Haaga-Helia
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Profitability comparison between option pricing models for American stock options after Subprime crisis

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Abstract

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Diversification of investments is an important aspect of any investor's portfolio. One of the alternative investment methods is option trading. To fully understand options´ potential, investors need to understand how they function and how they are priced. Therefore, this thesis covers three different pricing models and how profitable they were theoretically with chosen stock options after Subprime.

The pricing models used were Black-Scholes Model, Binomial Cox-Ross-Rubinstein Model and Monte Carlo Model. The stock option companies were Amazon, Netflix, Berkshire Hathaway, United Airlines and Salesforce.com.

The thesis is research based and it was performed as a quantitative analysis. The thesis contains four investigative questions to answer the research question which is: Which option pricing method would have been the most profitable for the selected stock options after Subprime? The analysis was done in multiple different Excel workbooks in order to calculate each model´s pricings for the selected stock options.

The results were constructed by analysing 23 different figures conducted from the analysis. The figures analysed return on investment calculations in a form of line graphs, averages, and medians.

The results are intriguing and clearly the best option pricing model was found. The best option pricing model was the Cox-Ross-Rubinstein binomial model. I recommend for further research to be done. The Cox-Ross-Rubinstein binomial model could be compared to other option pricing models as well. This thesis could also be continued as a master's thesis due to some difficulties mentioned in the research method chapter.

I am certain that anyone who is interested about options and option pricing models should read this thesis as this covers popular models in the field and could inspire others who are interested about them to do something similar.

Keywords
Investing, Options, Pricing Models, Black-Scholes, Cox-Ross-Rubinstein Binomial Model, Monte Carlo Model

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1 Introduction

Options trading is one of the most uncommon trading methods in the investment segment. Yet it is a big part of some of the biggest companies in the world. Options trading is a form of derivative investing methods. For many companies, it is a method of protecting their assets but nowadays it is a method for single investors as well. Options are riskier than many of the other investing methods and due to that, there are a lot of different pricing models for the options. The models are complex formulas and there are many types.

In this chapter, I am going to introduce the subject of my thesis and give background information to understand the research questions, demarcation, international aspect of the thesis, benefits of the thesis for the stakeholders, risk analysis and key concepts of the thesis. My thesis was done for a degree programme in international business and it covers topics in my accounting and finance major.

1.1 Background

The study was a desktop research into a field that I am very keen to. The mission of this thesis was to compare three different pricing models and to research which of them would be the wisest to use theoretically. Meaning which one would bring the biggest return on investment by their pricing. The research concentrated on stock options. The stocks were from five companies from the United States. The timeline starts a year after the Subprime ended, which was July 2010. The end of the timeline was 19th of February in 2020. This was when the SP500 set a new high.

Currently, the most popular way to invest is to do it by purchasing stocks from companies. This means that you buy a certain fraction of the company and you own it. This option is good for beginners in investing as the main idea is to get growth for the shares you own to sell them for profit later. (Town 2019.)

To become a more successful investor, it is recommended to do a diversification to your investment portfolio. This means that you do not put all your money into the same kind of investments. You need to use different investing methods to reduce the total “investment risk”. Usually, this means having growth assets and defensive assets. The growth assets more often create long term capital increase and defensive assets have lower capital increase, uncertainty, and volatility. (Dixon Advisory.)

Therefore, I wanted to seek for an alternative investment method as well. The alternative investment method in this case is going to be options trading. The key aspect of using options is to determine the price of the option. To understand this, you need to understand several pricing models. (Rieunier 2011.) Therefore, in this thesis, I will be researching which pricing model is the best to generate the most profit.

1.2 Research question

The target of this thesis was to show which one of the chosen pricing models is the most profitable to use in theory. To do this research, I needed to understand how the models worked on their own. After this, I needed to run all the models for the chosen stock companies. Then I could analyse the results within the stock company and afterwards across all stock companies. From these researches, I was able to see if there was correlation, significant difference and finally which pricing model performed the best. My research question and the investigative questions were the following:

RQ: Which option pricing method would have been the most profitable for the selected stock options after Subprime?

IQ1: Do the outcomes have statistical significance and correlation?

IQ2: What pricing model performed the best for companies themselves?

IQ3: What pricing model performed the best between companies?

Q4: What is the best pricing model?

Table 1 down below is presenting the theoretical framework, methods, and results of the thesis process.

Table 1. Overlay Matrix

Investigative Questions (IQs)	Theoretical Framework	Methods	Data Analysis/ Results
IQ1: Do the outcomes have statistical significance and correlation?	Black-Scholes, Cox-Ross-Rubinstein Binomial model, Monte Carlo model, selected companies stock data, risk-free annual rate	Running the formulas of the models with the given stock- and risk-free annual rate data	Analyzing correlation and big significances
IQ2: What pricing model performed the best for companies themselves?	Data from Q1	Analyzing the data what is the best model within the company.	Getting the best performing model within the company
IQ3: What pricing model performed the best between companies?	Data from Q1	Comparing the different results from the models between all the companies	Coming with the best model between all the companies
IQ4: What is the best pricing model?	Data from Q1, Q2 & Q3	Comparing the results from Q1, Q2 and Q3	Coming with the best model in total

1.3 Demarcation

Demarcation was an important aspect in this thesis as there were multiple similar pricing models and enormous number of companies that could be considered as big companies in the United States. The pricing models needed to be chosen carefully as there are many pricing models that are related to each other. I used three models: Black-Scholes, Cox-Ross-Rubinstein binomial model (CRR-model) and Monte Carlo. These models left out other models such as GARCH-model and Heston model. The data that was going to be input into the models must be only from the companies which were chosen. These were Amazon (AMZN), Netflix (NFLX), Berkshire Hathaway (BRK.B), United Airlines (UAL) and Salesforce (CRM). The timeline must be after Subprime according to the timeline I had given. The timeline was clear as the Subprime crisis ended in June 2009. To get annual volatility, the timeline started from 2010 July. The options were going to be treated as European stocks due to my skillset. This is explained more thoroughly in the empirical part of this thesis.

1.4 International aspect

This thesis most certainly covers the international aspect as the data is related to the US financial markets. It covers the US stock details and risk-free annual rate. The models are internationally used**.** Also**,** in Finland option trading is not as common compared to the US markets on an individual level. In Finnish investment platforms, the option trading possibilities are fairly limited. For example, Nordnet, which is the most used investment platform, does not have any US stock options**.** It only has Scandinavian stock options. (Nordnet Bank AB, 2020.)

1.5 Benefits

There are two outtakes from this thesis. Firstly, I got to educate myself on a topic that I am very interested in and on top of that I wish to be able to apply this knowledge to my future career. This also gave me good experience on how to handle big projects by myself and not with a group as our studies have been heavily focused on group tasks. Secondly, if I am fortunate enough, I get to share this research with someone who is interested on this topic area as well. Maybe I can make someone else do a thesis related to options as well or do additional research on the topic.

1.6 Key concepts

In this subchapter, I am going to introduce some key concepts that are important to know to understand my thesis.

The Subprime crisis is also known as the Mortgage crisis. The crisis started in 2007 and ended officially in June 2009. The main reason that caused this was the fact that people who could not afford big loans could get them. The interest rates were low for a long time and in 2004 the Federal Reserve noticed that there might be a bubble in creation. They tried to stop it with raising the interest rate but that did not work out and the bubble collapsed. (Fiorillo 2018.)

Spot price means the value of the stock at the purchasing time of the contract (Nasdaq 2016). On the other hand, *strike price* is a predefined price for a call or put option, which will be exercised on expiration day (The Options Guide). *Intrinsic value* is the subtraction of current stock price and the strike price (Nasdaq 2016).

Premium is a cost of option security. It is affected by the price of the underlying asset, volatility, and option maturity (Killian 2020).

2 Financial markets and Option pricing models

In this chapter, I am going to cover all the necessary basic info needed for understanding my thesis.

2.1 Basics of financial markets

Financial markets in a simple definition are places where traders sell and buy assets. The types of assets that are being traded varies substantially. The most common and known are stocks but there is in addition to that bonds, commodities, foreign exchange, and derivatives that can be traded. (Amadeo 2020a.) We have had a great bullish market for the past decade. History repeatedly brings bearish markets into financial markets and sometimes they become too extensive leading to financial crisis. Financial crisis happens when assets in the financial market or financial institutions lose a big part of their value in a short time of phase. The impact that it has to the whole world is enormous. After financial crisis recession happens more often. (Semczuk 2019.) The biggest recession of our lifetime has been the Great Recession. This crisis started in 2007 June and ended in June 2009. (Kaiser 2020.)

2.2 Types of Financial markets

Stock market is a marketplace where buyers and sellers exchange shares. The shares are from publicly listed companies. All big countries have their own stock exchange. The biggest market is in the USA but there are also other big ones in Asia and Europe. (Amadeo 2020b.)

The purpose of *bond markets* is to raise money for government and companies for their processes. Investors opportunities in these markets are by lending money to the company or company and receiving it back with a compensation after a certain time. (Corporate Finance Institute.)

By the name of this market, *commodities market,* you can understand what sort of market it is. Buyers and sellers exchange commodities such as oil, gold, and nickel. Commodities needed their own market because the prices of commodities, in general, is hard to predict. (Corporate Finance Institute.)

Foreign Exchange markets´ transactions happen by agreeing between the seller and buyer that one specific currency is exchanged to another currency with agreed exchange rate. The markets in total are open all the time as countries locate in different times zones. It used to be that the busiest time in foreign exchange was when the time zones of

New York and London crossed each other. In today's world, the Tokyo and Hong Kong cross are starting to be one of the busiest. (Eiteman, Stonehill & Moffett 2016.)

Derivatives market´s trading is done by a derivative security which is a deal between two parties whose payoff is relying on the value of an underlying asset (Gottesman 2016). Instruments that are used in derivatives markets are such as futures, options, forwards, and swamps. This thesis is going to cover the most important ones, futures, and options. These instruments are great for protecting your other investments. An investor could for example buy some of these instruments against their already owned assets to minimise the losses of the primary investment. Derivatives are anyhow risky because they are high in volatility and hard to price correct. (Corporate Finance Institute.)

