Università degli Studi di Milano - Bicocca
Scuola di Scienze
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Corso di Laurea in Informatica

Project Report

Business Intelligence per i Servizi Finanziari

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Chapter 1

Introduction

The financial assets analyzed for this project are the following:

- Apple Inc., founded in April 1976 by Steve Jobs, Steve Wozniak, and Ronald Wayne and had its first appear in the stock market in 1980.
- Microsoft Corporation, founded in April 1975 by Bill Gates and Paul Allen, and firstly named Micro-Soft Company. Eight years later became the Microsoft Corp. and had its first appear in the stock market in 1986.
- Amazon.com, Inc., founded in 1994 by Jeff Bezos and today is the most popular e-commerce, and not only that. Amazon entered in the stock market in 1997.
- Alphabet Inc., founded in October 2015, through a restructuring of Google Inc., has become the parent company of it and its various former branches. Note that since we have analyzed the relative stock since January 2010, for the period prior to 2015 we take as reference just Google Inc., which however is the leader among companies under Alphabet.

As we all know, these are four of the most big tech company in the world, and for many aspects they are related to each other.

Each instrument was compared with the market index Standard & Poor's 500, which is a market-capitalization-weighted index of the 500 largest U.S. publicly traded companies. The period of time taken into consideration to analyze all these assets starts form January 1, 2010 to October 31, 2019.

Chapter 2

Data Summary

Below a summary of the trends about the financial instruments analyzed.

2.1 Apple Inc. ((ticker: AAPL))

Figure 2.1: Adjusted close price of Apple.

We can see, in figure 2.1, in general a growing trend, but we can also see a point where there is a strong downward peak, in 2019, caused by the fact that the iPhone sales were down. However, thanks to its wearable segment, Apple Watch and AirPods, the company's business was lifted by strong performance[1].

2.2 Microsoft Corp. (ticker: MSFT)

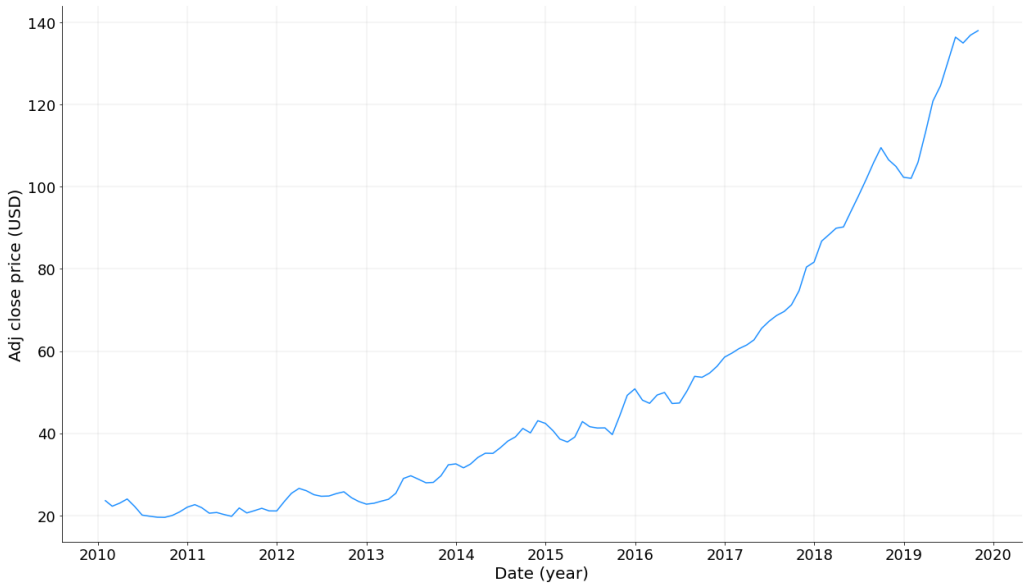

Figure 2.2: Adjusted close price of Microsoft.

Microsoft generally has a growing trend, as we see in figure 2.2, especially since mid 2016 we see a fast growing curve except for just about 3 months of loss in 2018, and then returning to growth.

2.3 Amazon.com Inc. (ticker: AMZN)

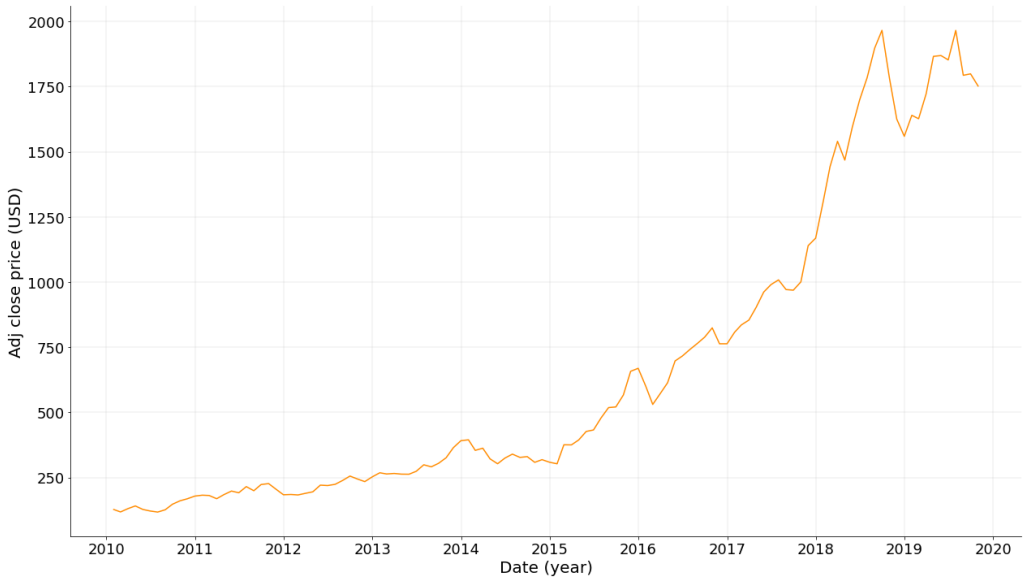

Figure 2.3: Adjusted close price of Amazon.

Actually, Amazon stocks are the 4th highest priced in NASDAQ market[2], and that's evident as we see in figure 2.3. The graph shows a growing trend, particularly from 2015 to passed mid 2018 there's almost an exponential growth, then seems to be swinging up and down.

2.4 Alphabet Inc. (ticker: GOOG)

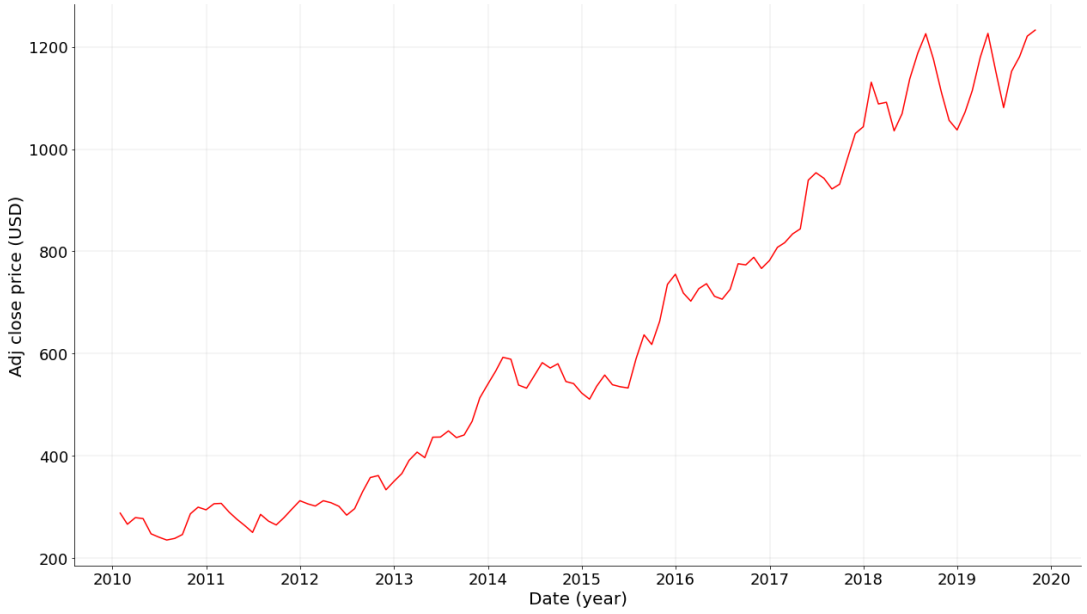

Figure 2.4: Adjusted close price of Alphabet Inc.

In this case, we also see, in figure 2.4, a growing trend but compared to the other three stocks taken into analysis, there's approximately a linear growth, except from passed mid 2018 on, where we can see a swinging up and down line. The cause is maybe related to the inquiries coming from 48 state attorneys against Google (and Facebook) about antitrust[3].

2.5 Comparing the four stocks

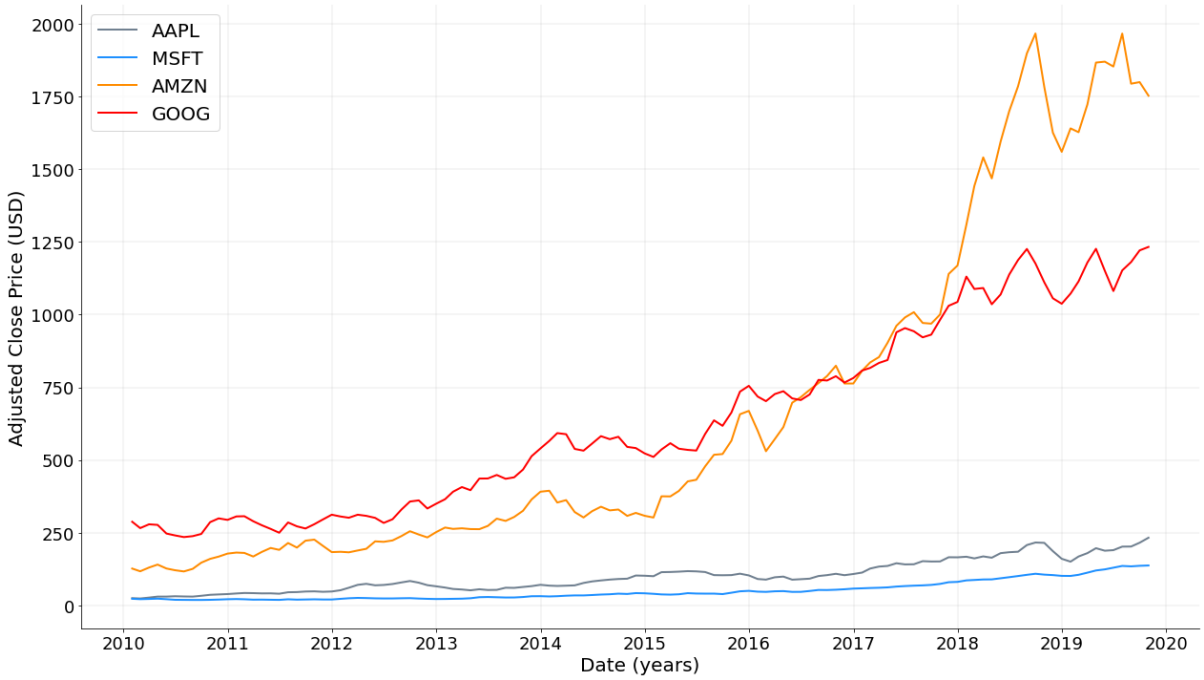

Figure 2.5: Adjusted close price of all four stocks.

The figure 2.5 shows a clear difference between the value of the price of each asset and also between the degree of growth of these.

Chapter 3

Descriptive Analytics

In this chapter will be presented a summary of the main results from exploratory data analysis including returns, variances and covariances at different time scale. Each financial instrument is been compared to the S&P500 index (ticker: ^GSPC), as a stock market benchmark.

3.1 Simple monthly return

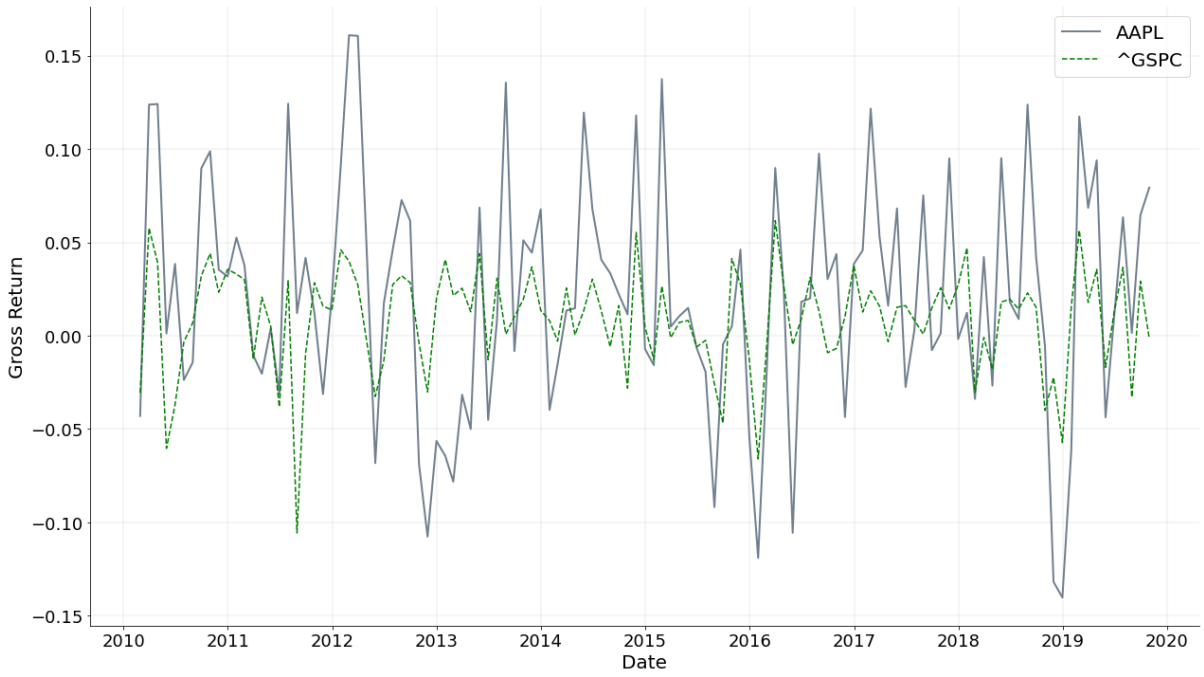

Figure 3.1: Simple monthly return of Apple and S&P500.

