

Analysing Amazon: A Comprehensive Study of Stock Performance, Influential Factors, and Future Predictions

URN: 6636836

Amazon, a retail giant with a market capitalization of \$1.88 trillion, has shown significant growth since its initial public offering (IPO) in 1997. Fitting a normal distribution to the daily returns across its lifetime, the annual drift and volatility were found for the share price, 43.8% and 56.6% respectively. Using Geometric Brownian Motion, the future prices, and uncertainties, of AMZN were predicted using these parameters, while European call and put options were priced using a 2-step Binomial Tree model over 2 months, being \$11.32 and \$8.77 for call and put options respectively. Quantitative and qualitative analysis led to the recommendation of a combination strategy involving shares and long put options for profit and risk mitigation.

1. INTRODUCTION & BACKGROUND

In the modern world, it is becoming more realised that companies, governments, and countries are at the whim of national and global economics and movements within stock markets. With the emergence of online stockbrokers such as Trading212 (UK)^[1] and Robinhood (USA)^[2] in 2013, the public are more interested in the stock market than ever before. The option of buying fractional shares allows a lot more of the population to invest their money in new ways. It is important, however, to understand the mathematics behind the dynamics and intricacies seen on share prices and other financial derivatives. In the modern economy, options were first traded by the Chicago Board of Trade, under their 'Chicago Board Options Exchange' (CBOE) in April 1973.^[3] Options are a contract that can be bought or sold, providing the owner with the right to buy an underlying asset, usually a share, at a certain price or time. There are different variations of options that provide more value than others in certain markets. Options are one of the most frequently traded assets, with CBOE having a trading volume of \$1.27 billion at the end of 2014.^[4] Their roots can be traced back to the Dojima Rice Exchange, led by the ruling class in Japan in the Edo period in the 17th century.^[5] The practices seen in Japan are very similar to that seen within the market today, but instead of just rice, investors can trade options on valuable stocks, such as Google or Amazon.

1.1 Amazon

Amazon was launched in July 1995 by Jeff Bezos,^[6] originally as an online bookshop, competing with smaller chains as well as larger companies such as Barnes & Noble. Becoming public less than 2 years after launching, Amazon started selling publicly on

15th May 1997, with its initial public offering (IPO) being 3,000,000 shares.^[7] Since its beginnings, it has grown and accumulated masses of customers due its expansion into selling a wide range of goods, becoming one of the largest online global retailers. However, the company is not limited to just retail, with additional ventures such as cloud computing (AWS) providing extra capital for the company, being announced, and launched in 2006.^[8] The Amazon share, listed as AMZN, has become one of the most sought-after commodities due to the companies control and presence on the online retail market. Also, with the announcement of Amazon Prime in 2005, Prime Video in 2011 and the acquisition of WholeFoods in 2017, investors want to join the ever-growing conglomerate that is Amazon.



Figure [1]: Share price of AMZN (USD \$) from its IPO in May 1997 to March 2024. The share price shown is the adjusted close price. Historical data sourced from Yahoo! Finance.

As of April 2024, Amazon has a market cap of \$1.88 trillion, making it the 6th highest valued company in the world.^[9] From 1995 to 2021, Bezos held the position of Chief Executive Officer (CEO), until he stepped down to become Executive Chairman to pursue other business ventures alongside Amazon. Andy Jassy is now the current CEO of Amazon, after taking the position following Bezos stepping down.^[10] The share price of AMZN since its 1997 IPO until March 2024 is shown in Figure [1].

Within this report, we aim to establish and quantify the trends seen within the share price of Amazon since its IPO and use these trends and features to induce future predictions. The basis of these predictions will be sourced from quantitative features seen in the data, along with real-world factors that have caused major movements within the share price. These can be Amazon exclusive, such as the introduction of Amazon Prime Day and the acquisition of WholeFoods, or