Futures are one of the most used derivatives (Kennedy 2019). They are also used by investors to price their current or possible assets (Corporate Finance Institute.) The instrument works by two parties doing an agreement to buy or sell an underlying asset with predetermined price and date. (Nasdaq 2016.)

2.3 Options

Options have the same structure for making an agreement as the futures. The difference in this instrument is that it gives the right to buy the underlying asset for the predetermined price. It is not an obligation. (Nasdaq 2016.)

There are two kinds of options, call and put options. A call option is a contract where you believe the underlying asset to go higher than the strike price. Put option on the other hand is vice versa. (Nasdaq 2016.) Purchasing options are standardized in a way that all contracts include 100 shares. (The Options Clearing Corporation 1994).

2.4 Option pricing models

Many factors affect the pricing of the options. The most common attributes are price of the underlying asset, exercise price, period of validity, volatility of the underlying asset, interest rate and payable dividends for underlying asset. (Nasdaq 2016.)

2.4.1 Black-Scholes

This model is regarded as “the mother of option pricing models”. It was founded in 1973 by Fischer Black and Myron Scholes. They eventually earned a Nobel prize in economics for this option pricing model. The model goes as follows:

$$C = Se^{-\delta T}N(d_1) - Ke^{-rT}N(d_2)$$

Where d1 and d2 go as follows:

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + (r - \delta + 0.5\sigma^2)T}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln\left(\frac{S}{K}\right) + (r - \delta - 0.5\sigma^2)T}{\sigma\sqrt{T}}$$

Where:

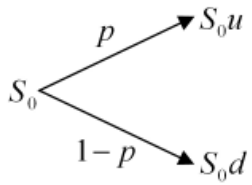
C: price(premium) of call option
S = Assets current market price
K =Strike price meaning the exercise price of an asset
σ = Historical volatility of the underlying asset
T = Time between purchase and expiration
r = risk-free interest rate
δ =dividend yield
N =natural numbers
ln = natural logarithm
e = Euler’s number

(Corporate Finance Institute.)

2.4.2 Binomial Model, Cox-Ross-Rubinstein Model (CRR-model)

There are many different binomial models. All of them have in common that they are constructing the option price through a binomial tree model. Binomial tree shows the different price changes of a stock over the time of the contract by steps. Each step has the opportunity of going up or down. The different binomial differs with the way how the up and down movement size has been counted. The thesis uses Cox-Ross-Rubinstein model as this is the most common one. (Hull 2012.)

Down below is one step of the binomial tree:



Where,

S_o= Spot price
P= Probability of an up movement
u= Up movement size (Cox-Ross-Rubinstein)
d= Down movement size (Cox-Ross-Rubinstein)

In order to get values of Cox-Ross-Rubinstein, there needs to be done a risk-neutral valuation. The formula for this goes in the following way:

$$pu + (1-p)d = e^{r\Delta t}$$

To assure that this calculation is correct there needs be done a calculation which goes as follows:

$$pu^2 + (1-p)d^2 - \left(e^{r\Delta t}\right)^2 = \sigma^2 \Delta t$$

After these the unknown values can be counted as follows:

$$p = \frac{e^{r\Delta t} - d}{u - d}$$
$$u = e^{\sigma\sqrt{\Delta t}}$$
$$d = e^{-\sigma\sqrt{\Delta t}}$$

By getting all the values for one binomial tree step, the calculation can be done to as many steps the research needs. In this thesis, there were 30 steps per one day.

The calculation this far calculates the value of the stock. To complete the calculation there needs to be calculations about payoff. As this thesis focused on calculations made for call option, the following formula was made for them only:

$$V_N = max(S_N - X, 0)$$

Where:

N= Price of the last step
VN= option price
X= Strike price
SN= Price of the stock

The final part was for discounting the payoffs from the previous phase. The calculation was done in the following way:

$$V_n = e^{-r\Delta t}(pV_u + (1-p)V_d)$$

Where:

n = Designates a node prior to expiry
Vn = option value
X = strike price
Sn = Spot price
p = *Probability of an up movement*
Vu = option value from node upper node at n+1
Vd = option value from the lower node at n+1
r = risk-free interest rate
Δt = step size between time slices of the model

(Goddard Consulting.)

2.4.3 Monte Carlo model

Monte Carlo simulation is one of the most known quantitative finance models. This pricing model needs three phases. First phase is to calculate multiple valuations in the future for the stock:

$$S(\Delta t) = S(0)\exp\left[\left(\mu - \frac{\sigma^2}{2}\right)\Delta t + \left(\sigma\sqrt{\Delta t}\right)\varepsilon\right]$$

Where,

S(0)= Spot price
S (Δt) = The stock price at a small time into the future
Δt = A small increment of time
μ= The expected return
σ= The expected volatility
ε= A random number sampled from a standard normal distribution

In this thesis, there were 2500 paths for each day. It is recommended to have even tens of thousands of phases. After that, the option price could be conducted with the following formula:

$$\text{Payoff}_{\text{call}} = \max(A - X, 0)$$

Where,
A = average asset value from all the paths
X= Strike price

(Goddard Consulting.)

At the end, the price needed to be discounted like in the binomial model by multiplying with the following equations:

*EXP(-r*t)*

Where,
EXP= exponential
r = risk-free annual rate
t = time in years

(Finance Train.)

2.4.4 Return on investment

After all the pricing models were completed there needed to be calculated all the profits that the models did for the stock option on expiration date. The formula was a simple return on investment calculation, which goes as follows:

$$\text{ROI}\ (\%) = (\text{Net Program Benefits} \div \text{Program Costs}) \times 100$$

(Phillips Pulliam & Phillips 2005.)

Before performing these calculations, the following steps needed to be done:

1. *Calculating Intrinsic Value = Subtracting the strike price value from the expiration day value.*

2. *Subtracting the premium from the Intrinsic value to calculate profit of one contract.*

3. *Profit of one contract *100 because contracts are bough in a set of 100.*

4. *Profit of 100 contracts divided by the amount of the 100 premiums which is the initial investment = ROI*

3 Research methods

This chapter is for introducing the thesis research design, the Excel workbooks design, base data collection and issues in these parts.

The research method was a desktop research done as quantitative analysis. There were many models to choose from and I ended up picking the most respected pricing model named Black-Scholes, Cox-Ross-Rubinstein binomial pricing model as its widely used in the finance world and Monte Carlo simulation pricing model as its one of the most important quantitative mathematics equations. These were also the most manageable for my skill set.

3.1 Research Design

This research needed to be divided into six parts as figure 1 shows. *The first phase* before the actual research was to do a lot of research about options in general. After understanding these I started doing research about option pricing models and testing how they worked. This was the base for starting the actual research.

Second phase was to do the calculations for all the models with all the companies for the selected timeline. At the same time, the return-on-investment calculations were done. Validity of the calculations was also done. Following this came *the third phase* which was answering to the first investigative question. This analysis was done by having three graphs according to the pricing models with the companies return on investment in percentage.

Fourth phase of the design was to answer to the second investigative question by analysing the company, specifically the results. This meant that the analysis would include for each company one line graph with all the different pricing models return on investment results and median and average graphs based on that.

Fifth phase of the research was meant to answer the third investigative question. This step was built by using the graphs from the third phase. As this part was analysing from the perspective of the models it was convenient to make average and mean calculations from the third phase graphs that were already built with that perspective.

The sixth and final phase used the analyses made from phase three to phase five. It summed up the key points and analysis on how many different categories certain model won or lost. By making this the conclusion part could be answered.

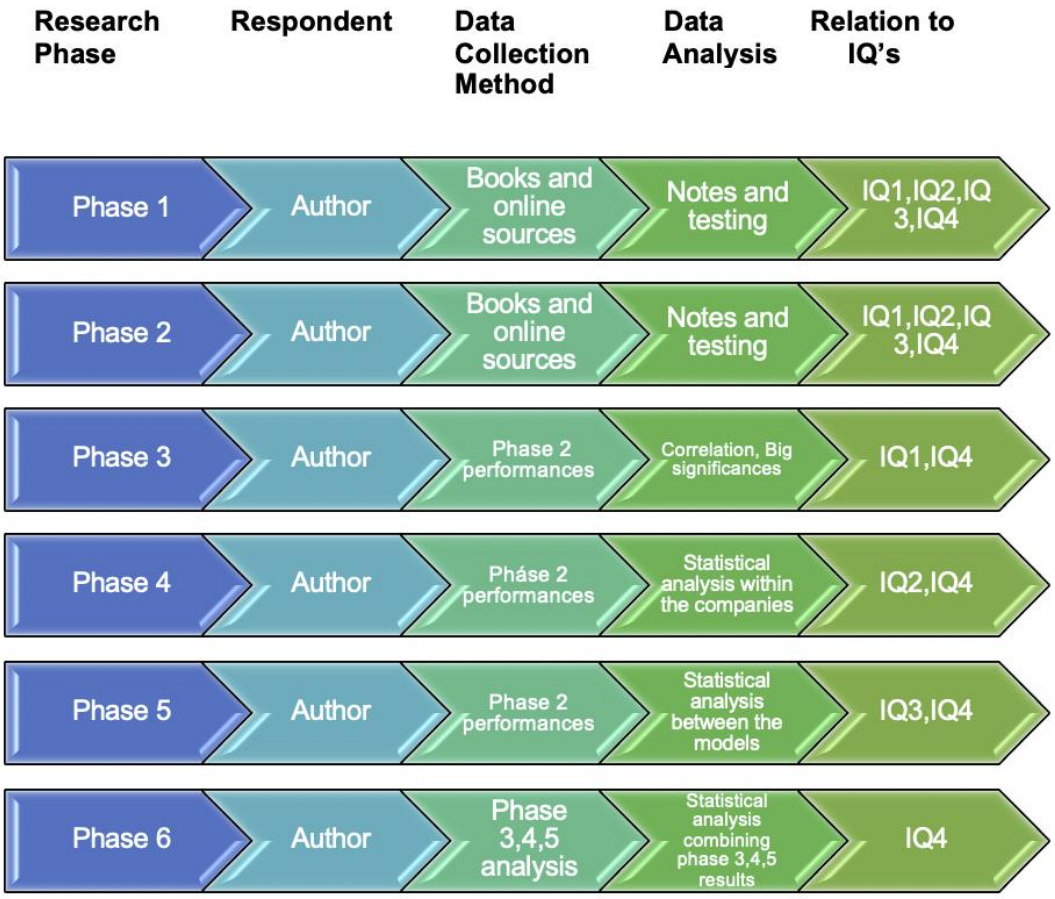


Figure 1. Research Methods

3.2 Calculations workbooks

I conducted the research by Excel and used five workbooks. The first wordbook was about stock information and other financials. This included stock closing prices, annual volatility calculated for stocks and free interest rate. The second workbook was about Black-Scholes calculations and it included option premiums for all the stock options, calculating the profit/loss of the valuation at the exercise date and return on investment, average, and median calculations for the return on investment. The third workbook was about Cox-Ross-Rubinstein binomial model calculations. This included the same component as the second workbook. The fourth workbook was about Monte Carlo calculations and it had the same components as the second and third workbooks. The fifth and final workbook was about the results of calculations and final analysis and it included the results from the second to the fourth workbook for easier use and analysation.