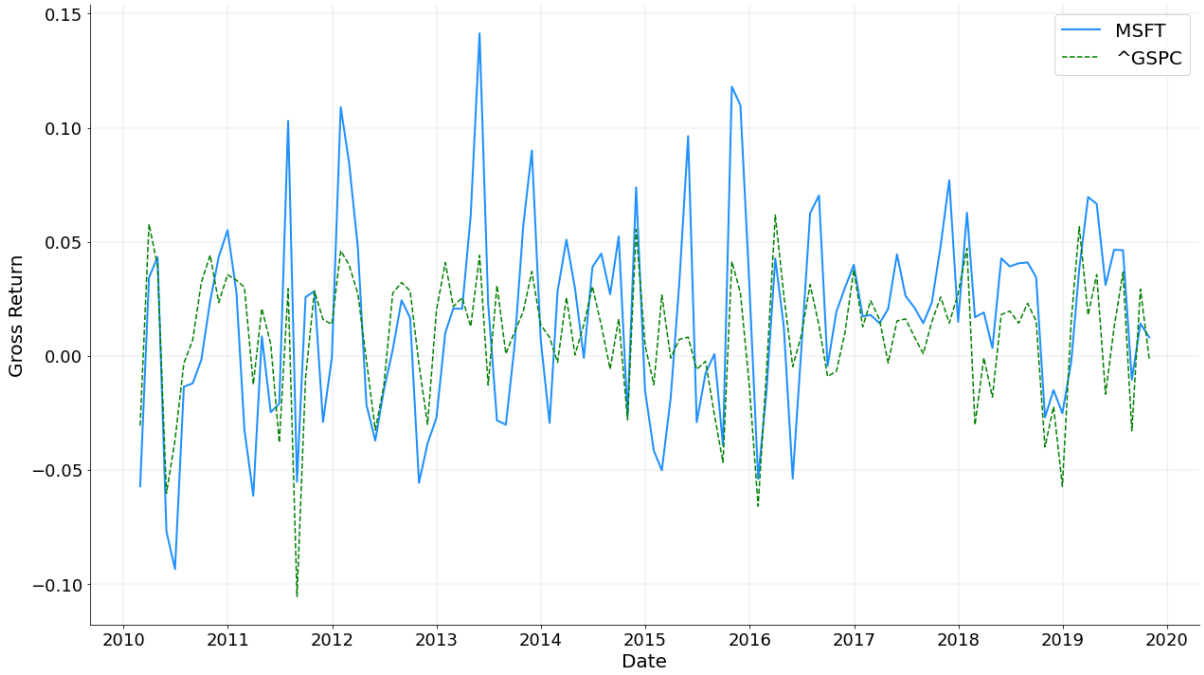

Figure 3.2: Simple monthly return of Microsoft and S&P500.

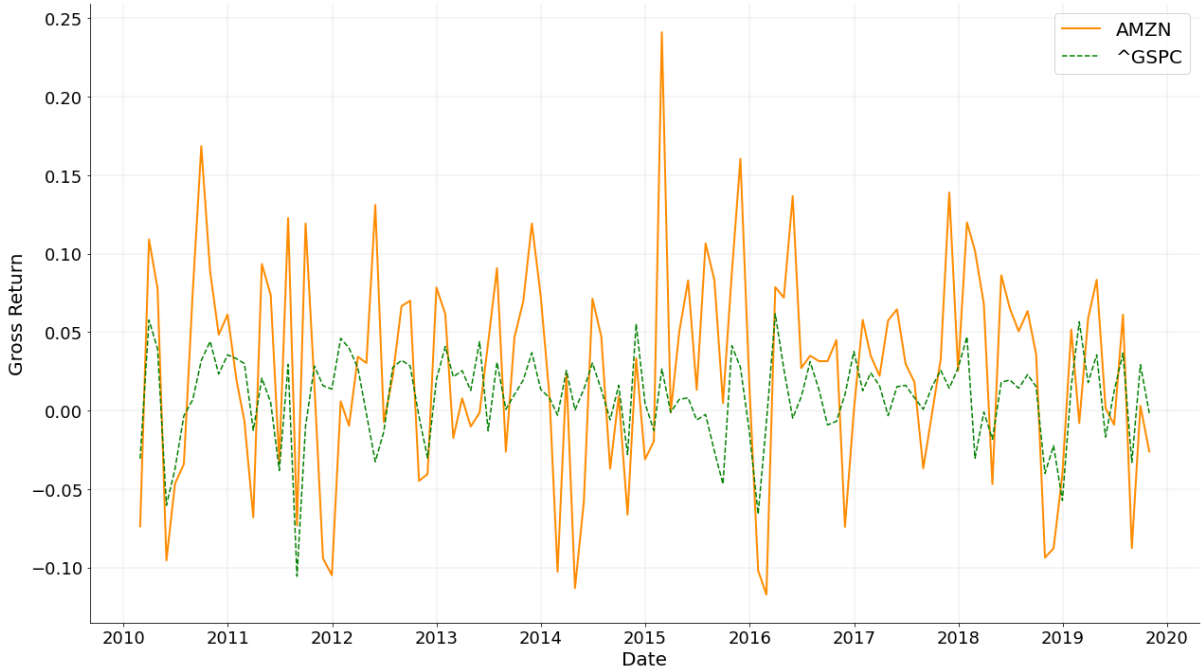

Figure 3.3: Simple monthly return of Amazon and S&P500.

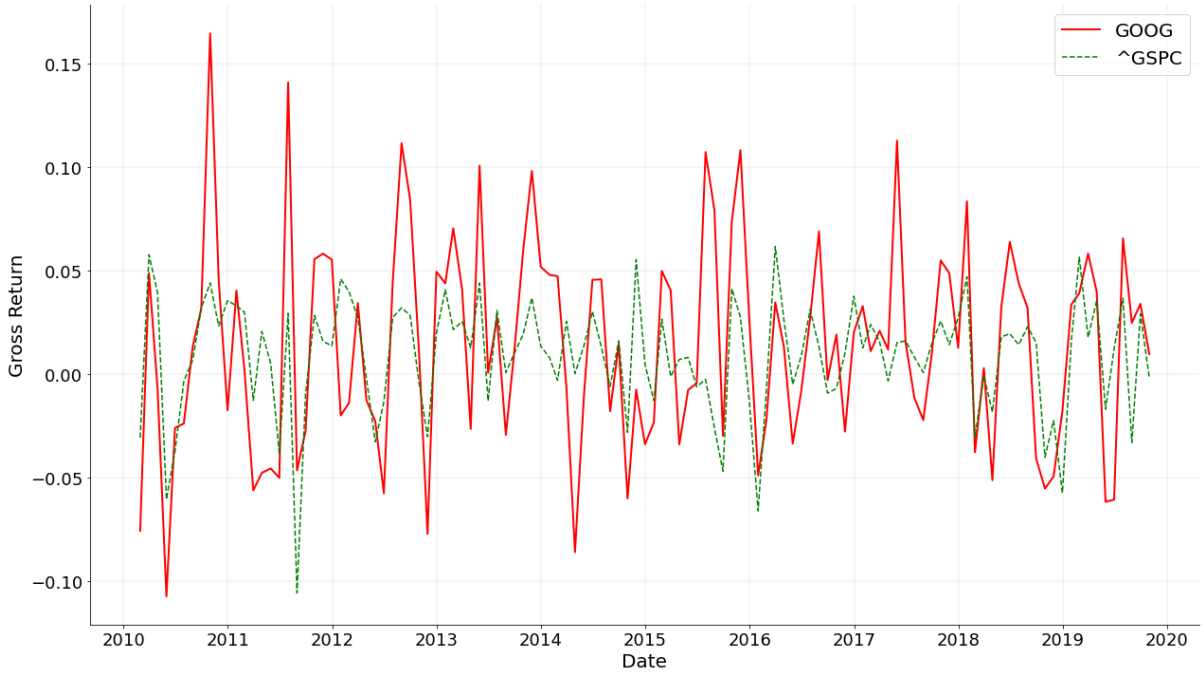

Figure 3.4: Simple monthly return of Alphabet and S&P500.

3.2 Continuously compounded monthly return

3.2.1 Apple Inc.

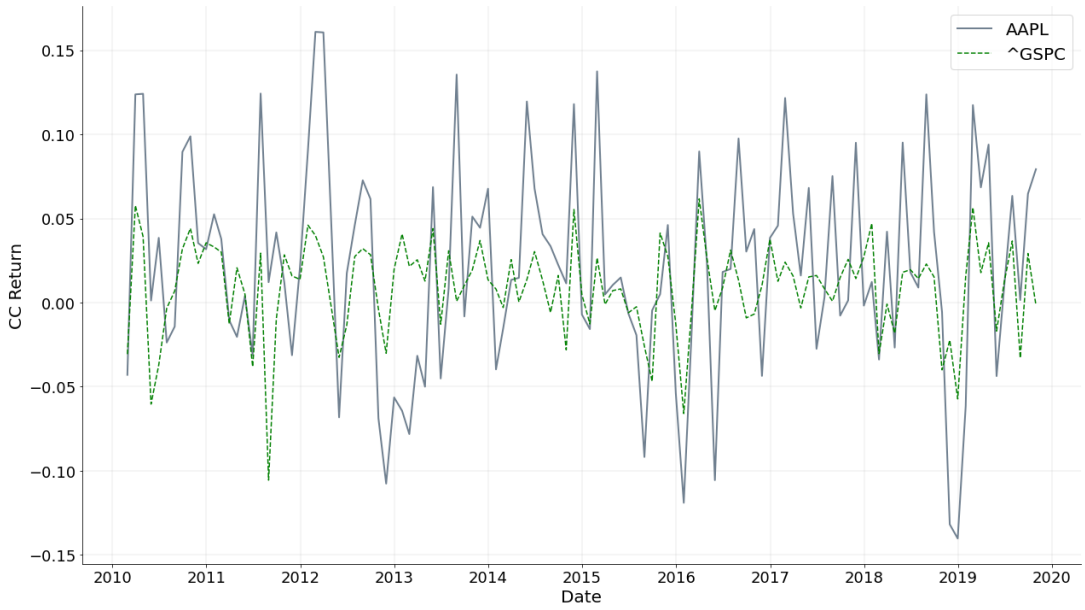

Figure 3.5: CC monthly return of Apple and S&P500.

Compared to the benchmark index, we can deduce from the graphs (figure 3.5 and figure 3.1) that Apple has had quite correlated returns, except in the periods between 2011 and

2012, where we can see an opposite trend in relation to the index. The S&P500 probably went down in august 2011 due to fears of contagion of the European sovereign debt crisis to Spain and Italy[4]. Also, this fall it could be related to the tragedy of the twin towers happened in September 2011. Considering Apple's trend, we see that it's not been affected by those facts in that period.

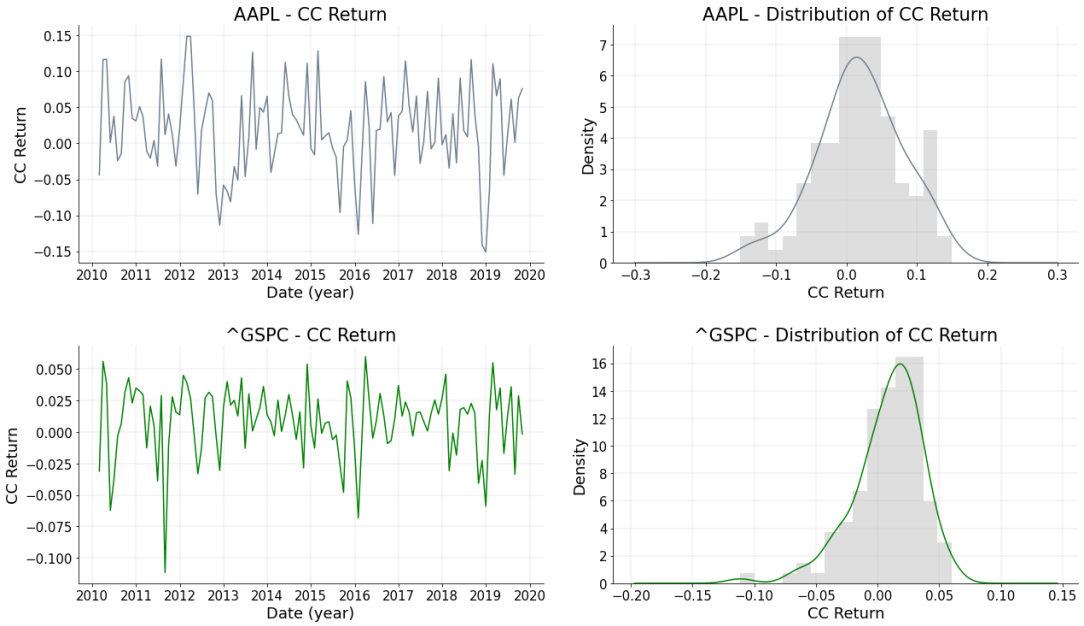

Figure 3.6: Comparison between AAPL and ^GSPC returns and distribution of returns.

