue forecast by the company in the next quarter or year.

| | | | | |
|---|---|---|---|---|
| Histogram of the % gap during the reporting period | Correlation coefficient between % gap at the time of the statement and the difference between the expected and actual earnings per share | Correlation coefficient between % gap at the time of the report and the difference between expected and actual revenue | Correlation coefficient between % gap at the time of the statement and the company's forecasted earnings | Correlation coefficient between % gap at the time of the report and the company's forecasted revenue |
| Scatter chart of values and average (red line) between % gap at the time of the report and the difference between expected and actual earnings per share | Histogram of the distribution of differences between expected and actual earnings per share | Correlation coefficient between the difference between expected and actual earnings per share and the difference between expected and actual revenue | Coefficient of correlation between difference between expected and actual earnings per share and forecasted company earnings | Coefficient of correlation between the difference between expected and actual earnings per share and the company's forecasted revenue |

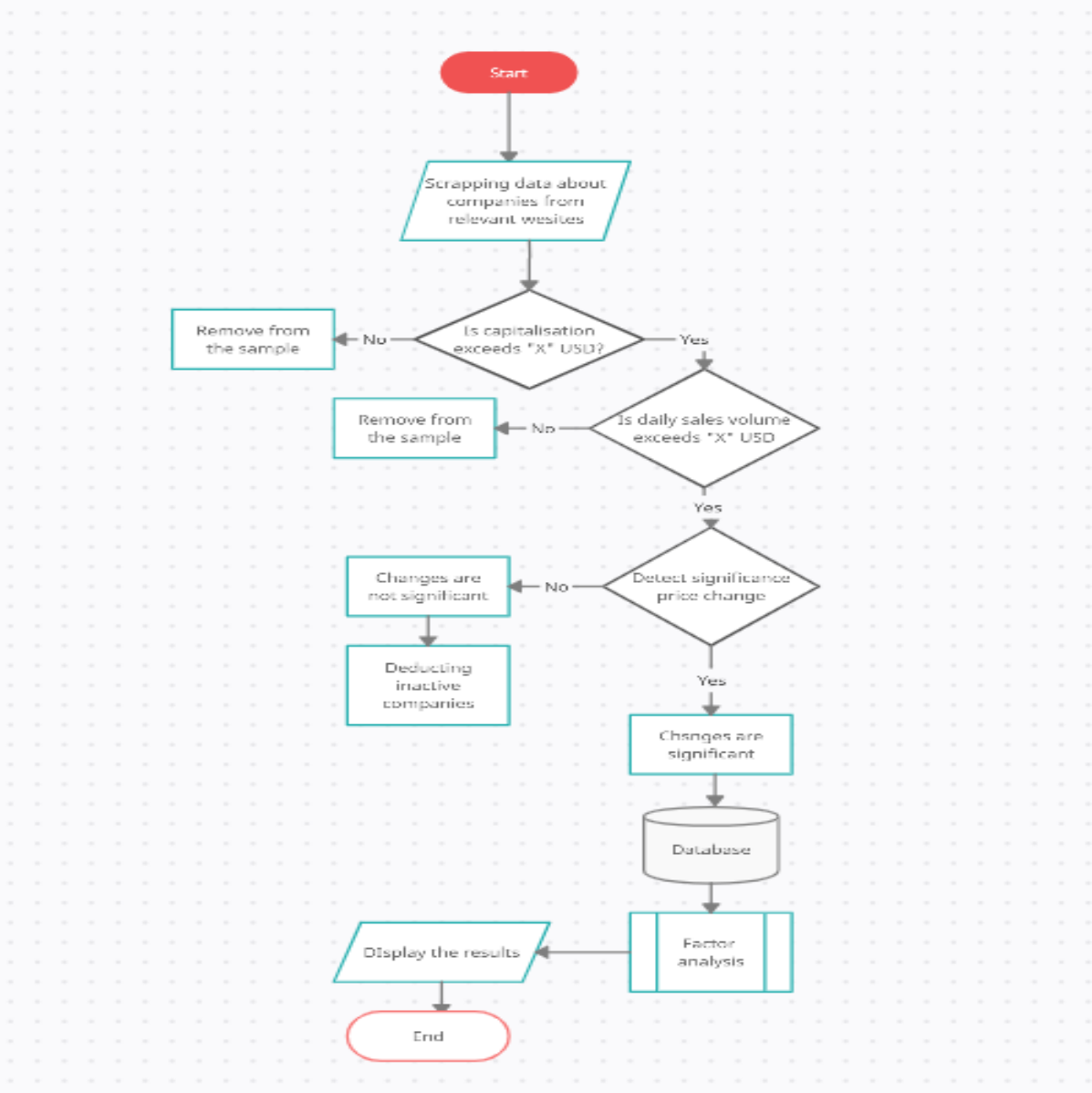
| | | | | |
|---|---|---|---|---|
| Scatter chart of values and average (red line) between % gap at the time of the report and the difference between the estimated and actual revenue | Scatter chart of values between the difference between the expected earnings per share and the difference between the expected and actual revenue | Histogram of the distribution of differences between estimated and actual revenue | Coefficient of correlation between the difference in estimated and actual income and forecasted earnings of the company | Correlation coefficient between the difference in expected actual earnings per share and the company's forecasted revenue |
| Scatter chart of values, between % gap at the time of the report and the company's forecasted earnings | Scatter chart of values between the difference in expected and actual earnings per share and the forecasted earnings of the company | Scatter chart of the difference between the expected and actual profitability of the company | Histogram of the distribution of forecasted profits of the company | Correlation coefficient between forecasted company earnings and forecasted company revenue |
| Scatter chart of values (red line) between % gap at the time of the report and the company's forecasted revenue | Scatter chart of the difference between the expected and actual earnings per share and the company's forecasted revenue | Scatter chart of values between expected and actual revenue differences and forecasted revenue of the company | Scheduling of forecasted earnings and forecasted revenue of the company | Histogram of the distribution of the company's forecasted revenue |