3.3 Data collection

All the financial information was collected from Yahoo! Finance and exported to Excel. It was easy to do as you only needed to put in the company name and go to historical prices and put in your preferred timeline. After this, all you needed to do was to import as an Excel file. It was hard to find a reliable source after testing multiple databases. Many of them differed from each other, even about such things as how many trading days there were. Yahoo! Finance was the most reliable as the exported data came in the same format every time. Also, it was more convenient to have American stocks because there was more information related to their stocks and options. To get the risk-free interest rate, I went to a website called Macro trends as it is known for having a lot of trustworthy economical data. In there I chose to take the values from a historical 10-year treasury rate as these rates are used for giving house loans as well.

The models are taken mainly taken from John C. Hull´s book *Options, Futures, And Other Derivatives* (2012). In order to get them more visual, I needed to take them from reliable websites. The models are quite advanced mathematics which means there are a lot of factors that were taken for granted. The information for these has also been taken from reliable sources. To understand the models better I had watched a lot of video material on how these models function. For example, such videos where a professor has created a video where he builds one of these models in Excel.

3.4 Issues concerning the research

During this research I realised that the topic is to advance for myself, so I had to simplify it. As the stocks options that were to be used for these models are American. This meant that they could be exercised at any time. This makes the calculation too hard and therefore I decided to treat them as European ones. This means that they could be only exercised at the expiration date. This was possible with American stocks if they did not share dividends.

The profits of the options were conducted from the calculated prices that the pricing models did. This means that they are not the actual prices that occurred on a specific date. The reason for this is that there was not available free bid/ask spread data for option prices that go until 2009.

4 Results

In this chapter, I analyze the graphs that the pricing models produced and answer to the investigative questions based on them.

4.1 Data analysis for IQ1 Correlations or Big significance

This part of the chapter was investigating if there were any correlation and significances based on the graphs.

4.1.1 Black-Scholes performance

Black-Scholes model in figure 2 gave a correlation and a big significance. figure 2 indicated that apart from Netflix and Amazon the rest of the companies were going in a similar pattern. Netflix was going in this similar pattern mostly and had few individual spikes that stood out. Amazon on the other hand was not going in a similar pattern at all. Amazon had its own upward and downward spikes that stood out significantly.

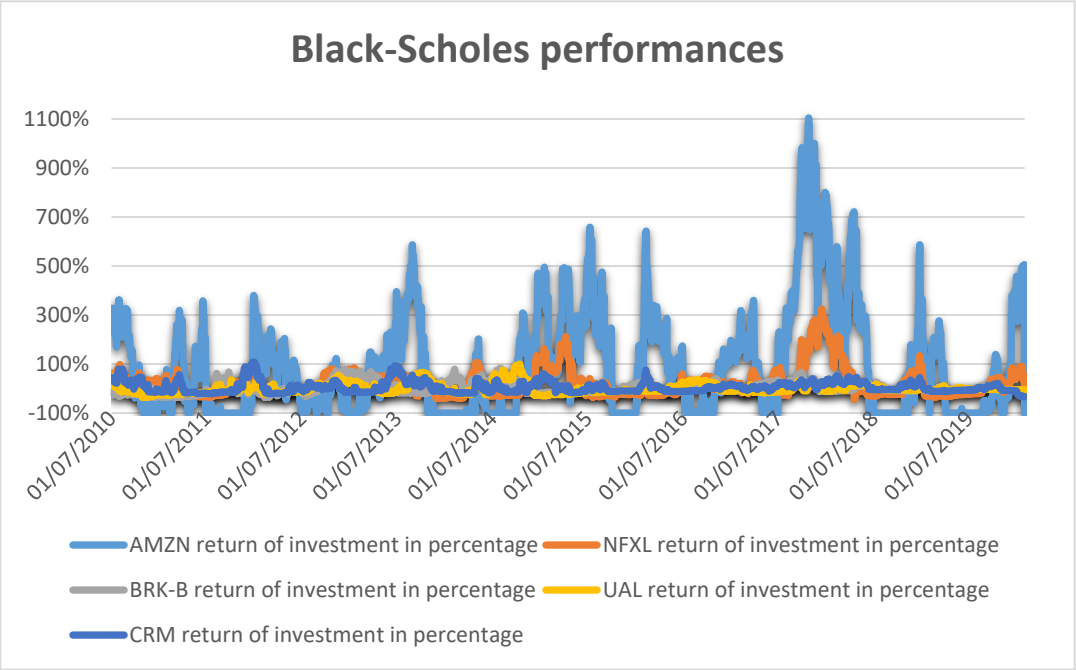


Figure 2. Black-Scholes performances

Figure 3 and figure 4 gave a better insight into the results. These two graphs gave completely different overviews for the companies that seemed to have similar patterns and strengthened the point that Netflix and Amazon had gone to a completely different level. The only ones that were similar were Berkshire Hathaway and United Airlines with having

-1% difference in a median graph and having a 2% difference in an average graph. The median was more accurate as it is unlikely that you would get the best trades there has been in this timeline. The best trades on this occasion are driving the averages high.

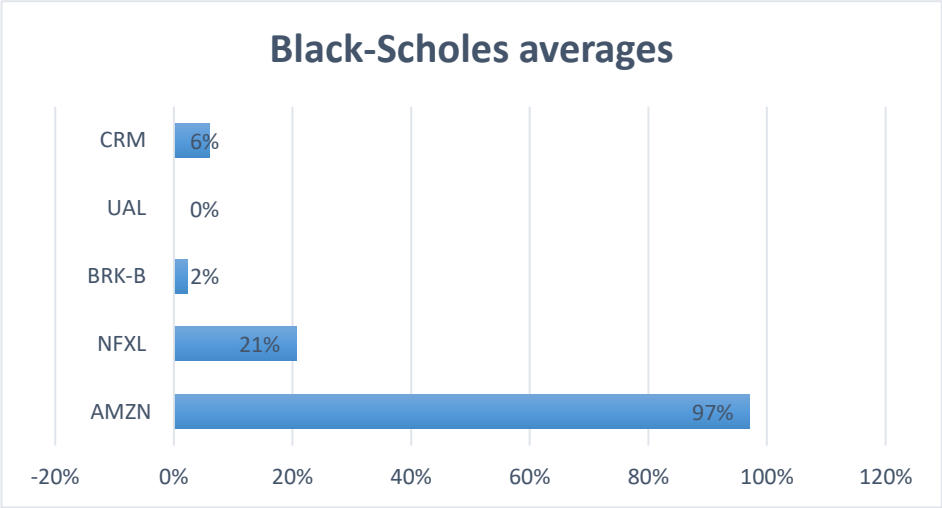


Figure 3. Black-Scholes averages

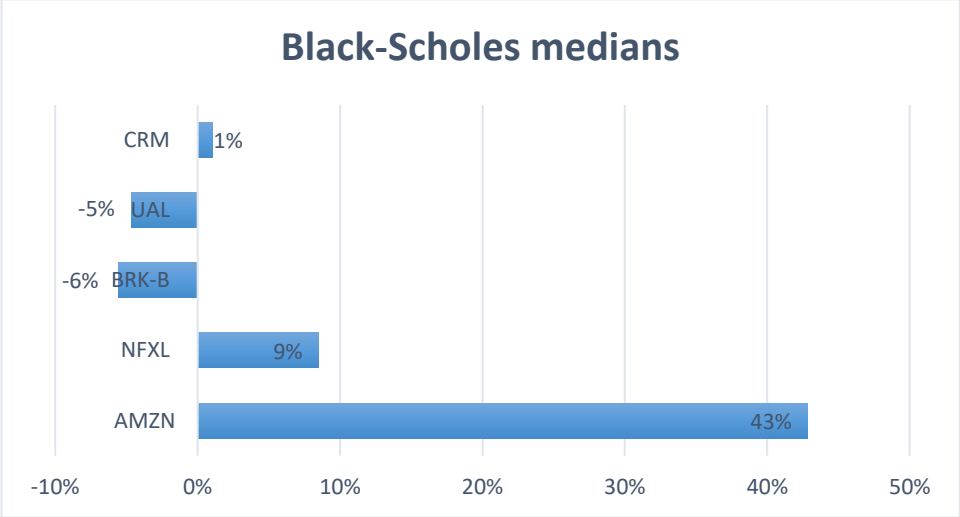


Figure 4. Black-Scholes medians

4.1.2. Cox-Ross-Rubinstein binomial model performance

In figure 5 it was clearly visible that there were correlating pairs but as a whole, the sample group did not correlate. Netflix and Amazon were having significant spikes, and, on many occasions, they correlated. The other pair was Berkshire and United Airlines. They did not have such enormous spikes as the other pair, but their results went in a similar pattern as it can be seen from figure 5.