Around the end of 2011 there's a decrease and then in 2012 an upward peak occurs. The causes, respectively, are probably related to the Steve Jobs' death and in the other hand the revenue of the new iPhone 4s. Another obvious point is the downward spike in late 2019, caused by the drop of iPhone sales in China, especially when President Donald Trump declared he would increased tariffs on $200 billion of Chinese goods to 25%[5]. Probably the related growth is given by the great revenue from wearable devices, such as Watch and Airpods.

3.2.2 Microsoft Corp.

In this case we notice, in figure 3.7, there's a greater correlation between the return of Microsoft and the benchmark index than in the previous case (figure 3.5). In comparison with the Apple trend, particularly between 2010 and 2011, it's evident that while the company of Cupertino was growing with some up and down, Microsoft had a downward peak. That fall was caused by the loss of confidence from investors in the company, that's because of for the past 10 years, the MSFT stock was mostly bouncing around a range between $22 and $32, and in 2010 went down by 15%, even if the Nasdaq went up by 11% and the broader S&P500 increased by 7%. So investors were worried that consumer demand for PCs was slowing down, while Mac, iPad, Android and Google posed

a long-term threat instead[6].

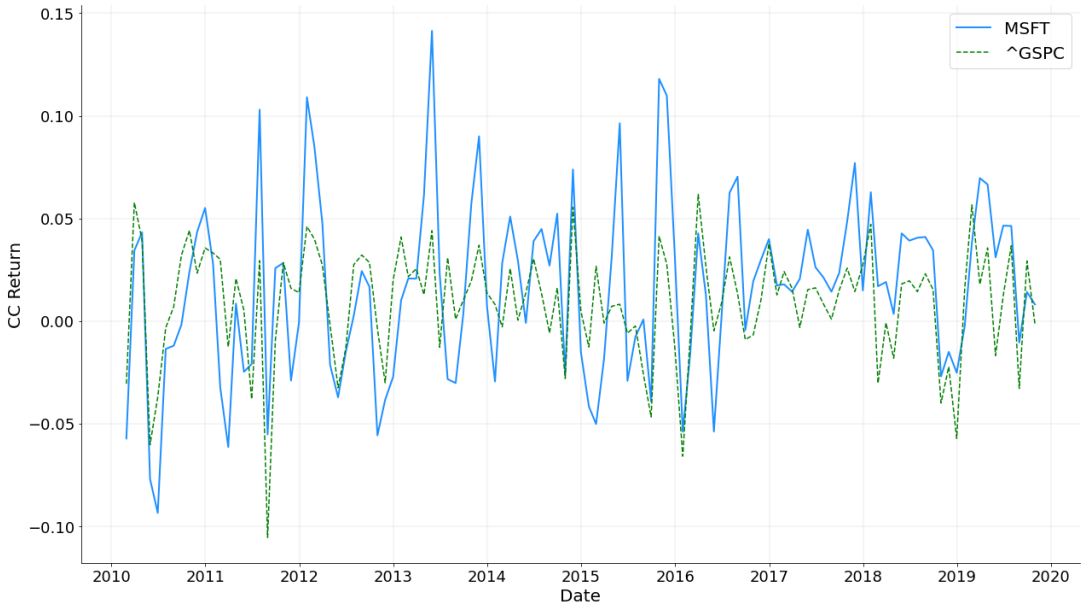

Figure 3.7: CC monthly return of Microsoft and S&P500.

However, going forward, in 2013 Microsoft had a good year, probably thanks to the new Windows OS and the Windows Phone Segment, and for the rest of the years the trend is quietly correlated to that of the index taken as a reference.

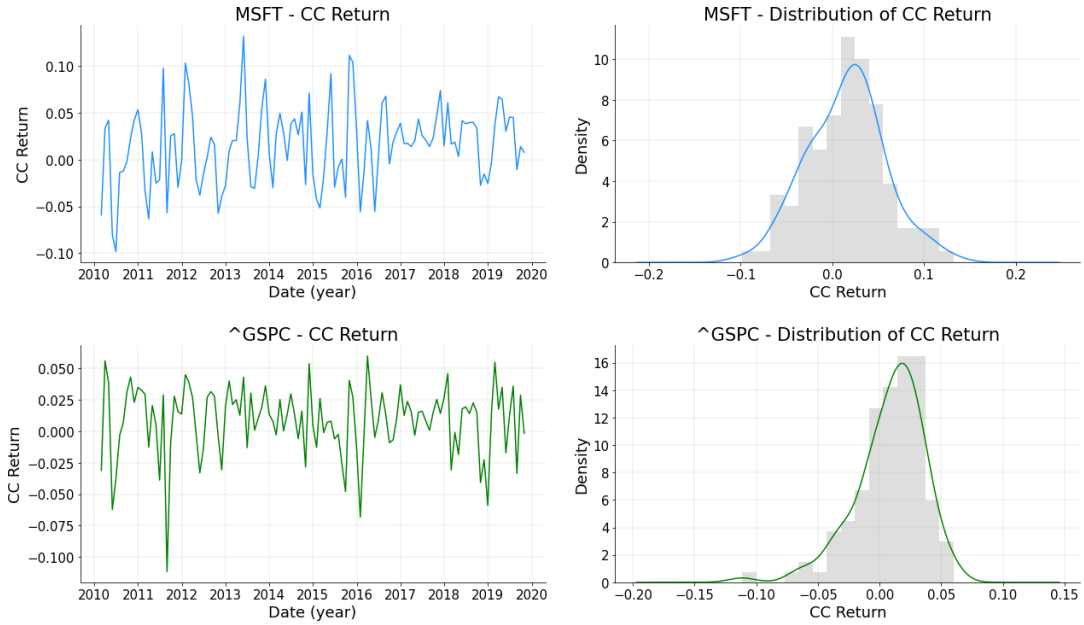

Figure 3.8: Comparison between MSFT and ^GSPC returns and distribution of returns.

3.2.3 Amazon.com Inc.

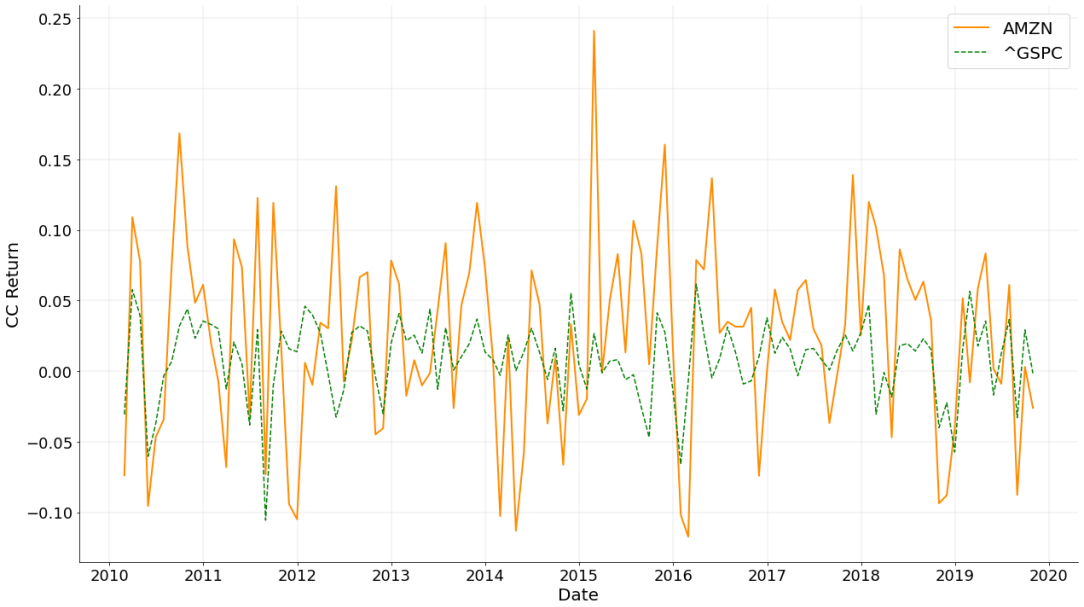

Figure 3.9: CC monthly return of Amazon and S&P500.

Even in this case, we can deduce from the figures 3.9 and 3.10 that Amazon has had quietly the same behavior of the S&P500 index in terms of cc monthly return, but clearly with more evident peaks. In particular we see a strong upward peak in the nearly 2015, that year was a good period for the company, largely thanks to the success of Amazon Web Services (AWS) and obviously because net sales increased by 23% [7] on the e-commerce.

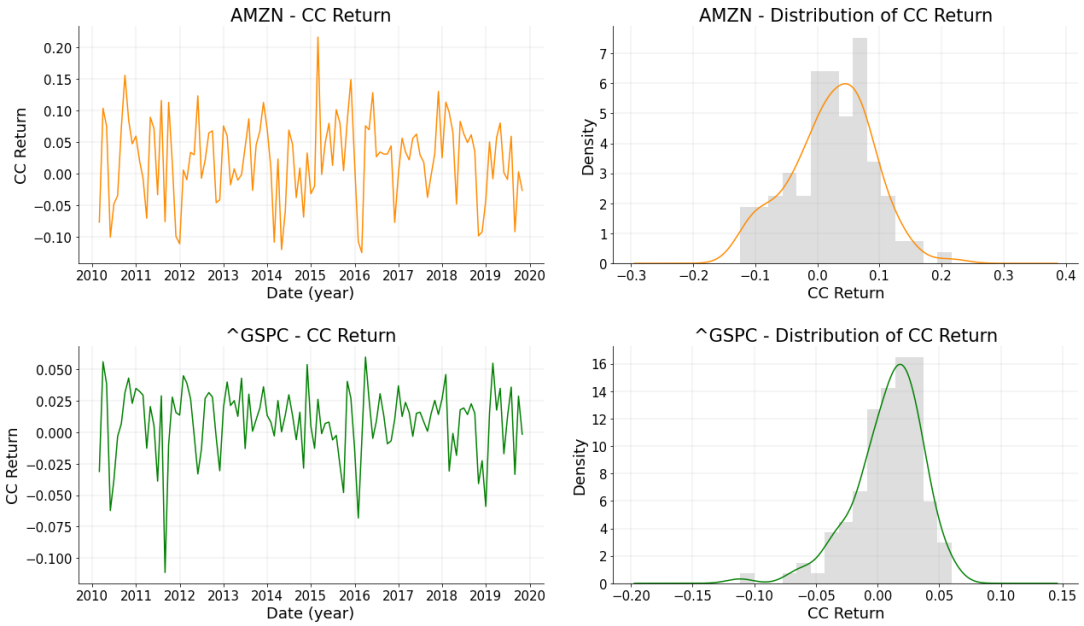

Figure 3.10: Comparison between AMZN and ^GSPC returns and distribution of returns.

3.2.4 Alphabet Inc.

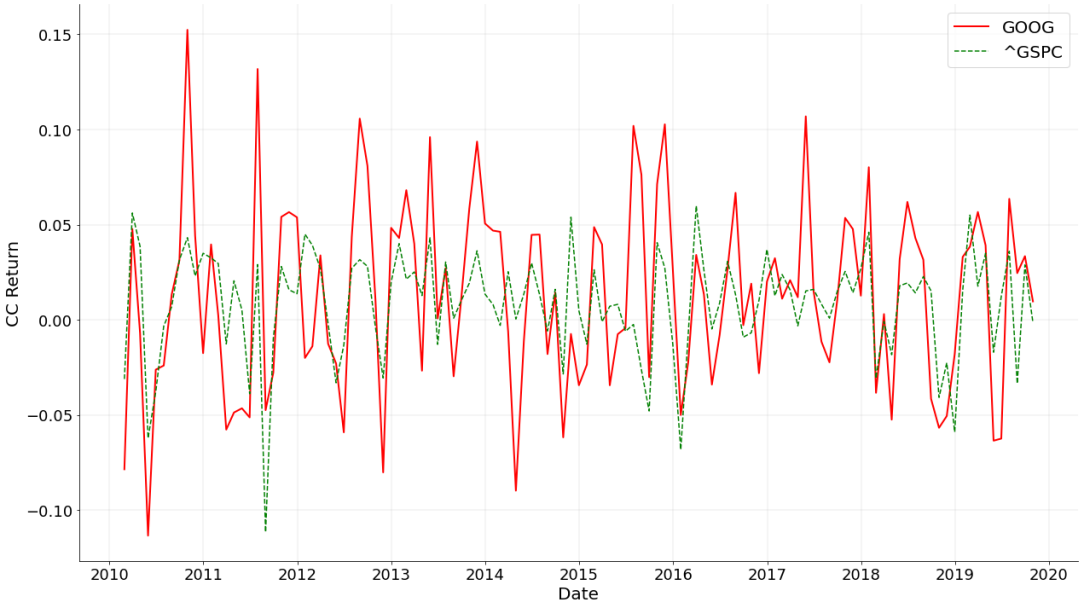

Figure 3.11: CC monthly return of Alphabet and S&P500.