Source: designed by authors

**Figure 11**: Figure 10 Explanations by sections

As can be seen from the Fig 9 and Table 2, in the industrial sector, the greatest influence on price fluctuations during the reporting period had short positions (r=0.83) and capitalisation (r =-0.57). The financial sector has the strongest correlation between % gap and earnings forecast (r=0.9). In the extractive sector, the number of short positions (r=0.7), capitalisation (r=-0.6), and difference between expected and actual profit (r=0.66) had the greatest impact on price movements during the reporting period. The prices of technology companies and the health sector are most dependent on the number of open short positions, respectively, r=0.78 and r=0.81.

Therefore, the fragment of the algorithm for identifying factors influencing price fluctuations in the interim reporting period can be presented as follows (Figure 12).




Source: developed by authors using Creately

**Figure 12**: The fragment of the algorithm for identifying factors influencing price fluctuations in the interim reporting period

It should be noted that the process shown at the Figure 11 can be repeated if needed.

## 5. Conclusions and Outlook

In the research, an algorithm for determining the impact of certain factors on the dynamics of US stock prices during the winter quarterly report of 2020 was designed. For this purpose, we have narrowed the sample of companies to 200. Only those sectors of the economy in which a significant portion of companies (more than 30%) showed active price dynamics during the quarterly reports were selected.

Having analyzed the value distribution graphs, distribution histograms and correlation coefficients, it was determined that the highest price dynamics were observed during the quarterly reporting period.

The largest impact on price movements during that period was seen by the number of open short positions (r=0.68) and capitalisation of companies (r=0.42).

Changes in the prices of the companies' shares over the year can be used as an indicator of future price volatility during the period of quarterly reports, but the correlation analysis did not reveal any significant correlation. If our sample is divided into two groups (companies with growing value and companies with falling value during the year), a positive correlation coefficient value can be obtained.

Among financial indicators, the strong influence on the price movements at pre-market and post-market (gap) has a forecast for the next year/quarter earnings per share (r= 0.81), and revenue forecast (r= 0.55). The company's results were also affected by a lower impact on price movements during the quarterly reports.

We have also identified areas where this research can be expanded. All companies may be divided by groups depending on the stage of development. Such a selection can be made based on the coefficient of book value of the company to market value of the company as well as on the dynamics of revenue growth and P/E ratio. This will allow the impact factors for each group to be identified, as it appeared in the research process that they can be different for these groups.

According to our research, one of the most important indicators that influenced the share price performance is the number of short positions. It is possible to deepen the research by in-depth study of the capital structure in terms of share volumes, i.e. how many shares belong to insiders (managers and employees), pension and hedge funds, how many shares are owned by individuals. Then it is possible to assess the impact of certain groups of stockholders on stock exchange prices. In particular, insiders can be the first to know accurate information or they can spread provocative information. Individuals are the most responsive to the reports. Hedge funds and pension funds have large portfolios of shares and look forward to the earnings season to close their positions on the back of high liquidity during this period, thereby significantly increasing the volatility of prices. Different groups of market participants have different motives for investing money and therefore react to different performance. Understanding the structure of shareholder capital will allow us to correctly forecast price fluctuations and put the appropriate limitations into the price forecasting algorithm for trading platforms.

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