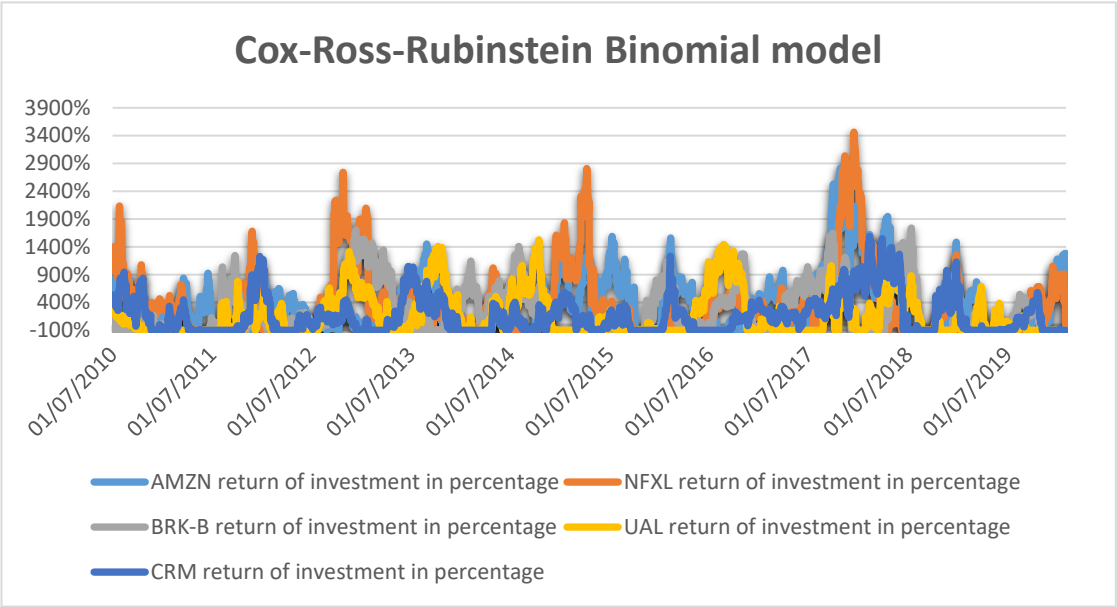


Figure 5. Cox-Ross-Rubinstein Binomial model

The more accurate average and median graphs figure 6 and figure 7 told a different story compared to figure 5. Berkshire Hathaway and United Airlines did not share the same values as Berkshire Hathaway was almost 80% higher on average compared to United Airlines. The difference was even bigger in figure 6 as United Airlines was the only one with negative values. The significant factor in this set of results was that all the stocks options were having massive gains in percentage.

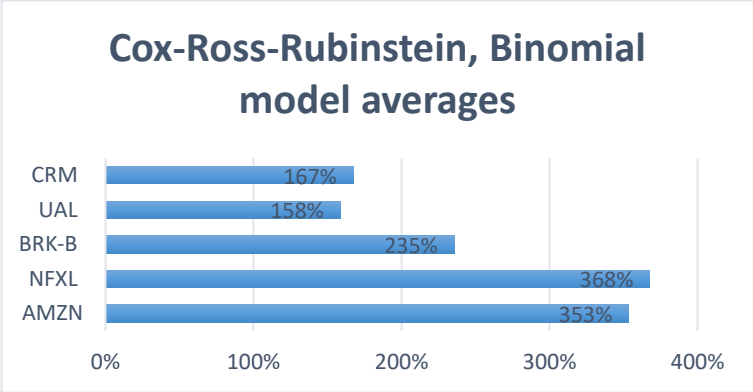


Figure 6. Cox-Ross-Rubinstein, Binomial model averages

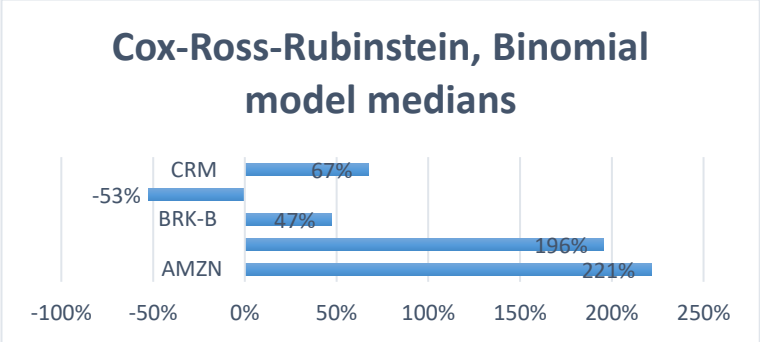


Figure 7. Cox-Ross-Rubinstein, Binomial model medians

4.1.3. Monte Carlo model performance

The results in figure 8 graph were diverse. Amazon had the biggest significance compared to the other models' results. Other companies apart from Netflix were having a similar pattern. Netflix occasionally followed the pattern, but it had its own spikes that differed from the rest of the group. Amazon's massive returns were something that needed to be noted as it is strangely big compared to others.

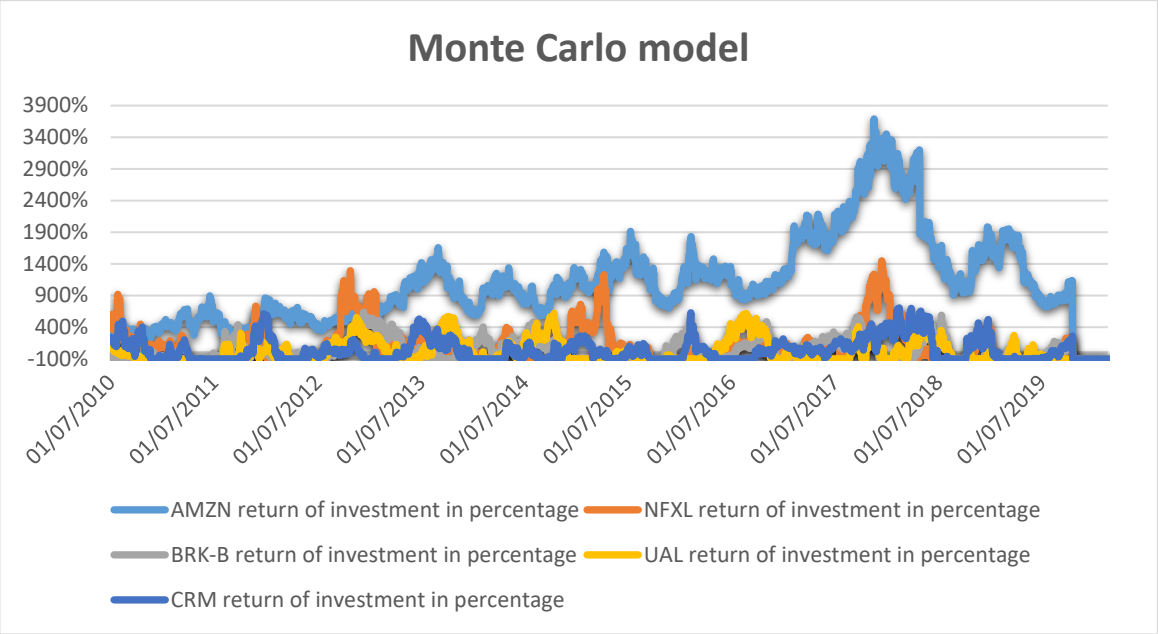


Figure 8. Monte Carlo model

Figures 9 and 10 below told a clearer story. Salesforce.com, United Airlines and Berkshire Hathaway had very small returns on average. If we look at the median percentage return three of the companies were on the negative side. This makes Amazon's success even stranger.

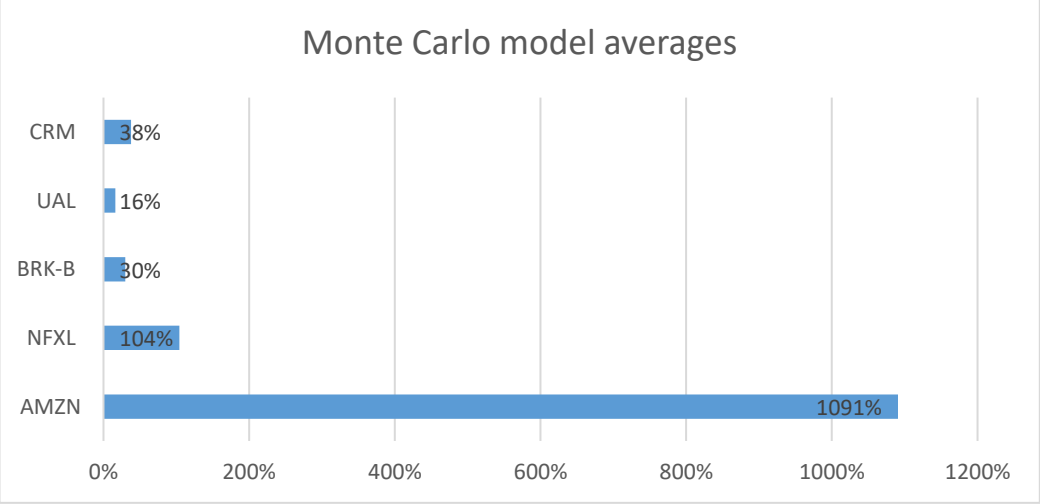


Figure 9. Monte Carlo model averages

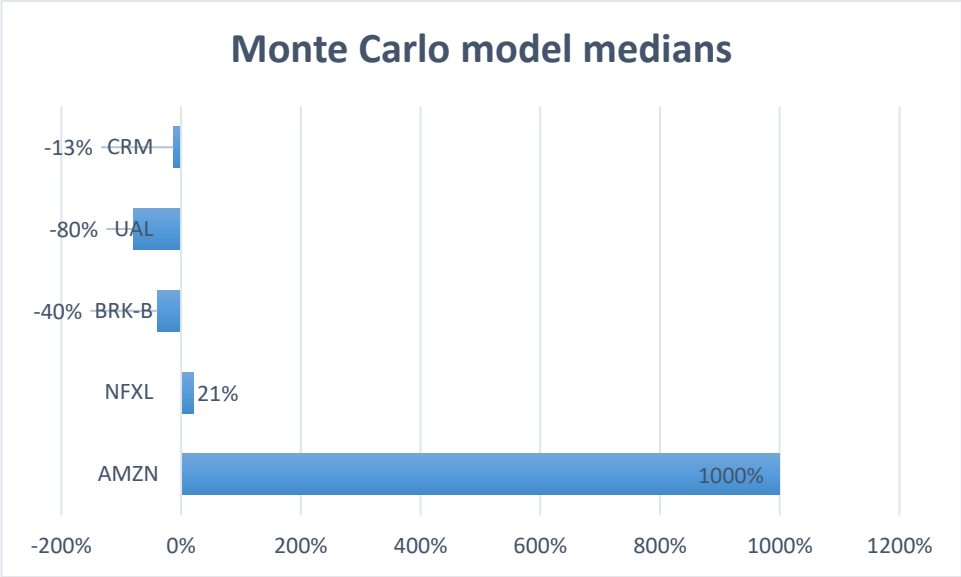


Figure 10. Monte Carlo model medians

4.2 Data analysis for IQ2: What pricing model performed the best for companies themselves?

The second part of this chapter is about researching which model had the best return on investment for the company.