The growth and decrease of the returns of the two financial instruments are often coincide. In general we can see lots of downward peak, between 2010 and 2015, maybe the highest in this considered time series, and the causes are primarily Amazon, Apple, and Facebook [8]. The explanation could be that on Amazon or using Siri by Apple for example, we can do specific search in less time, so this cause a decreasing use of Google's search engine.

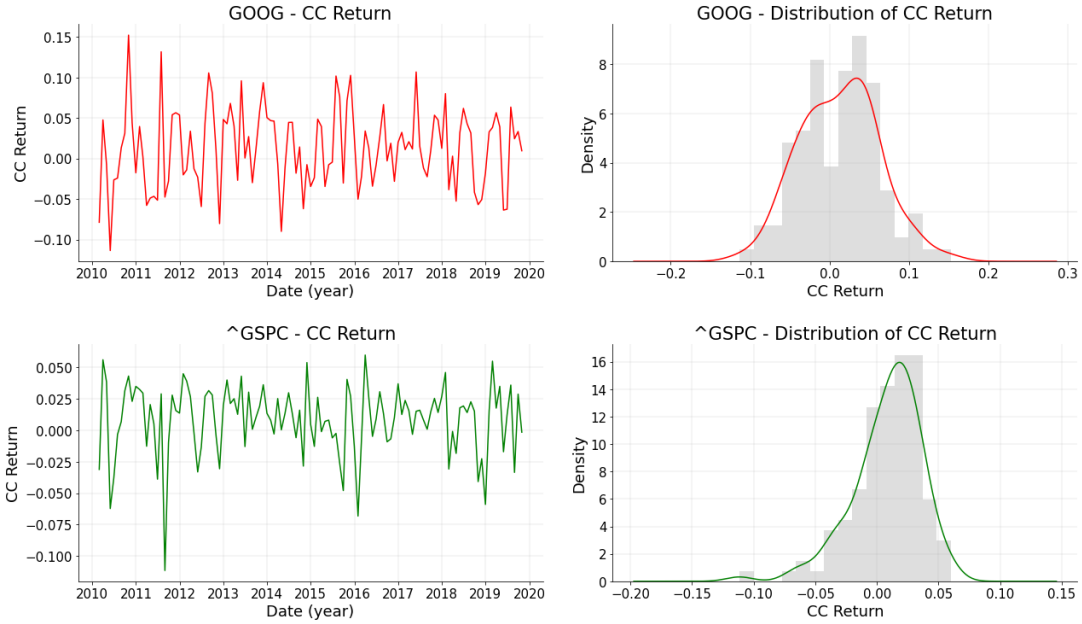

Figure 3.12: Comparison between GOOG and ^GSPC returns and distribution of returns.

3.3 Univariate descriptive statistics

- **Mean**: measures the center of the mass of the pdf (probability density function).
- **Variance and Standard Deviation**: measure the spread of the data around the mean.
- **Kurtosis**: measures of the "tailedness" of the probability distribution.
  - if $= 0$, then the tail is the same as that of a normal distribution;
  - if < 0, then the tail is thinner than that of a normal distribution;
  - if > 0, then the tail is thicker than that of a normal distribution;
- **Skewness**: measures the symmetry (or asymmetry) of a distribution
  - if $= 0$, then the distribution is symmetric, so it's a normal distribution;
  - if < 0, then the distribution has longer left tail than the normal one;
  - if > 0, then the distribution has longer right tail than the normal one;

Analyzing the data, it results that the security with the most outliers is Apple, with 2 of them, followed by the other three which has 1 outlier each.
About kurtosis, we can say that Alphabet has the lowest value, also negative, and Microsoft has the greatest. While regarding skewness, we have that Apple has the lowest value and Alphabet has the greatest instead.

3.3.1 Apple Inc.

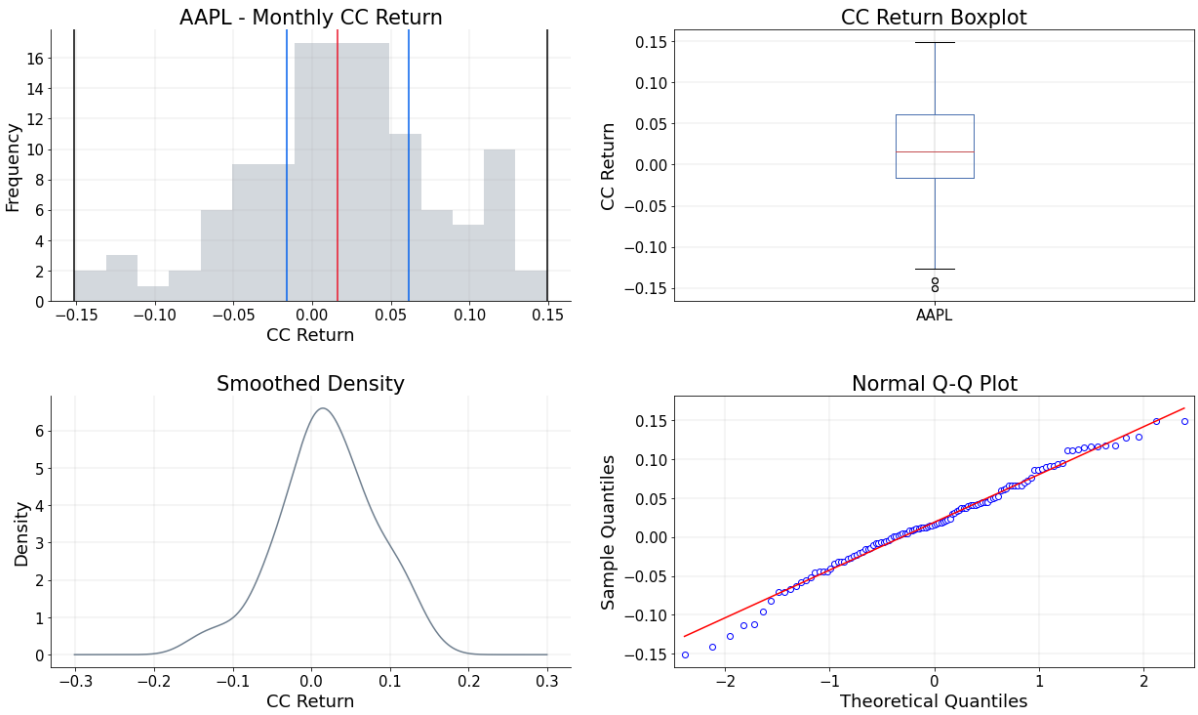

Figure 3.13: Diagnostic plots of AAPL.

0%	25%	50%	75%	100%
-0.1511	-0.0159	0.0160	0.0615	0.1493

Table 3.1: Quantiles of monthly cc return of AAPL.

Mean	Variance	Standard Dev	Kurtosis	Skewness
0.0189	0.0038	0.0616	0.1228	-0.2669

Table 3.2: Descriptive statistics of monthly cc return of AAPL.

Analyzing the plots in figure 3.13, it's clear that for the period taken into consideration Apple had 2 negative outliers, almost certainly related to the drop of iPhone sales in the Chinese market[5]. Taking a look at the table 3.2, particularly considering kurtosis and skewness, we can deduce respectively that the distribution has a slightly thicker tail and also a left tail little bit longer than a normal distribution.

3.3.2 Microsoft Corp.

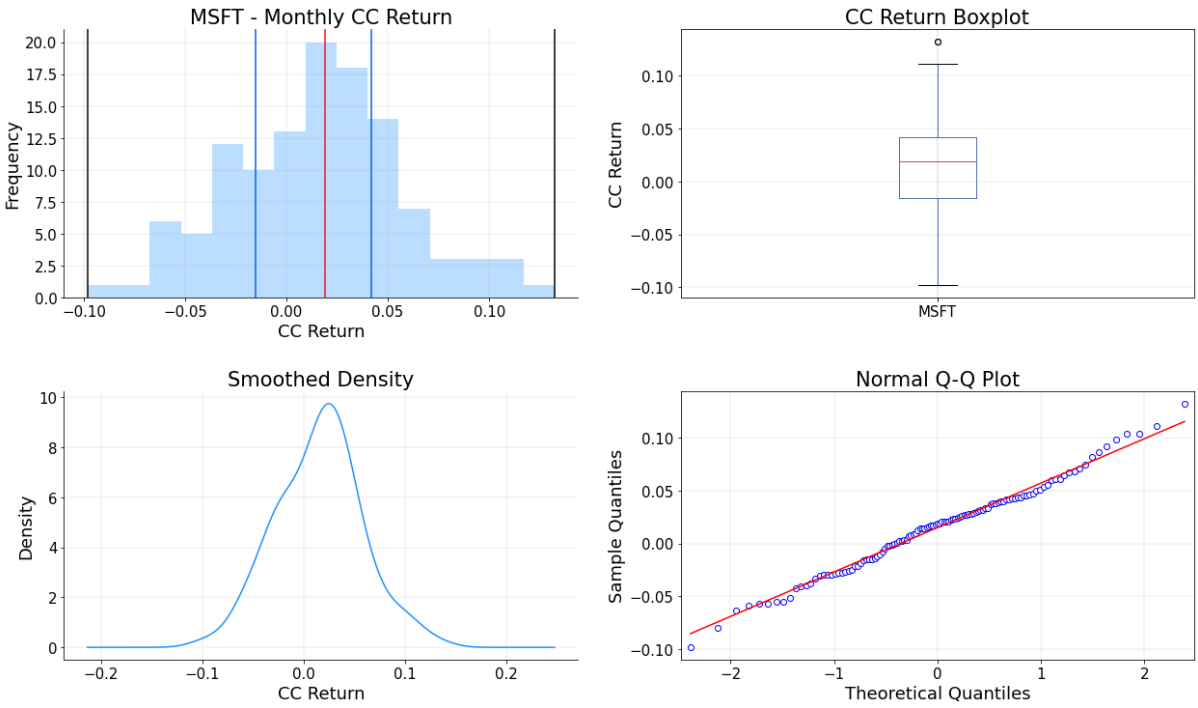

Figure 3.14: Diagnostic plots of MSFT.

0%	25%	50%	75%	100%
-0.0982	-0.0152	0.0188	0.0418	0.1322

Table 3.3: Quantiles of monthly cc return of MSFT.

Mean	Variance	Standard Dev	Kurtosis	Skewness
0.0151	0.0018	0.0422	0.1481	0.0367

Table 3.4: Descriptive statistics of monthly cc return of MSFT.

From the figure 3.14, particularly looking at the boxplot and the normal Q-Q plot, we can see a positive outliers around a rate equals to 0.13 of cc return. Considering the table 3.4, taking a look at the value of kurtosis and skewness, we can deduce respectively that the distribution has a very slightly thicker tail, but we can say approximately like a normal, and also two tails roughly symmetric such as a normal distribution.

3.3.3 Amazon.com Inc.

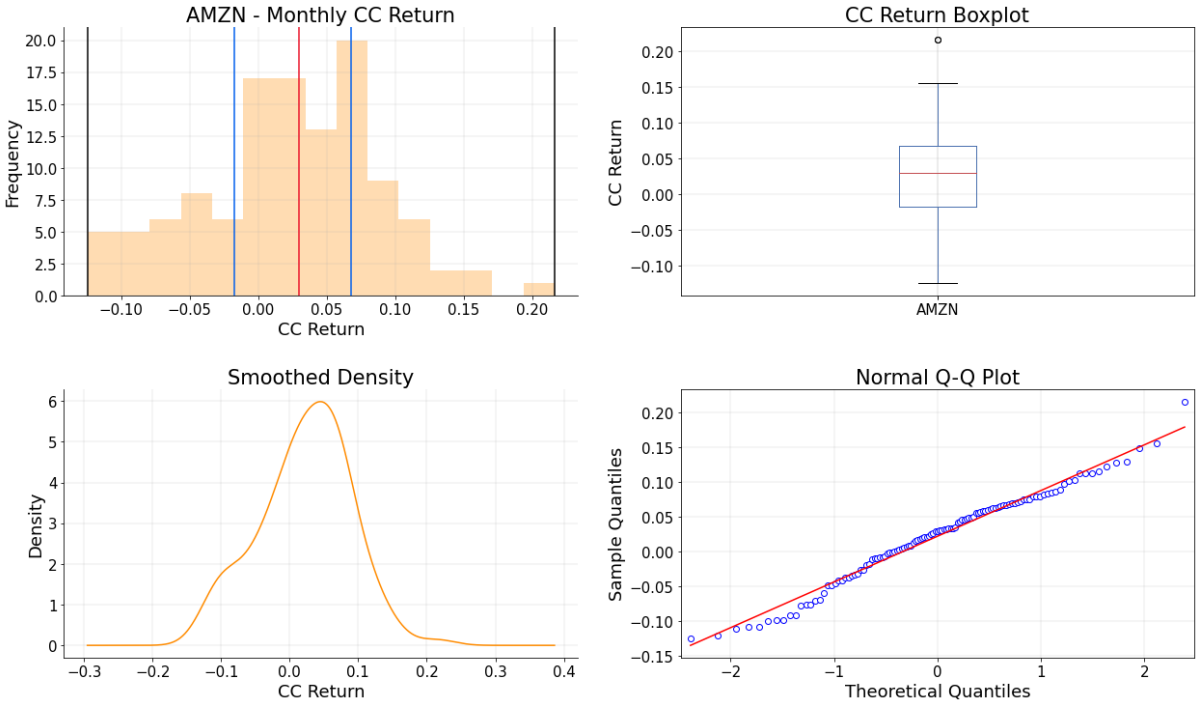

Figure 3.15: Diagnostic plots of AMZN.

0%	25%	50%	75%	100%
-0.1247	-0.0176	0.0299	0.0677	0.2160

Table 3.5: Quantiles of monthly cc return of AMZN.

Mean	Variance	Standard Dev	Kurtosis	Skewness
0.0224	0.0044	0.0661	-0.0506	-0.1825

Table 3.6: Descriptive statistics of monthly cc return of AMZN.

Considering the figure 3.15 and the table 3.6 we can do some observations. Firstly, we see a positive outlier, around a rate of 0.22. As we said in previous section, this is maybe related to a large use of AWS and to growing selling rate of the Amazon e-commerce in 2015. Besides, about the distribution, the value of kurtosis indicates that it has a slightly thinner tail than a normal and skewness indicates that the distribution has a left tail which is a little longer than the normal one.

3.3.4 Alphabet Inc.

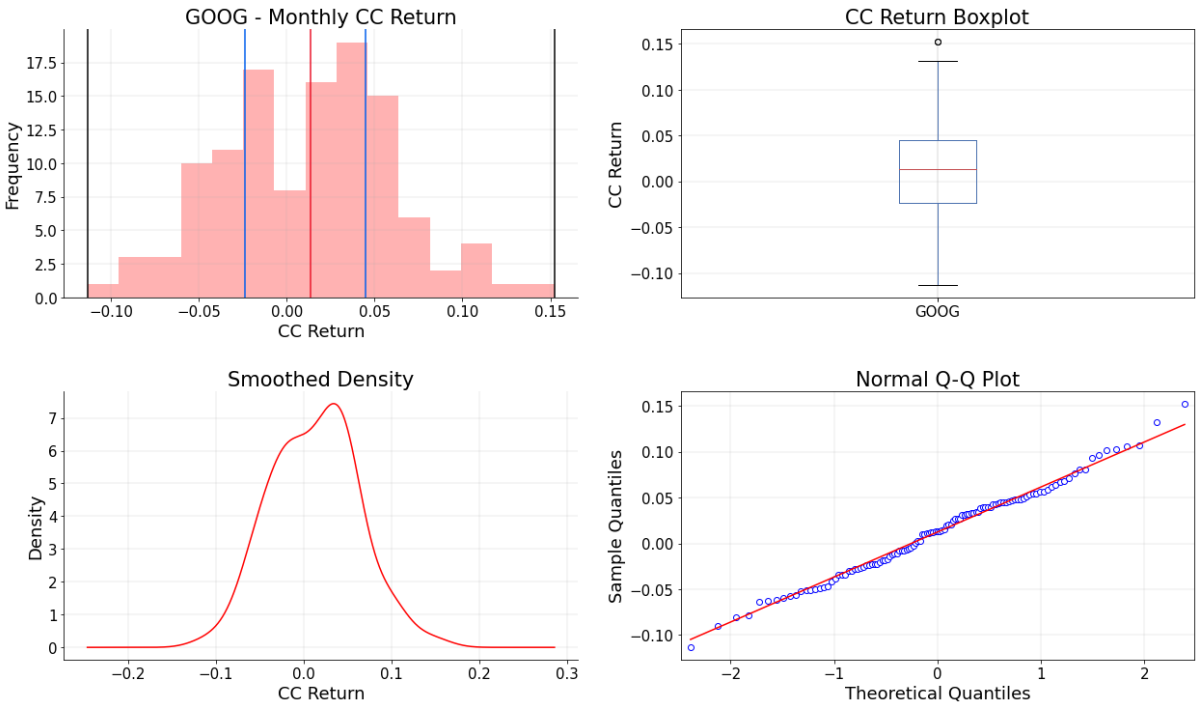

Figure 3.16: Diagnostic plots of GOOG.

0%	25%	50%	75%	100%
-0.1134	-0.0235	0.0133	0.0448	0.1524

Table 3.7: Quantiles of monthly cc return of GOOG.

Mean	Variance	Standard Dev	Kurtosis	Skewness
0.0124	0.0024	0.0493	-0.0930	0.1088

Table 3.8: Descriptive statistics of monthly cc return of GOOG.

Observing the data above and considering the period taken into analysis, we can notice that Alphabet has one positive outlier around 0.15, registered between 2010 and 2011. That doesn't seem related to any news of that years. Through the table 3.8, in particular looking at kurtosis and skewness values, we can say, respectively, that the distribution has slightly thinner tail and a right tail which is little bit longer than the normal distribution.

3.3.5 Comparing the four financial instrument

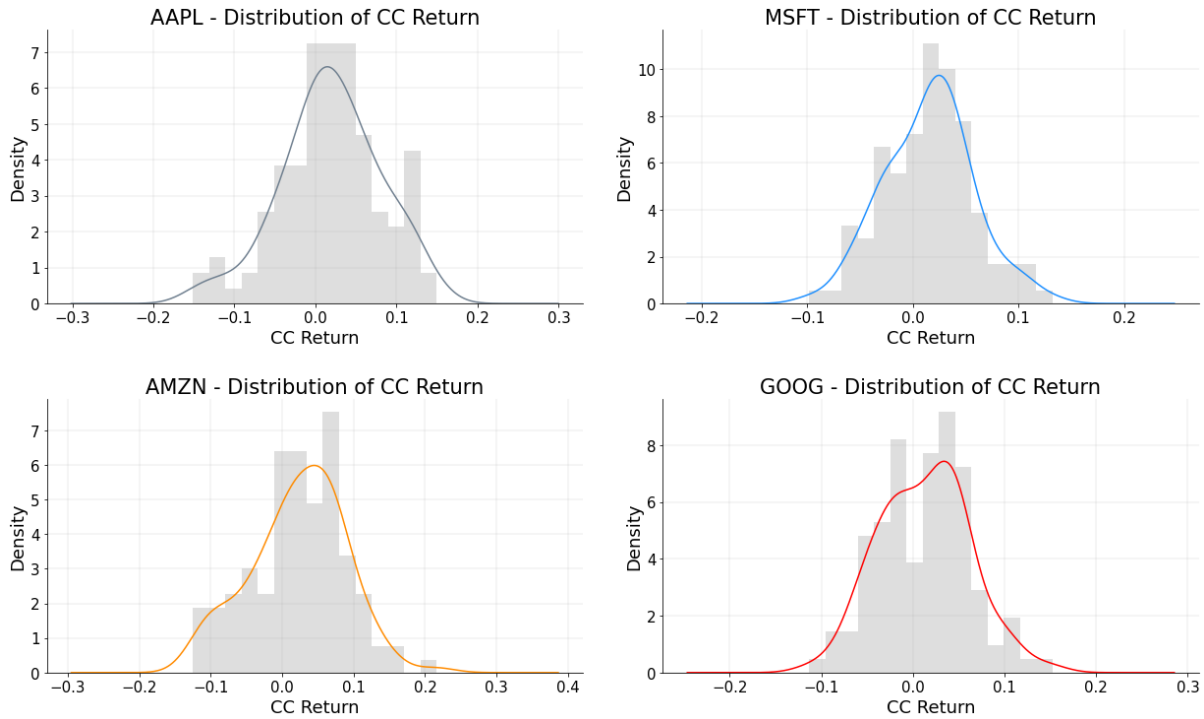

Figure 3.17: Comparison of each asset cc return histogram.

Observing globally the for plots of each asset, we can notice that the distribution that is closest to a normal one, is the Microsoft's distribution. We can also observe that, in general, Alphabet has positive and negative returns with more high frequency, compared to the others, making this financial instrument more risky, even if the positive returns seems to be greater than the negatives. A good long term investment, in that period of time and with a moderate level of risk, it could be Microsoft.
Also we can notice, from the figure 3.19, that Apple has the largest amount of outliers compared to the others.

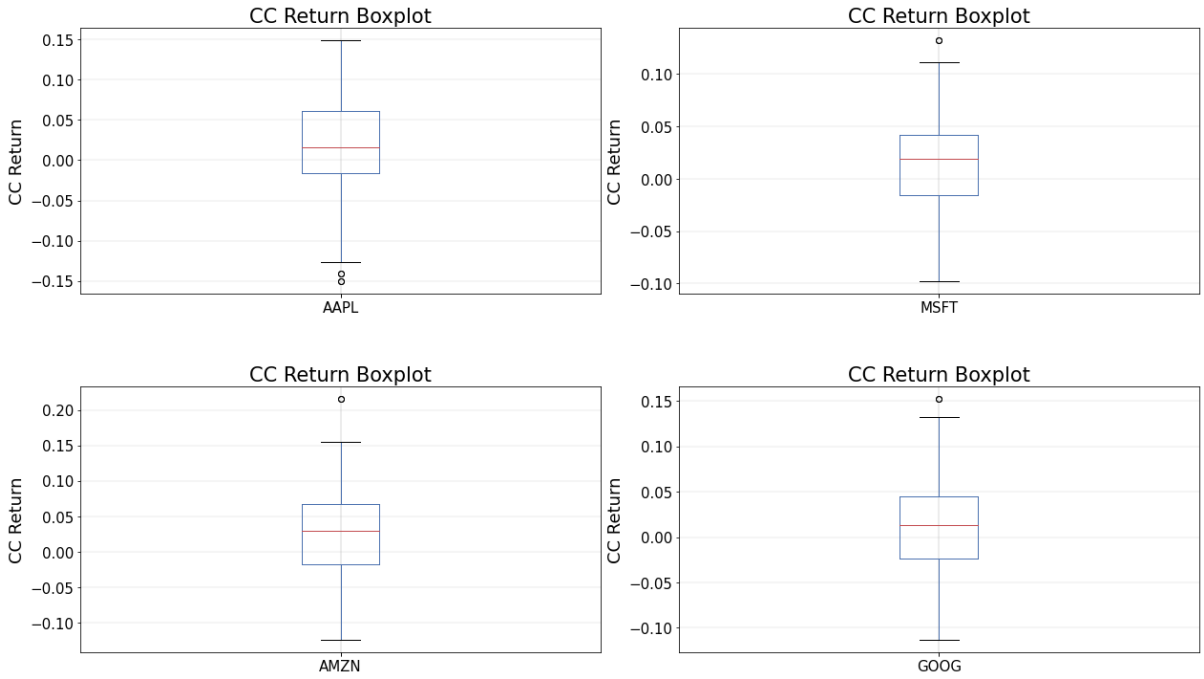

Figure 3.18: Comparison of all boxplots.

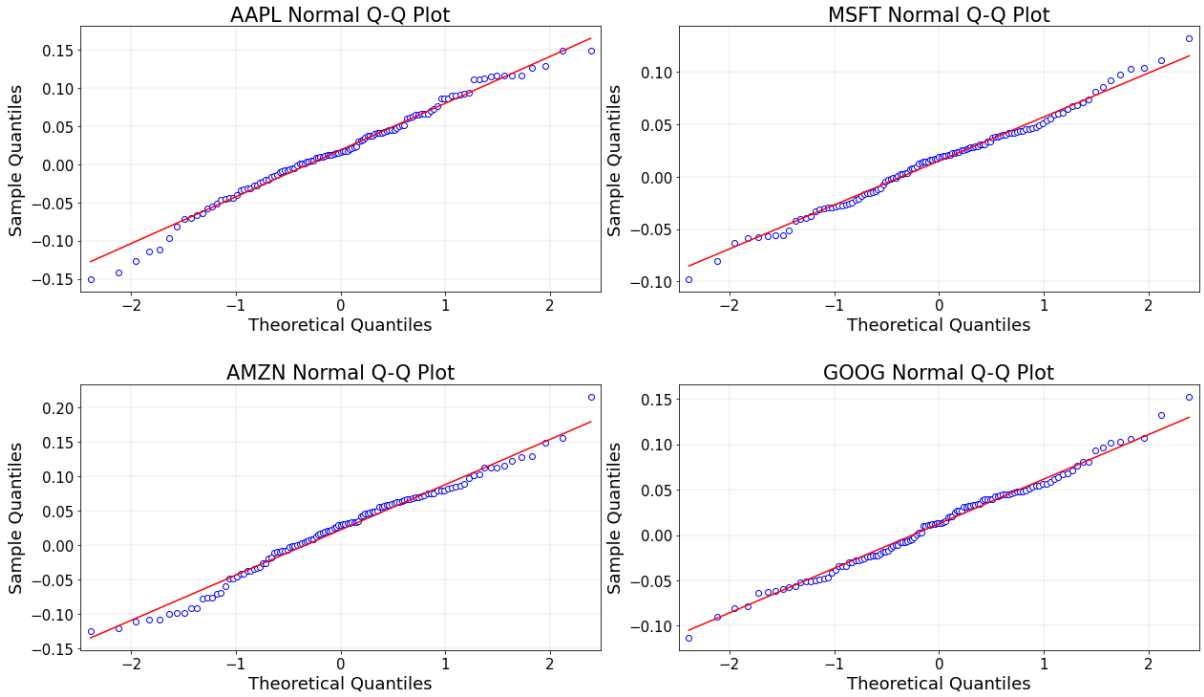

Figure 3.19: Comparison of all Normal Q-Q plots.