4.2.1 Amazon's performance with the pricing models

The pricing models performed in a similar pattern, but the differences were big between the models. Figure 11 shows that the Black-Scholes model had a positive return in general, but it did not hit the same highs as the Cox-Ross-Rubinstein model and Monte Carlo model. Therefore, figure 12 justifies that the Black-Scholes model had the worst average and median results. Cox-Ross-Rubinstein model is having similar results as the Black-Scholes model, but the returns were bigger therefore it was the second-best performing model as the figure 12 showed as well. Monte Carlo-model had the best returns and beats the other models clearly. The figure 12 shows that the average and median returns were almost 800% bigger than the second-best performing model.

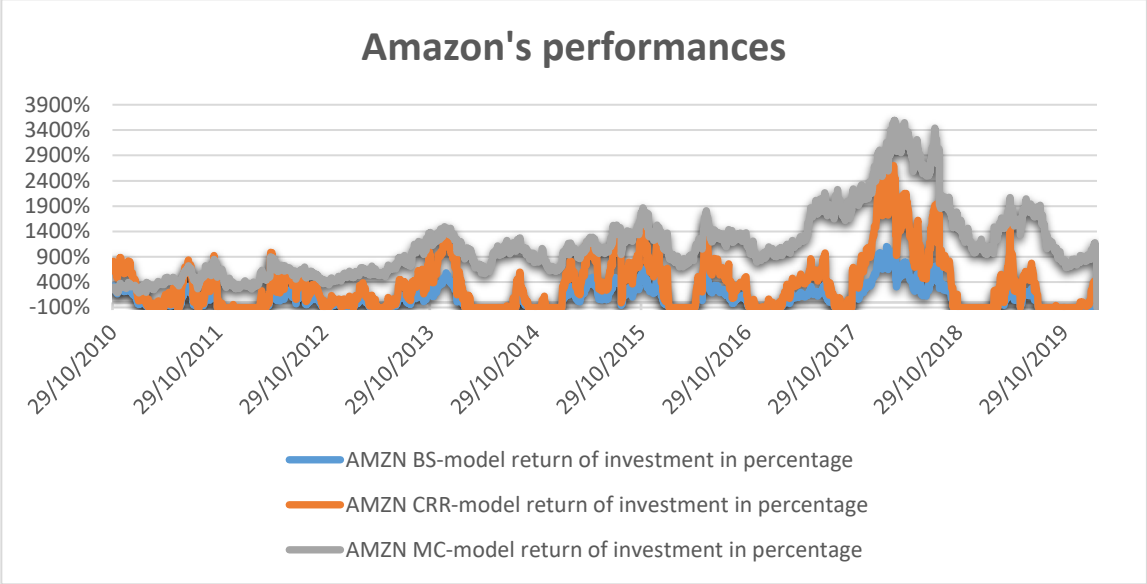


Figure 11. Amazon's performances

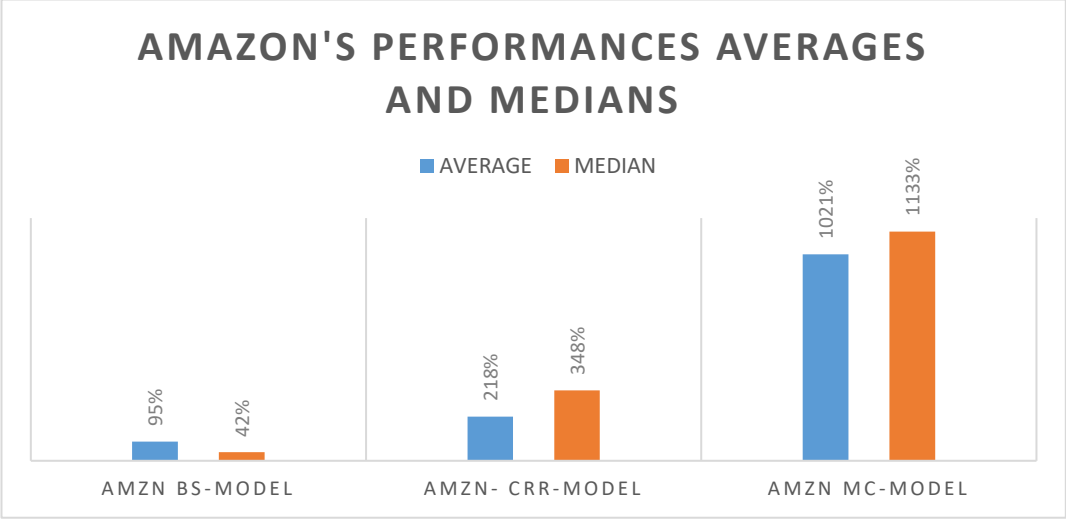


Figure 12. Amazon's performances averages and medians

4.2.2 Netflix's performance with the pricing models

For Netflix, the results differed a lot compared to Amazon. The models followed a similar pattern but when an upcurve occurred the difference of the models could be seen significantly in figure 13. The Black-Scholes model had small returns in general. The figure 13 showed that the curve was quite steady apart from a few big up curves. And that was also what figure 14 indicated. Therefore, the average return was 20% and the median only 7%. The few big returns raised the average, but the median told that the returns have been mainly low. The Monte Carlo model performed better, and, on the uptrend, it gained a good portion of returns. Monte Carlo model performances also had the most losses compared to other models.

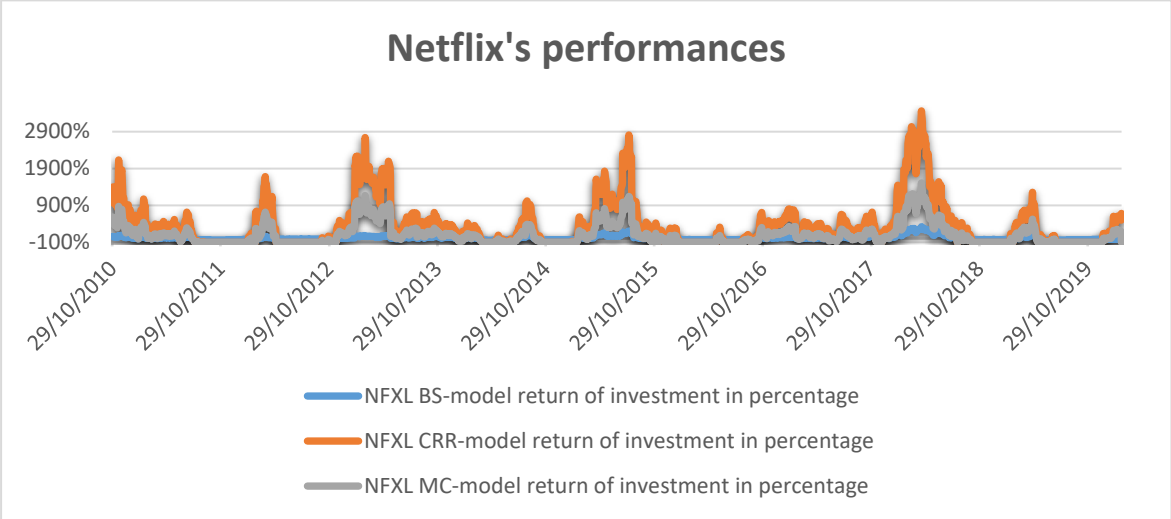


Figure 13. Netflix's performances

Therefore, the figure 14 showed that the average is 32% returns from investment and a median of 111%. Cox-Ross-Rubinstein model was the best performing model this time and it was purely due to the fact that it gained the most on the up curves. Also, at the down curves, it gained the most.

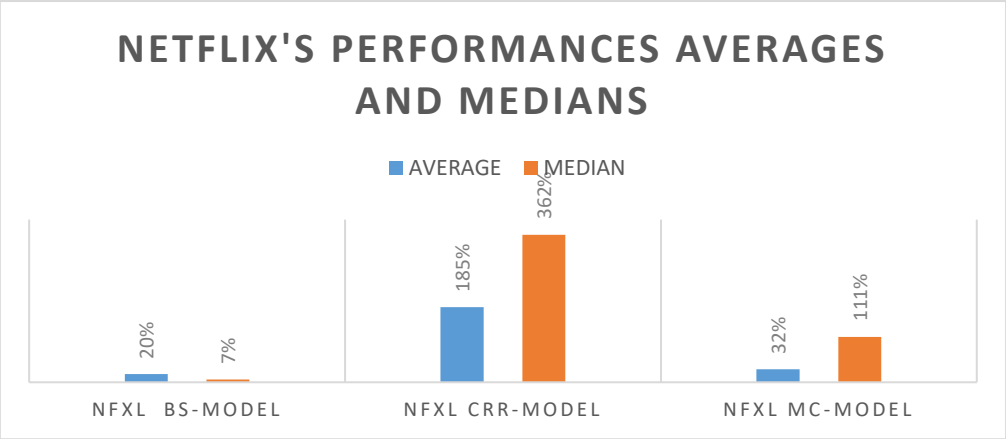


Figure 14. Netflix's performances averages and medians

4.2.3 Berkshire Hathaway's performance with the pricing models

In this run of samples Black-Scholes model seemed to have minimal gains compared to the other models. As the line was very linear in figure 15. In the figure 16, the results were showing the same. The average was only 2% due to some of the higher results and the median was -6%. The second-best performing model was the Monte Carlo model. It had multiple occasions with high returns but not as high as Cox-Ross-Rubinstein model. Another noticeable fact about the performance of Monte Carlo was that it loses on multiple occasions the whole initial investment. Figure 16 indicated this as well. The average was -

33% and the median 35%. Cox-Ross-Rubinstein model was in this sample the best performing model again. The main reason for this was that on the up curves Cox-Ross-Rubinstein model gained more than others. Cox-Ross-Rubinstein model lost the initial investment many times as well. Therefore, the figure 16 showed a similar pattern as the Monte Carlo model. The average was 66% and the median was 245%.