3.4 Bivariate distribution analysis

In this section we'll see the bivariate analysis (i.e. covariance, linear correlation with the help of scatter plots) of each financial instrument respect to the others and respect to the market index S&P500 taken as benchmark in this report. The analysis's been made in two differnt time scale, which are monthly analysis and daily analysis.

3.4.1 Monthly analysis

Figure 3.20: Scatter plot of monthly cc return of each asset related to ^GSPC.

	AAPL	MSFT	AMZN	GOOG	^GSPC
AAPL	0.003796	0.001139	0.001289	0.001005	0.000927
MSFT	0.001139	0.001780	0.001044	0.000991	0.000757
AMZN	0.001289	0.001044	0.004363	0.001648	0.000889
GOOG	0.001005	0.000991	0.001648	0.002431	0.000799
^GSPC	0.000927	0.000757	0.000889	0.000799	0.000778

Table 3.9: Covariances of monthly cc return.

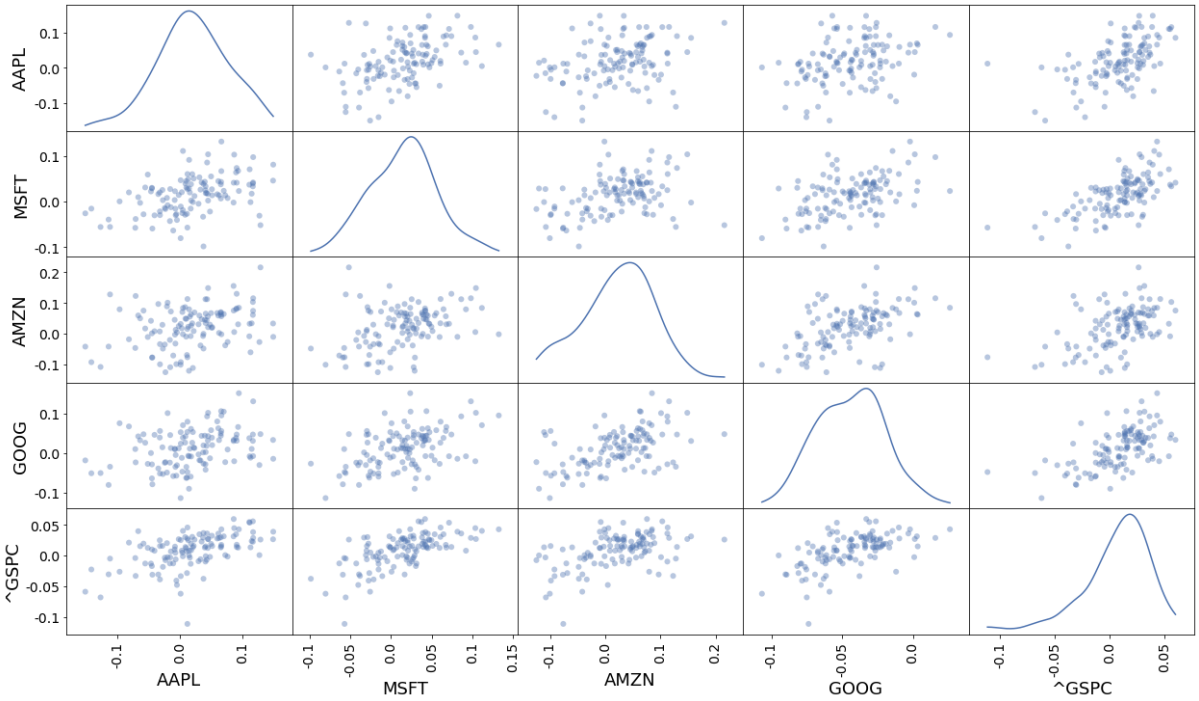

Figure 3.21: Scatter plot of monthly cc return of all stocks.

	AAPL	**MSFT**	**AMZN**	**GOOG**	**^GSPC**
AAPL	1	0.438076	0.316823	0.330711	0.539436
MSFT	0.438076	1	0.374561	0.476261	0.643044
AMZN	0.316823	0.374561	1	0.505849	0.482252
GOOG	0.330711	0.476261	0.505849	1	0.580925
^GSPC	0.539436	0.643044	0.482252	0.580925	1

Table 3.10: Pearson correlation of monthly cc return.

We can easily note that each asset has pretty good linear correlation with the market index considered, and it seems that Microsoft does better than the others with about 64%, as confirmed the data in table 3.10, Amazon does the worst instead, with about 48% linear correlation with the index. Observing the other pairs, we see that there's also a pretty good linear correlation between Alphabet and Amazon, around 50%. Also between Microsoft and Alphabet, and Microsoft and Apple, respectively around 47% and 44%, so no wonder since they have the web search and hardware/software production in common. Other pairs show a moderate linear correlation ranging from 31% to 37%.

3.4.2 Daily analysis

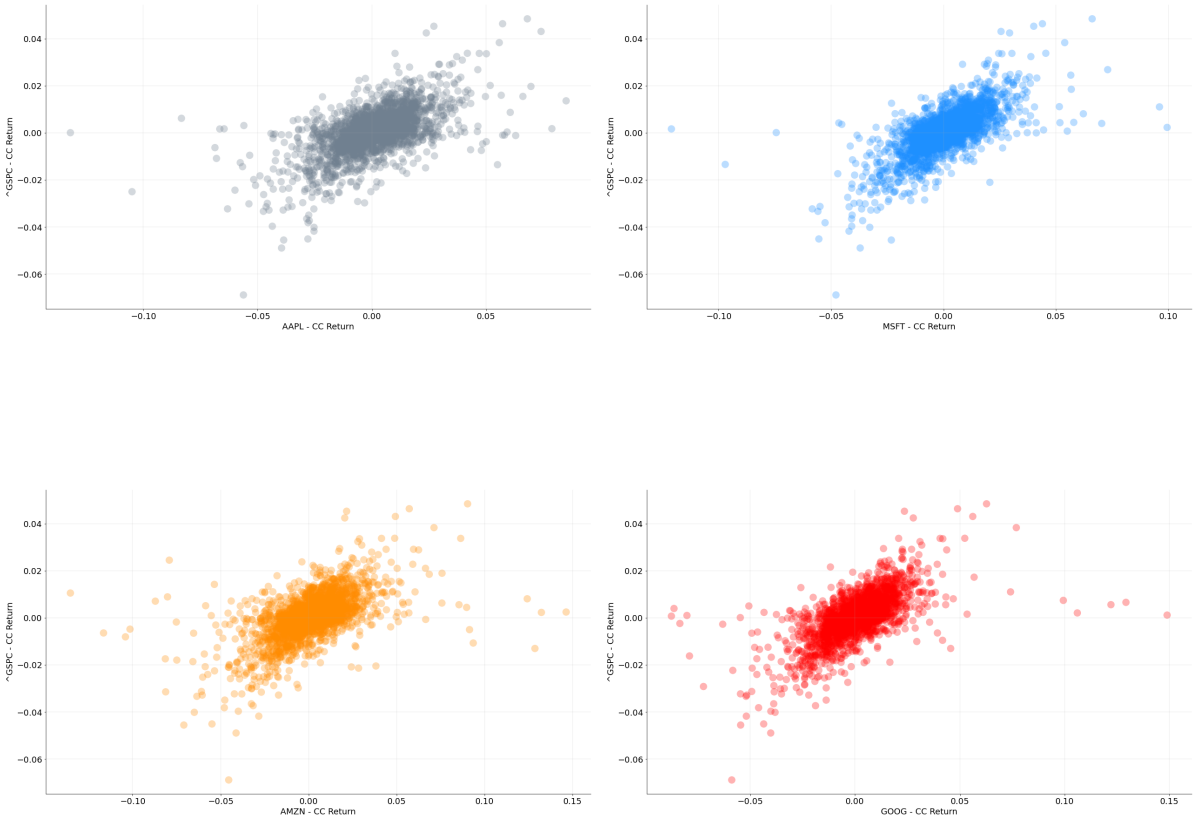

Figure 3.22: Scatter plot of daily cc return of each asset related to ^GSPC.

	AAPL	**MSFT**	**AMZN**	**GOOG**	**^GSPC**
AAPL	0.000266	0.000108	0.000127	0.000117	0.000091
MSFT	0.000108	0.000207	0.000137	0.000121	0.000094
AMZN	0.000127	0.000137	0.000383	0.000169	0.000105
GOOG	0.000117	0.000121	0.000169	0.000237	0.000093
^GSPC	0.000091	0.000094	0.000105	0.000093	0.000088

Table 3.11: Covariances of daily cc return.

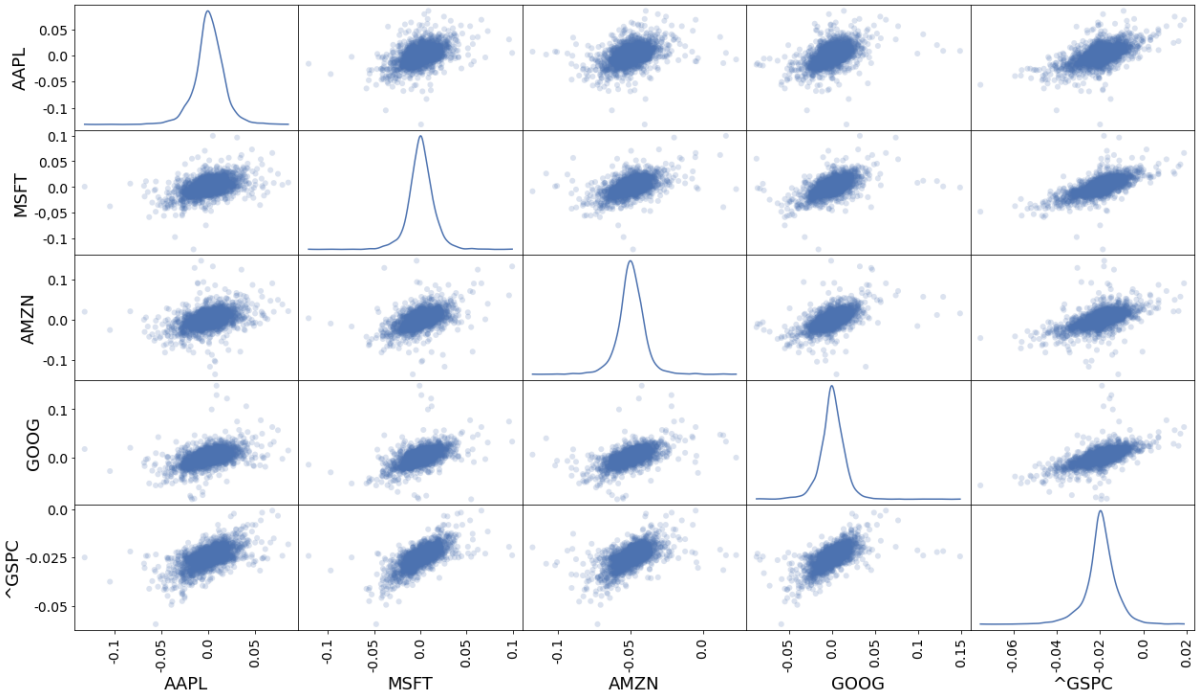

Figure 3.23: Scatter plot of daily cc return of all stocks.

	AAPL	**MSFT**	**AMZN**	**GOOG**	**^GSPC**
AAPL	1	0.458483	0.398394	0.466700	0.593922
MSFT	0.458483	1	0.487462	0.544290	0.694653
AMZN	0.398394	0.487462	1	0.560886	0.569745
GOOG	0.466700	0.544290	0.560886	1	0.640434
^GSPC	0.593922	0.694653	0.569745	0.640434	1

Table 3.12: Pearson correlation of daily cc return.

Doing a daily analysis, we firstly see that the linear correlation increased globally, assuming values ranging from 39% to almost 70%. Especially between each asset respect to the market index ^GSPC. We have that Microsoft has a pretty strong daily linear correlation with the index around 69%, and also Alphabet with the 64%.

Chapter 4

Beta Computation

The beta of a security measures the linear dependence of the return of the security respect to the return of the market, in proportion to the volatility ratio asset/market. We can speak, informally, about the beta value as that coefficient, which tell us something about the movement and volatility of the asset respect to the whole market (i.e. a benchmark index). To compute the beta, we'll use the following equation.

$$\beta = \frac{Cov(R_i, R_m)}{Var(R_m)} = \rho(R_i, R_m)\frac{\sigma_i}{\sigma_m},$$

where:
R_i = return on an individual stock,
R_m = return on the benchmark index,
$Covariance$ = how changes in a stock's returns are related to changes in the market's returns,
$Variance$ = how far the market's data points spread out from their mean value.

In this chapter we'll analyze the beta coefficient, during the time period taken into consideration (i.e. January 2010 - October 2019), of each asset using as a benchmark the market index S&P500.

4.1 Beta coefficient and time series

Observing the table 4.1, we see that AAPL has a $\beta \approx 1.202407 > 1$, this means that the asset moves in the same direction of the market but with greater volatility. We can do the same reasoning considering MSFT and AMZN. Otherwise, GOOG has $\beta \approx 0.981632 \rightarrow 0 < \beta < 1$, and this tell us that the asset moves in the same direction of the market, but its volatility can be $<$ or $>$ than the volatility of the market.

AAPL	**MSFT**	**AMZN**	**GOOG**
1.202407	1.152483	1.036267	0.981632

Table 4.1: Beta coefficient calculated on monthly cc return.

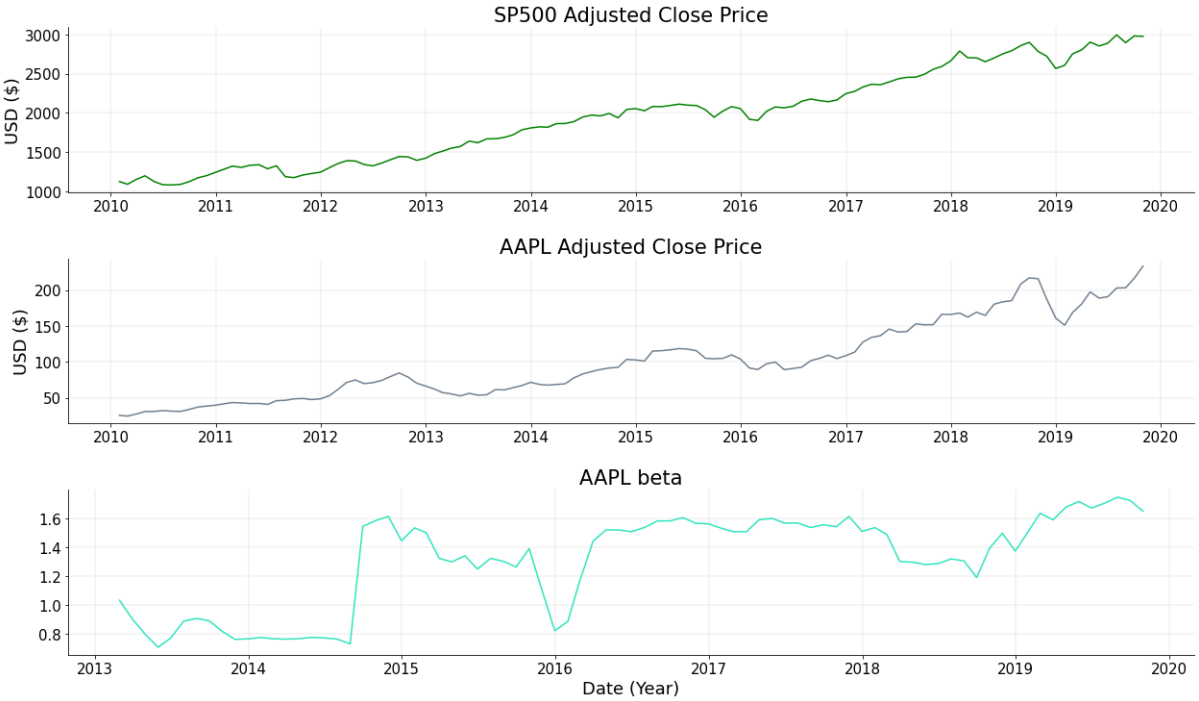

Figure 4.1: Apple's beta time series.

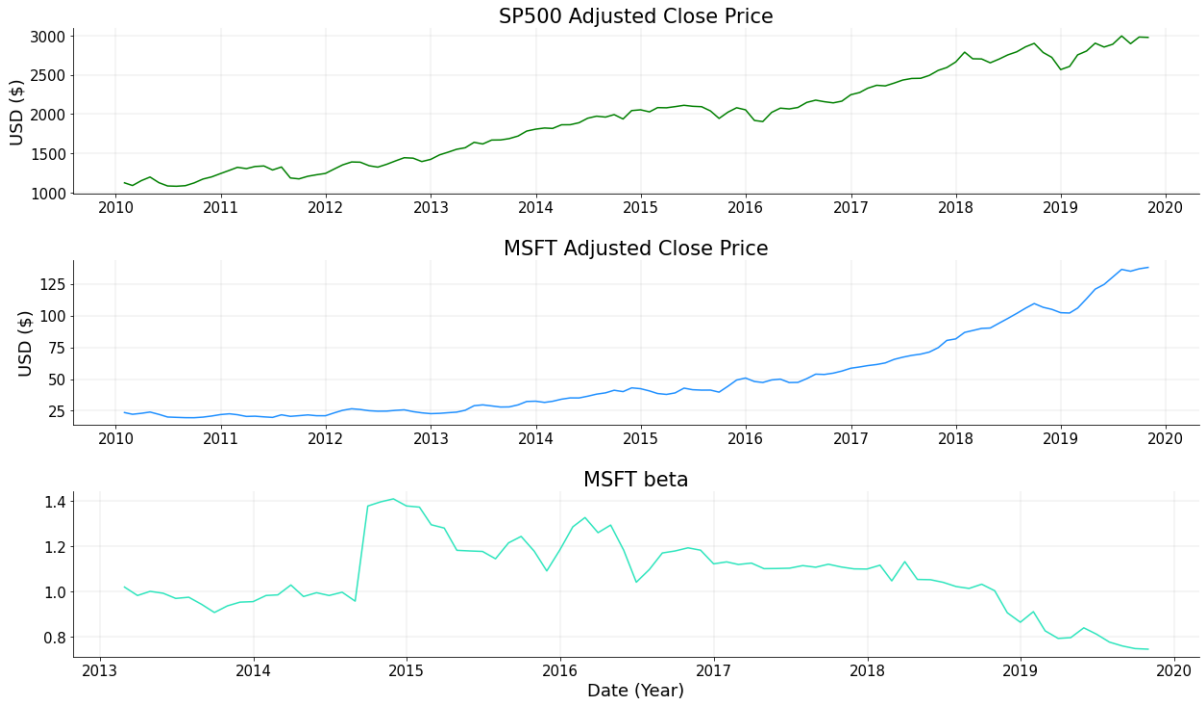

Figure 4.2: Microsoft's beta time series.

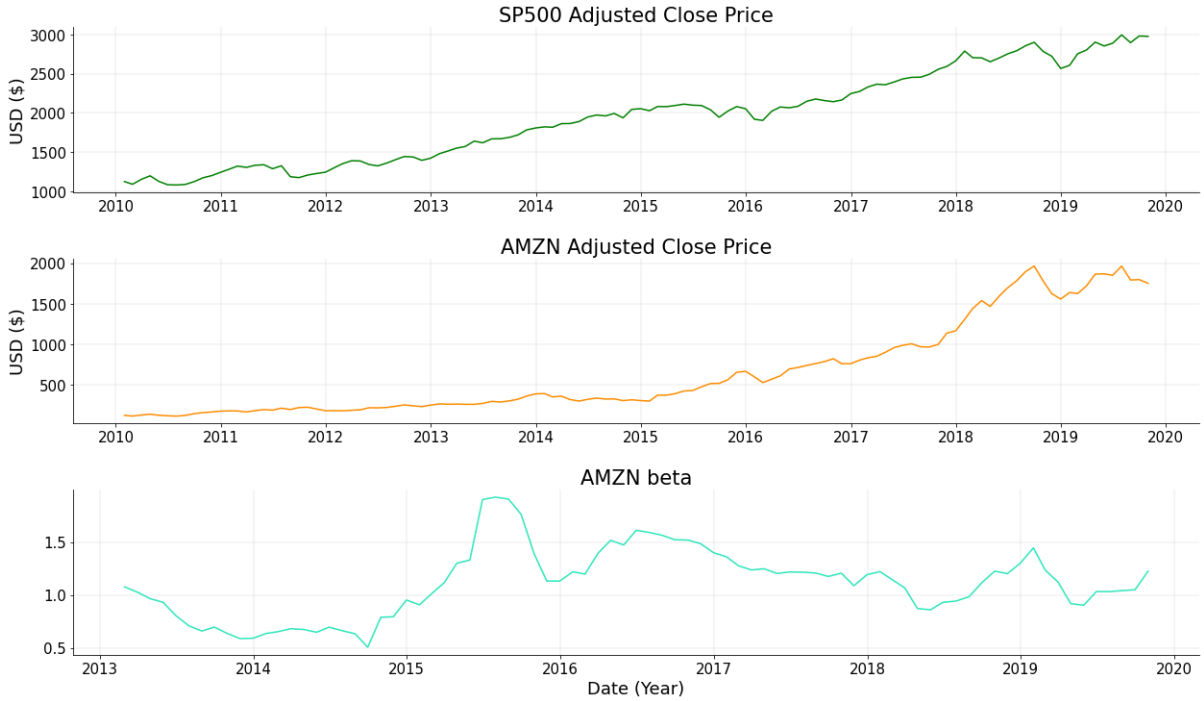

Figure 4.3: Amazon's beta time series.

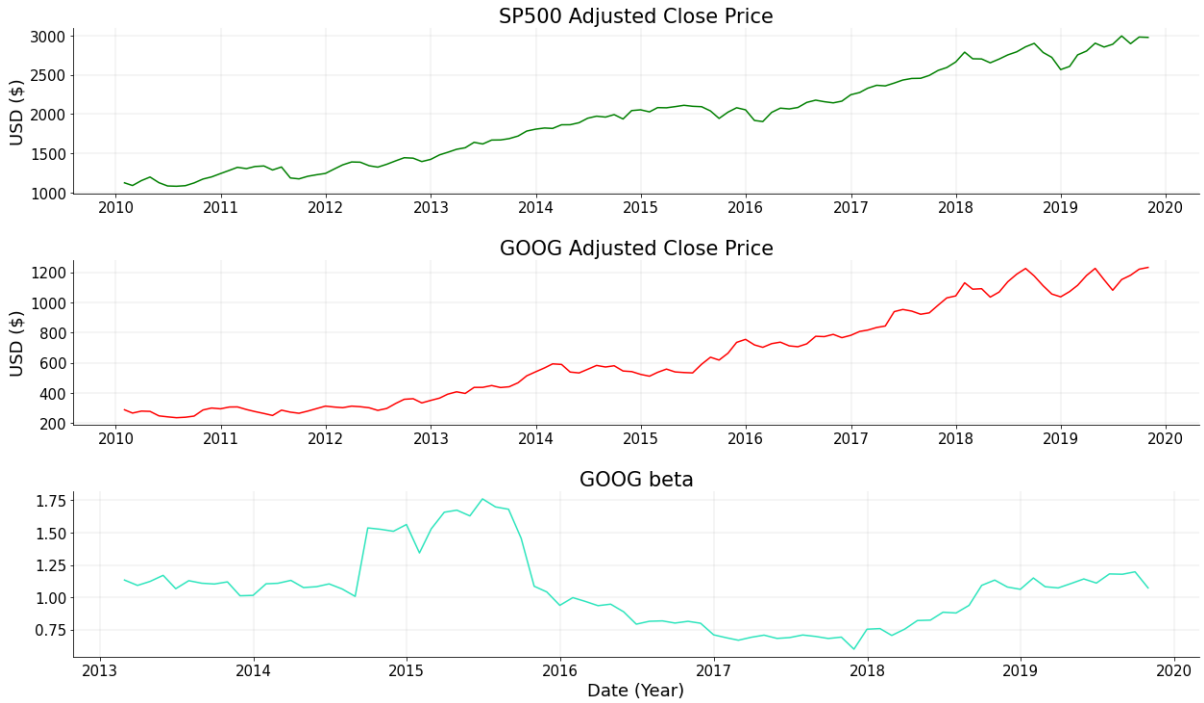

Figure 4.4: Alphabet's beta time series.

Chapter 5

Predictive Analytics

We'll see the results of a predictive analytics on the adjusted close price, which is been done considering the same time period for each stock, that is January 2010 - October 2019. Specifically, 96 months as training set, 10 months as test set and 12 months as validation set.

The forecasting is been performed by using a Support Vector Regression (SVR) model. The SVR is a linear regression model commonly used in machine learning and data mining. An SVR thus solves an optimization problem that involves primarly three parameters: the *regularization* parameter (often referred to as C), the *error sensitivity* parameter (often referred to as ϵ), the *kernel* and its internal parameters (e.g. the γ which represent the kernel coefficient which defines how far the influence of a single training example reaches, with low values meaning 'far' and high values meaning 'close'). In particular, the kernel used is the *Radial Basis Function* or simply RBF Kernel.
Finally, as performance measures we'll consider the Mean Absolute Error (MAE), the Root Mean Squared Error (RMSE) and the R^2 coefficient, or coefficient of determination, which simply tell us some information about the goodness of fit of a model. In regression analysis, the R^2 coefficient of determination is a statistical measure of how well the regression predictions approximate the real data points. An R^2 of 1 indicates that the predictions perfectly fit the data.

5.1 Apple Inc.

Observing the figure 5.2 we can see that the SVR model didn't catch the downward peak in earlier 2019, presenting approximately a constant price instead. From mid-2019 it performed pretty good and it seems that the almost regular trend of the asset influenced positively the predictions.