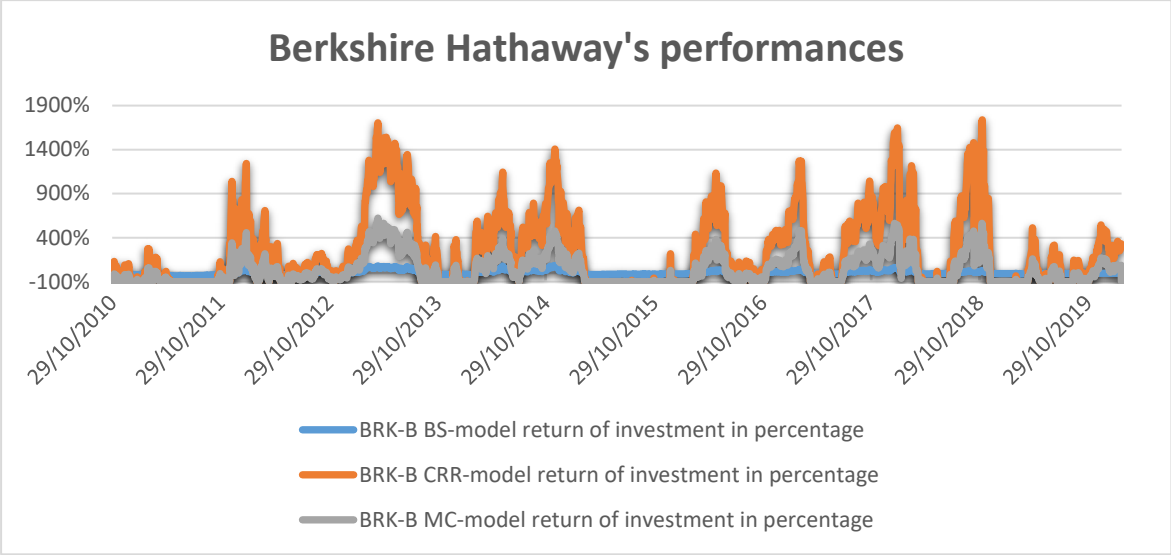


Figure 15. Berkshire Hathaway's performances

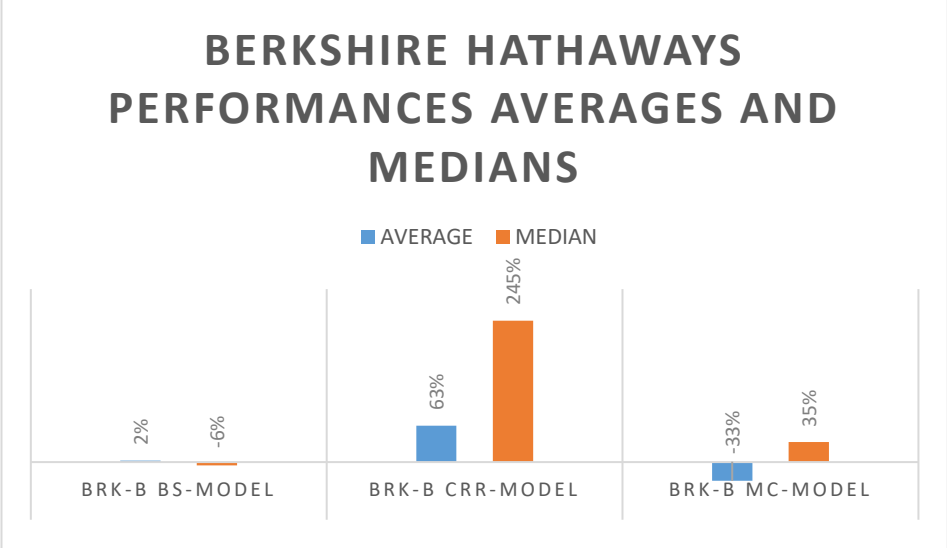


Figure 16. Berkshire Hathaway's performances and averages

4.2.4 United Airlines performance with the pricing models

Black-Scholes model had the least returns in this sample. The curve was going steadily by having few minimal up curves and down curves as seen in figure 17. Figure 18 was indicating the same. As the average was 0% and the median -5%. This told that some positive curves have affected the average scale to be 0% and not negative. Monte Carlo

model had good returns as the figure 17 shows but there were too many total investment losses. Therefore figure 18 indicated median of 20% but -71% on average. Cox-Ross-Rubinstein model had the same issues as it lost the whole initial investment many times but the gains on the upcurve were once again bigger than Monte Carlo had. Thus, that figure 18 results had a similar pattern as Monte Carlo model had but better. The average was -36% and a median was 166%.

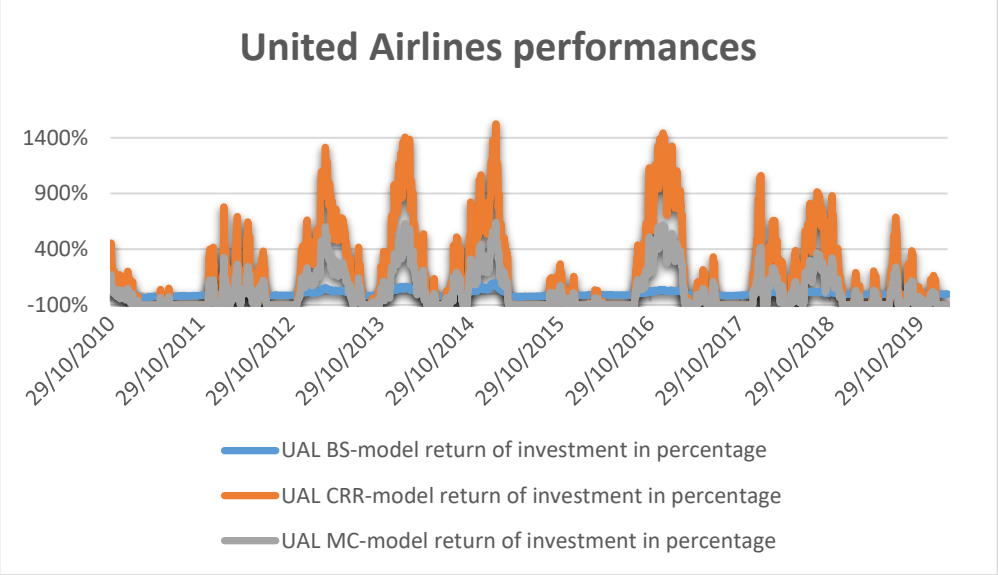


Figure 17. United Airlines performances

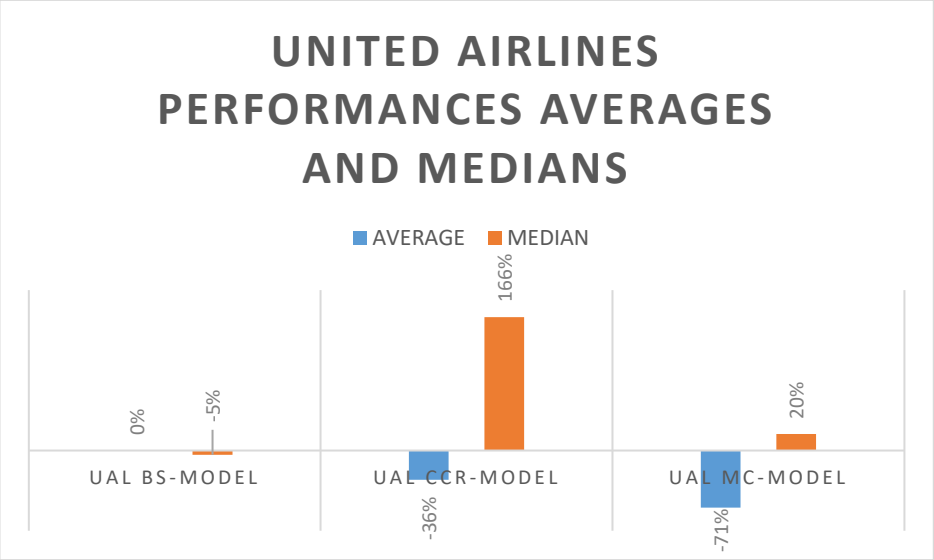


Figure 18. United Airlines performances averages and medians

4.2.5 Salesforce's performance on the pricing models

The Black-Scholes model was going in a linear steady pattern with few small highs and spending time in the negative side occasionally as figure 19 indicated. Figure 20 did not

tell any different. The average return of investment was 6% and the median 2%. The Monte Carlo model had its highs when there is an upcurve and the gains are great. There occurred a lot of times when the investment lost all its value as well. Therefore, figure 20 values showed that the average was -5% and the median 43%. Cox-Ross-Rubinstein model seemed to be performing the best in this sample and had the same pattern as Monte Carlo model, but the gains on the up curve seemed to be twice as big or more. Due to that figure 20 indicated an average score of 46% and median 174%.