MAE	**RMSE**	R^2
13.2798	18.3658	0.7850

Table 5.1: Performance measures about AAPL forecast.

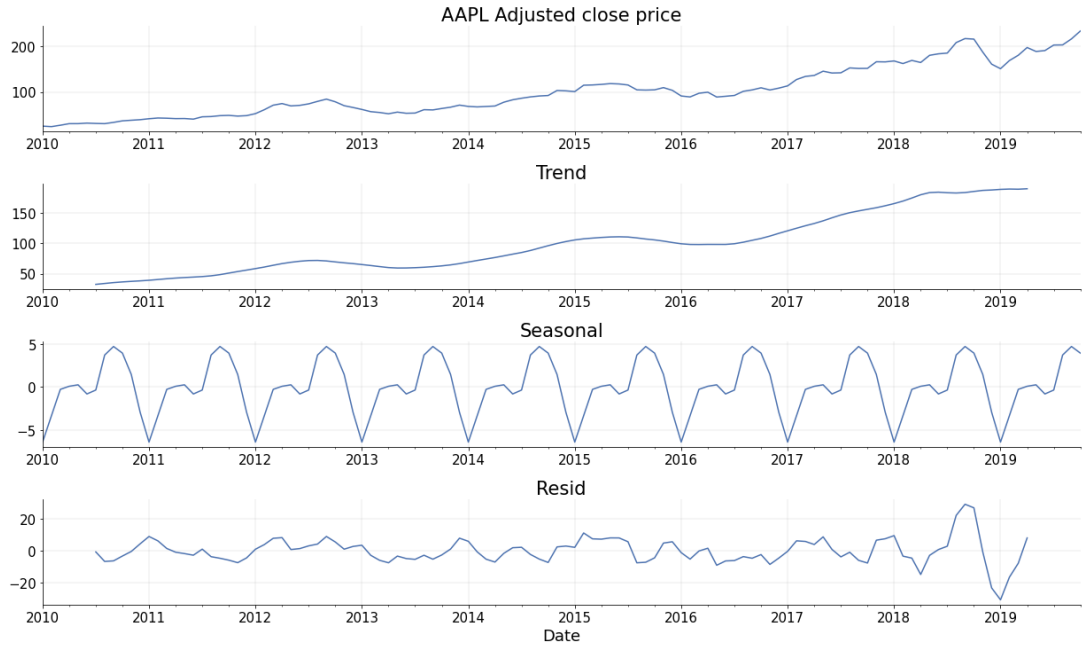

Figure 5.1: Seasonal decomposition of the adjusted close price of AAPL.

Figure 5.2: Result of forecasting on the adjusted close price of AAPL using a SVR.

5.2 Microsoft Corp.

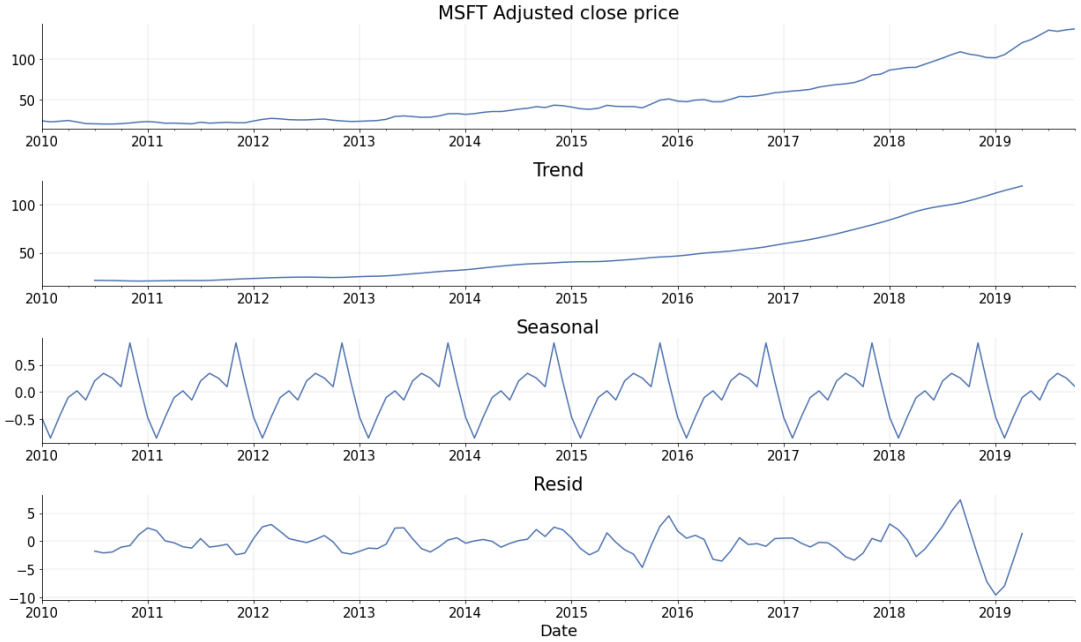

Figure 5.3: Seasonal decomposition of the adjusted close price of MSFT.

In this case, looking at figure 5.4, we can see that the model did very well predictions, and as we can read in table 5.2 it has a confidence level around 99%. As we saw in previous chapters, this security has a variance pretty close to 0 (table 3.4) and the lowest among the four asset analyzed, and also has very linear trend, that's why the regression model performed so well.

MAE	**RMSE**	R^2
2.2242	3.2267	0.9948

Table 5.2: Performance measures about MSFT forecast.

Figure 5.4: Result of forecasting on the adjusted close price of MSFT using a SVR.

5.3 Amazon.com Inc.

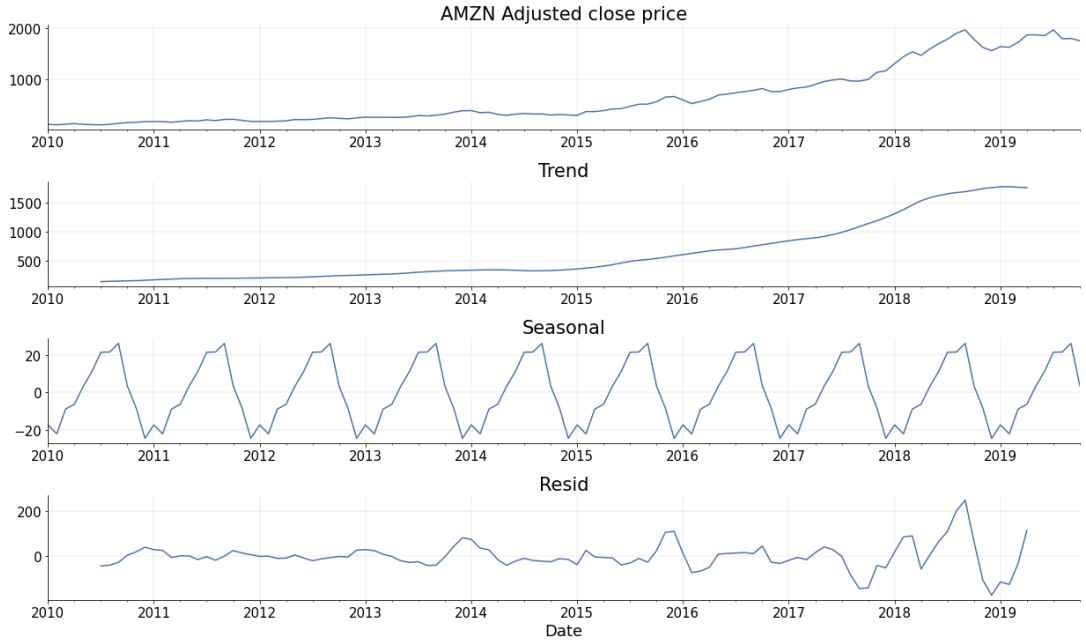

Figure 5.5: Seasonal decomposition of the adjusted close price of AMZN.

Considering the figure 5.6 and the table 5.3, we can say that even in this case the model performed well. Though, respect to the real value, it seems slightly translated to the right and presenting a growth at the end of the series instead of a decrease.

Figure 5.6: Result of forecasting on the adjusted close price of AMZN using a SVR.

MAE	**RMSE**	R^2
68.8731	93.8453	0.9701

Table 5.3: Performance measures about AMZN forecast.

5.4 Alphabet Inc.

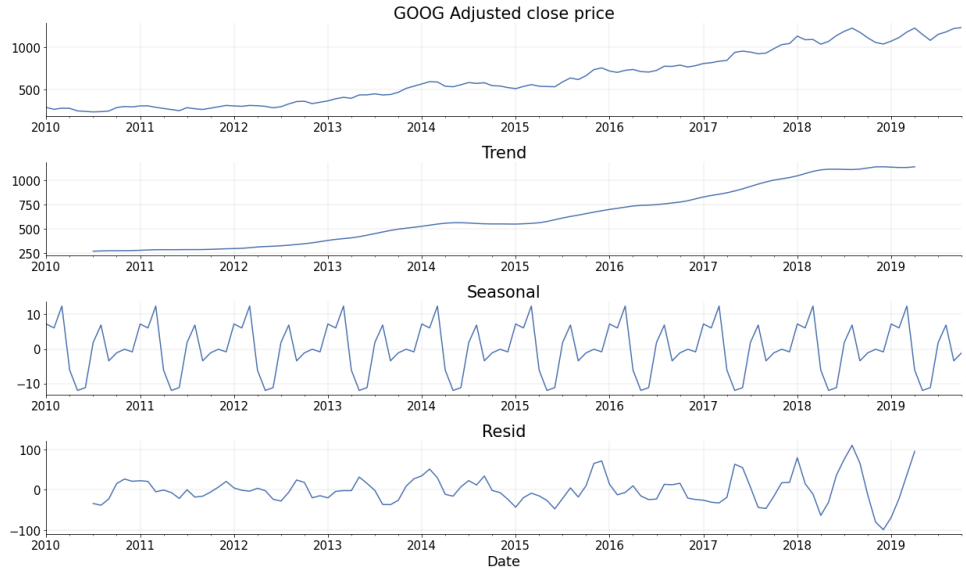

Figure 5.7: Seasonal decomposition of the adjusted close price of GOOG.

As we can notice from figure 5.8, considering the actual values observed and those predicted, the SVR model did good in general, except for that downward peak, which is stronger than what happened actually.

Figure 5.8: Result of forecasting on the adjusted close price of GOOG using a SVR.

MAE	**RMSE**	R^2
31.7597	104.5816	0.7906

Table 5.4: Performance measures about GOOG forecast.

Chapter 6

Portfolio Management

The portfolio management is been done using the beta values of each financial instrument to set the relative weight. Specifically we consider a higher weight for a higher beta value. The beta's been calculated as following:

$$\beta = \frac{Cov(R_{asset}, R_{index})}{Var(R_{index})}$$

Then each weight's been calculated using the following equation and obtaining the values in table 6.1. The beta's been calculated as following:

$$w_i = \frac{\beta_i}{\sum_{i=1}^{n} \beta_i}, i \in 1, .., 4$$

Asset	β_i	w_i
1:AAPL	1.202407	0.274975
2:MSFT	1.152483	0.263558
3:AMZN	1.036267	0.236981
4:GOOG	0.981632	0.224486

Table 6.1: Weight of each asset in portfolio.

The available budget is $50,000 and it's distributed according to the weights calculated previously, but bearing in mind that the number of shares to be purchased has to be an integer value. Besides, the time period of the investment start from January 2, 2019 to October 31, 2019, i.e. a 10 months investment. The situation at the beginning of the investemet is presented in table 6.2.

Asset	**Distribution** ($)	**Open price** ($)	**Shares to buy**	**Invested** ($)
1:AAPL	13,748.74	154.79	88	13,621.96
2:MSFT	11,224.32	99.10	113	11,198.21
3:AMZN	13,177.90	1,539.13	8	12,313.04
4:GOOG	11,849.04	1,045.85	11	11,504.35
Total	50,000	-	220	48,637.56

Table 6.2: Summary of the portfolio at start date.

At the end of the 10 months, specifically on October 31, 2019, we sell all the assets in portfolio, obtaining the following situation.

Asset	**Close price** ($)	**5% Tran. costs** ($)	**Close net price** ($)
1:AAPL	246.76	12.34	234.42
2:MSFT	142.10	7.11	134.99
3:AMZN	1,776.66	88.83	1,687.83
4:GOOG	1,260.11	63.01	1,197.10

Table 6.3: Summary of the portfolio at end date.

Then we can calculate the return of each asset and of the portfolio, using the following equation.

$$R(t_0, t_1) = \frac{P_1 - P_0}{P_0},$$

where t_0 and t_1, called the *holding period*, are respectively the start date and the end date, and so the P_0 and P_1 are respectively the price of the asset on start date, since we buy it, and the price on end date, since we sell it.
Globally, The portfolio had a positive income with approximately 28.62% returns.

Asset	**Open price**	**Close net price** ($)	**Shares owned**	**Return**	**P&L**
1:AAPL	154.79	234.42	88	0.5144	7,007.19
2:MSFT	99.10	134.99	113	0.3622	4,056.10
3:AMZN	1,539.13	1,687.83	8	0.0966	1,189.58
4:GOOG	1,045.85	1,197.10	11	0.1446	1,663.80
Total	-	-	220	0.2862	13,916.67

Table 6.4: Summary of the portfolio.

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