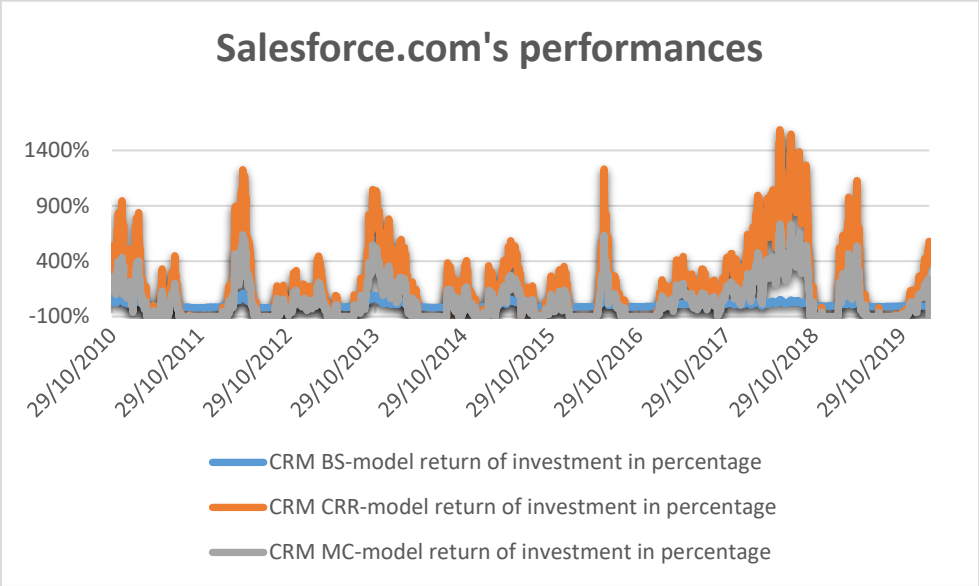


Figure 19. Salesforce.com performances

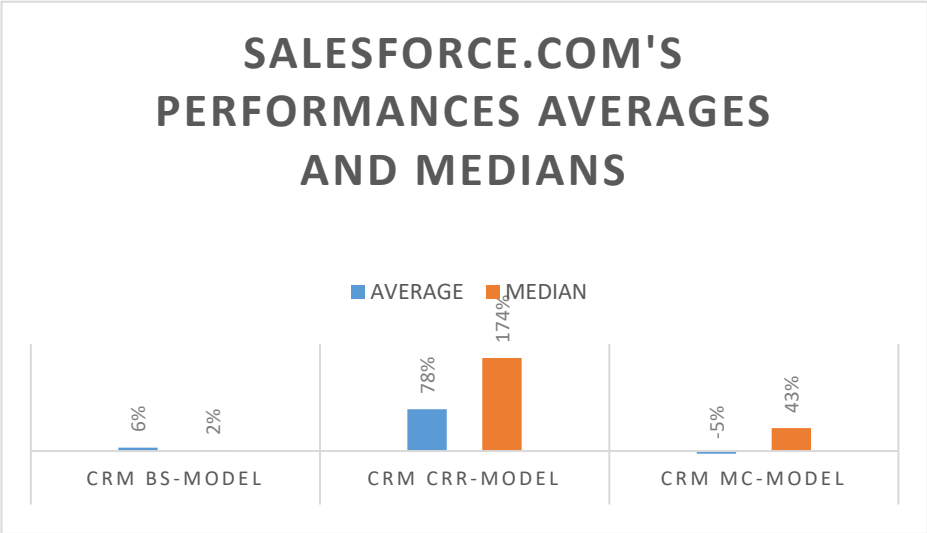


Figure 20. Salesforce.com's performances averages and medians

4.3 Data analysis for IQ3: What pricing model performed the best between companies?

The third subchapter is going to look at the overall averages and medians of the models by summing up the companies result by pricing models.

In figure 21 each model´s company results were summed up and then averaged. This shows that Monte Carlo model had the best average return on investment in total. The score was 189% and the second-best which was Cox-Ross-Rubinstein had 102%. The difference was huge. On figure 22 can be seen similarly counted data but about their medians. Here the results differed. In this table Cox-Ross-Rubinstein model had the best score by having 245%. The second best was Monte Carlo model by having 43% This means that Cox-Ross-Rubinstein model beat Monte Carlo model by 202%.

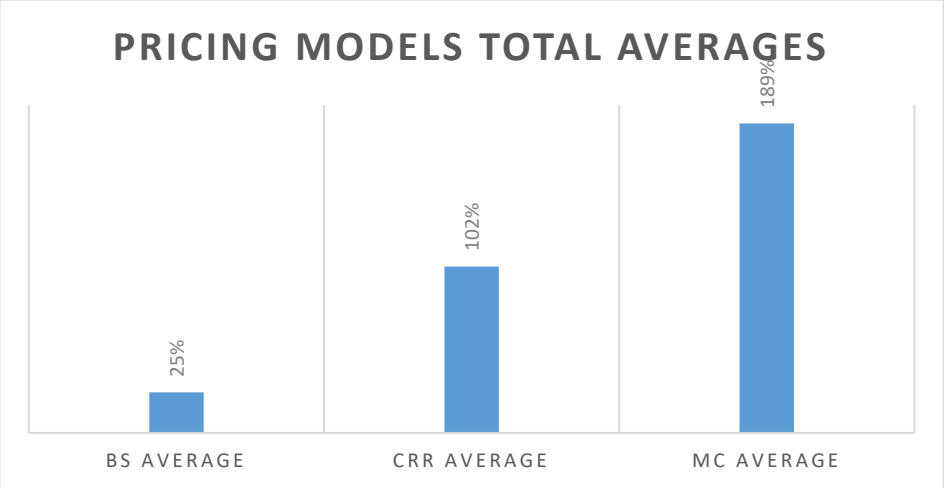


Figure 21. Pricing models total averages

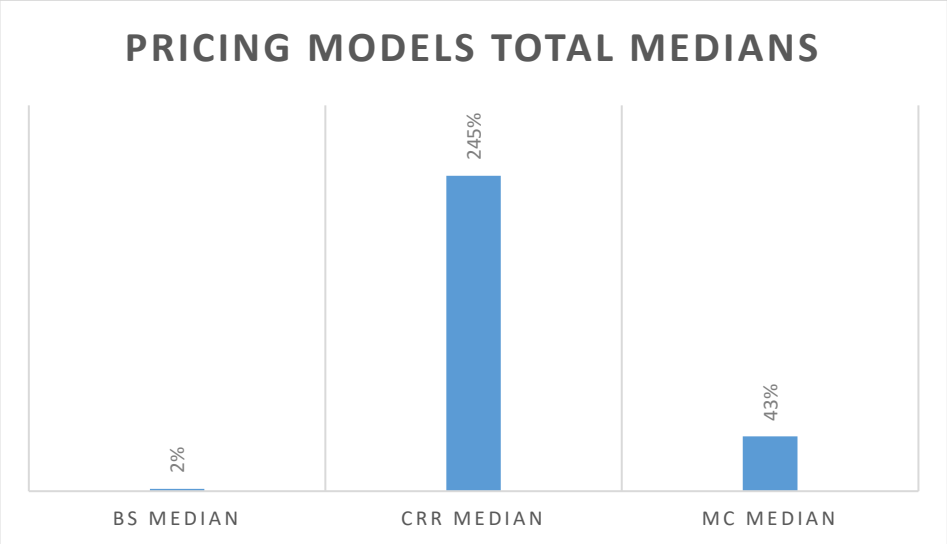


Figure 22. Pricing models total medians

4.4 IQ4: What is the best pricing model?

The answer to the best pricing model was conducted from investigative question 1, 2 and 3. IQ1 was to help if there was some significance for example that should be taken into consideration when valuing the data from IQ2 and IQ3.

IQ2 analysis gave 7/10 times a result that Cox-Ross-Rubinstein model would have been the best due to its biggest returns by average and median. Monte Carlo model won one of the samples runs which were with Amazon. Black-Scholes model won the average part of United Airlines average part of figure 18 (in chapter 4.2.4), but Cox-Ross-Rubinstein binomial model won the median part by far.

In IQ3 Monte Carlo model won the average investment return part and Cox-Ross-Rubinstein model won the Median one. In this case, I had to take the notes that I had taken from IQ1. In that part, we could see that there was a massive significance in Amazon's sample with Monte Carlo model. The values went over 3000% at few points and in general, the results were 3-5 times bigger than other companies Monte Carl samples. Therefore, I made a statement that those values increased the average of figure 21 and therefore it bet Cox-Ross-Rubinstein model on average. This needed to be tested and figure 23 showed that this assumption was correct. The average of Monte Carlo model fell to -19% from 189%. At the same time Cox-Ross-Rubinstein binomial model fell to 72% from 102%.

Despite that fact, there were enough sections where Cox-Ross-Rubinstein model had performed better than the other models. This additional research (Figure 23) strengthened the assumption.

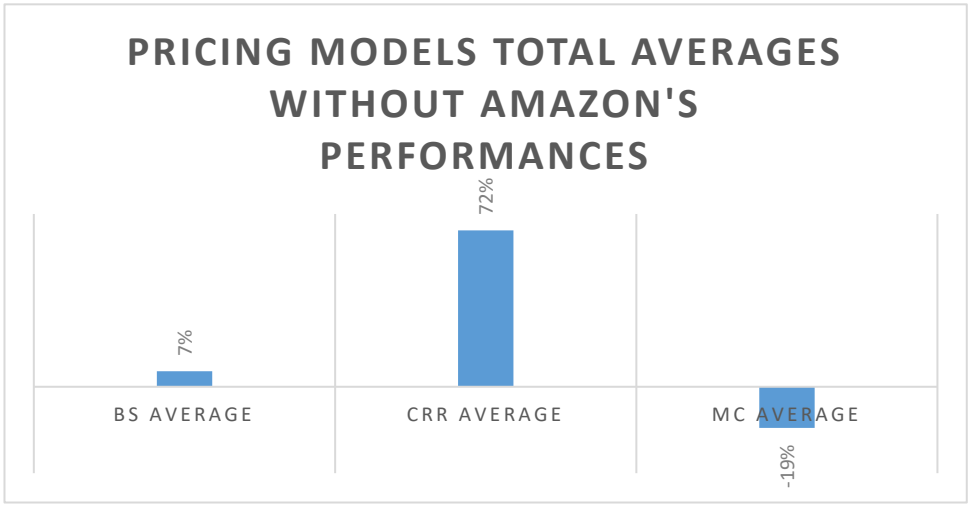


Figure 23. Pricing models total averages without Amazon's performances

As all the models had the same input data, it meant that all the samples had the same Intrinsic Value**.** Cox-Ross-Rubinstein binomial model had the best premium pricing towards that. They did not lose the whole total investment that often as Monte Carlo model for example. This can be seen from all line graphs and average and median charts. Black-Scholes model values were the lowest of the time and more worryingly the median values were most of the time lower than the average values. Therefore Cox-Ross-Rubinstein binomial model seemed to be clearly the best pricing model out of these three models.

5 Conclusion

In this final chapter of the thesis, I will cover the research question´s answer in key findings, suggestions for further research, validity, reliability, and relevance. On top of that, I am going to reflect on my own learning and the whole thesis process.

5.1 Key Findings

The first subchapter is dedicated to key findings that answer to the investigative questions and the research question.

The first investigative question was: Do the outcomes have statistical significance and correlation? The answer was that there was a correlation between United Airlines, Salesfore.com and Berkshire Hathaway in the models. Netflix and Amazon correlated between themselves occasionally, but they were a lot higher compared to the rest. These two companies were causing the big significances. Amazon's performance with Monte Carlo model needed to be noted as it affected the results too heavily.

The second investigative question was: What pricing model performed the best for companies themselves? Cox-Ross-Rubinstein binomial model had the better of the results. The model had a better average return on investment on three of the five companies. Cox-Ross-Rubinstein model had also better median return on investment results on four of the five companies.

The third investigative question was: What pricing model performed the best between companies? The answer for this is that Cox-Ross-Rubinstein won the median calculation by 202% advantage but lost to the average calculations by 87%. The median score had a bigger advantage and as it is regarded as a better value because it tells about the consistency, Cox-Ross-Rubinstein binomial model was better.

The fourth and final investigative question was: What is the best pricing model? This answer was done by combining the results form investigative question 1, 2 and 3. The results indicated that Cox-Ross-Rubinstein model was the best performing as it outperformed the other models in the majority of the tests. Also, after doing additional research this verdict strengthened a lot. The most significant factor was that Cox-Ross-Rubinstein had the best median values by far. This indicates that this model is very profitable often.

The research question was: Which option pricing method would have been the most profitable for the selected stock options after Subprime? This can be answered by the points made in investigative question four. The Cox-Ross-Rubinstein model outperformed the other models in most of the comparisons as mentioned and therefore it would have been the most profitable model to use for the stock option after the Subprime crisis.

In my opinion, the results were pleasing as I had found during research that Cox-Ross-Rubinstein types of binomial models are used in the actual finance world.

5.2 Suggestions for further research

I would suggest more research into this topic with bigger resources and maybe as a master thesis. I would recommend adding the possibility of exercising the options with American standards, meaning that the options could be exercised whenever wanted until the expiration date. Also, the likeliness of the trades happening could be a good added research. As there was no availability to get the historical ask/bid spread prices it made it impossible to analyse if the pricing would indicate to purchase the option or not. Finally, I would recommend analysing other option pricing models to Cox-Ross-Rubinstein model as it resulted to be the best performing pricing model.

5.3 Validity, Reliability and Relevance

Validity issues could occur due to the factors mentioned in the previous chapter. If all of those were added to this research and the results would be the same, then I would call this a bulletproof thesis. This thesis is reliable as all the sources are reliable and used correctly. The relevance of this thesis is in investing segment high. As this is a growing investment method pricing of the instrument seems to be a vital point in that.

This thesis in my opinion was a rich and broad thesis for a Bachelor of Business Administration thesis. Overall, the thesis process was great and inspiring but the whole process could have been better if this would have not been done in the time of Covid-19 because like everyone else, I felt stressed under the overall circumstances that the global pandemic has caused.

5.4 Reflection on own learning

As a learning journey, this has been by far the most productive ones in my school path or even in my whole lifetime. Doing this thesis taught me discipline and that the results do not come easy. In addition to that, my academical writing and understanding has developed greatly. Using Excel for hundreds of hours taught me better skills on that and also inspired me to learn to code as these processes would have been more doable with coding skills. Additionally, most importantly I got hundreds of hours of knowledge in a field that interest me – that seems to be the most important aspect when doing a thesis.

References

Amadeo, K. 2020a. *An Introduction to the Financial Markets.* The Balance. URL: https://www.thebalance.com/an-introduction-to-the-financial-markets-3306233. Accessed 14 July 2020.

Amadeo, K. 2020b. *How the Stock Market Works.* The Balance. URL: https://www.thebalance.com/how-does-the-stock-market-work-3306244. Accessed 14 July 2020.

Corporate Finance Institute. *What Are Derivates?* URL: https://corporatefinanceinstitute.com/resources/knowledge/trading-investing/derivatives/. Accessed 20 July 2020.

Corporate Finance Institute. *What are Financial Markets?* URL: https://corporatefinanceinstitute.com/resources/knowledge/trading- investing/financial-markets/. Accessed 17 March 2020.

Corporate Finance Institute. *What Are Option Pricing Models?* URL: https://corporatefinanceinstitute.com/resources/knowledge/valuation/option-pricing-models/. Accessed 20 September 2020.

Corporate Finance Institute. *What is the Black-Scholes-Metron Model?* URL: https://corporatefinanceinstitute.com/resources/knowledge/trading-investing/black-scholes-merton-model/. Accessed 20 September 2020.

Dixon advisory. *Benefits of diversification*. URL: https://www.dixon.com.au/investment-advice/benefits-of-diversification. Accessed 16 March 2020.

Eiteman, D., Stonehill, A., Moffett, M. 2016. *Multinational Business Finance*. Essex: Pearson Education Limited. Accessed 17 April 2020.

Finance Train. *Option Pricing Using Monte Carlo Simulation.* URL: https://financetrain.com/lessons/option-pricing-using-monte-carlo-simulation/ Accessed 8 June 2020.

Fiorillo, S. 2018. *What was the Subprime Mortgage Crisis and how did it happen?.* URL: https://www.thestreet.com/personal-finance/mortgages/subprime-mortgage-crisis-14704400. Accessed 7 April 2020.

Goddard Consulting. *Option Pricing Using The Binomial Model.* URL: https://www.goddardconsulting.ca/option-pricing-binomial-index.html Accessed 15 June 2020.

Goddard Consulting. *Option Pricing - Monte-Carlo Methods*. URL: https://www.goddardconsulting.ca/option-pricing-monte-carlo-index.html Accessed 1 August 2020.

Gottesman, A. 2016. *Derivates Essentials: An Introduction to Forwards, Futures, Options, and Swaps.* New Jersey: John Wiley & Sons, Inc. Accessed 15 April 2020.

Hull, J. C. 2012. *Options, Futures, And Other Derivates.* Essex: Pearson Education Limited. Accessed 20 March 2020.

Kaiser, E. 2020. *Recession ended in June 2009*. NBER. Reuters. URL: https://www.reuters.com/article/us-usa-economy-nber-idUSTRE68J2JJ20100920. Accessed 15 July 2020.

Kennedy, M. 2019. *Types of Derivatives in Exchange-Traded Funds (ETFs).* The Balance. URL: https://www.thebalance.com/derivatives-in-etfs-1214889. Accessed 15 July 2020

Killian, A. 2020. *Option premiums explained. IG*. URL: https://www.ig.com/en/news-and-trade-ideas/option-premiums-explained-200330. Accessed 27 July 2020.

Nasdaq Helsinki. 2016. *Opi Optiot.* Helsinki. Accessed 29 July 2020.

Nordnet Bank AB. 2020. *Optiot.* URL: https://www.nordnet.fi/markkinakatsaus/optiolistat?currency=SEK&underlyingSymbol=NOKIA%20SEK&expireDate=1608246000000. Accessed 16 April 2020.

Pulliam Phillips, P. & Phillips, J. 2005. *Return on Investment Basics*. Association for Talent Development. Accessed 20 March 2020.

Rieunier, G. 2011. *Why use a model to price options?*. URL: https://www.trad-ingfloor.com/posts/fx-options-101-why-use-a-model-to-price-options-2597. Accessed 16 March 2020.

Semczuk, N. 2019. *What Is a Financial Crisis?* Smart Asset. URL: https://smartasset.com/credit-cards/what-is-a-financial-crisis. Accessed 15 July 2020.

The Options Clearing Corporation. 1994. *Understanding Stock Options*. Chicago. URL: http://www.cboe.com/learncenter/pdf/understanding.pdf Accessed 15 June 2020.

The Options Guide. *Strike price.* URL: https://www.theoptionsguide.com/strike-price.aspx. Accessed 7 April 2020.

Town, P. 2019. *How to invest money: A Simple Guide to Growth your Wealth in 2020.* URL: https://www.ruleoneinvesting.com/blog/how-to-invest/how-to-invest-money/. Accessed 16 March 2020.

Data

Macrotrends*. 10 Year Treasury Rate – 54 Year Historical Chart*. URL: https://www.macro-trends.net/2016/10-year-treasury-bond-rate-yield-chart. Accessed 21 July.

Yahoo! Finance. *Amazon.com Historical Data*. URL: https://finance.yahoo.com/quote/AMZN/history?period1=1243814400&period2=1590969600&interval=1d&filter=history&frequency=1d Accessed 18 July 2020.

Yahoo! *Berkshire Hathaway, inc. Historical Data*. URL: https://finance.yahoo.com/quote/BRK-B/history?period1=1246406400&period2=1590710400&interval=1d&filter=history&frequency=1d&includeAdjustedClose=true Accessed 20 July 2020.

Yahoo! *Netflix, Inc. Historical Data*. URL: https://finance.yhoo.com/quote/NFLX?p=NFLX&.tsrc=fin-srch Accessed 18 July 2020.

Yahoo! Finance. *Salesforce.com, inc. Historical Data*. URL: https://finance.yahoo.com/quote/CRM?p=CRM&.tsrc=fin-srch Accessed 20 July 2020.

Yahoo! *United Airlines Holdings Inc. Historical Data*. URL: https://finance.yahoo.com/quote/UAL?p=UAL&.tsrc=fin-srch Accessed 17 July 2020.