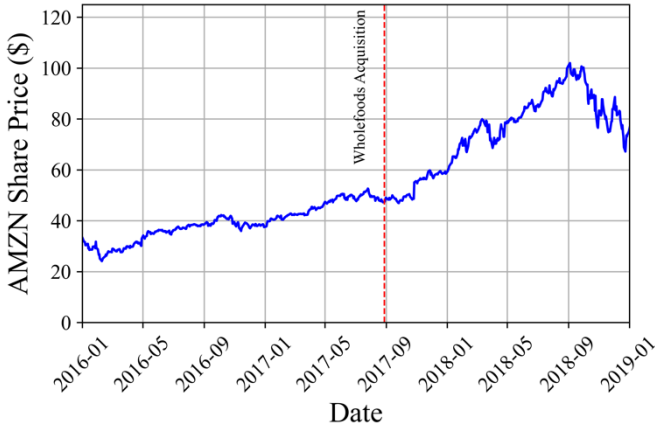


Figure [2]: Share price of AMZN (USD \$) from 01/2016 to 01/2019. Red line indicating the announcement of the acquisition of WholeFoods by Amazon in 09/2017. A return of investment (ROI) of approximately 100% occurred between 09/2017 and 09/2018 due to the acquisition.

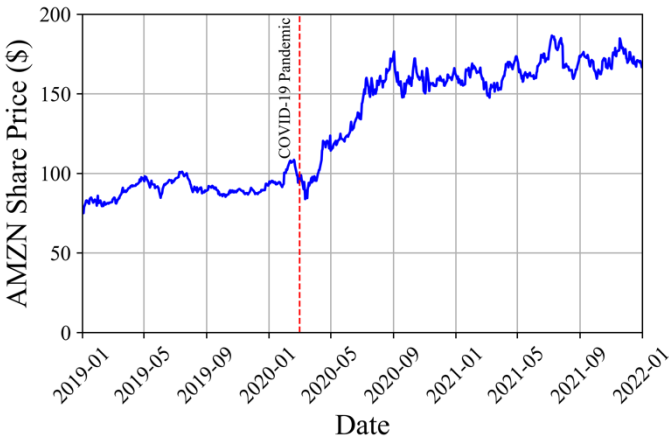


Figure [3]: Share price of AMZN (USD \$) from 01/2019 to 01/2022. Red line indicating the beginning of the COVID-19 pandemic. An ROI of 50% can be seen between 03/2020 and 09/2020.

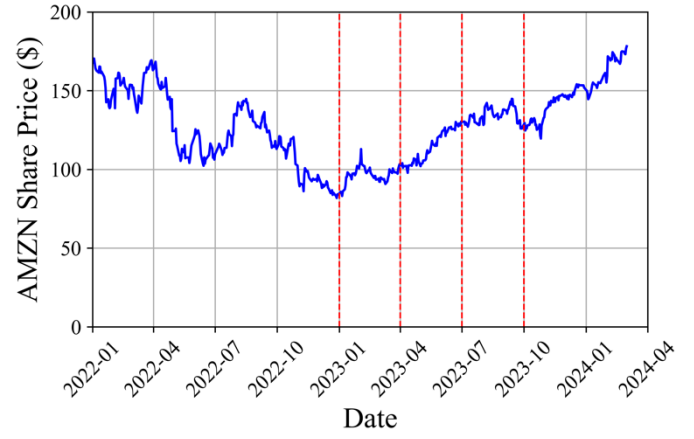


Figure [4]: Share price of AMZN (USD \$) from 01/2022 to 03/2024. Red lines indicating the release of the quarterly earnings reports in 2023, where each quarter surpassing the previous. Q1 '23 it was \$127.4 billion and Q4 '23 was \$170 billion.

instead global factors that affected the entire market, like the COVID-19 pandemic. Figures [2], [3] & [4] show some of the key pivotal moments in the share price dependent on real-world factors. The entire historical data from the IPO to March 2024 is used in the analysis as 27 years is a reasonable window to derive financial analysis from, seen in some long-term investments. By combining both the quantitative features and the influences of global events, we aim to create a strong investment strategy for Amazon, for investors in 2024.

1.2 Financial Mathematics

In this analysis, several mathematical techniques are utilised to obtain insights from the financial data. Firstly, to understand the drift and volatility of the AMZN share price, the daily returns can be plotted as a histogram, followed by modelling that histogram to a gaussian (or normal) distribution. Drift and volatility are descendants of Brownian Motion, a model postulated to predict the random movements of small particles, such as pollen.^[11] These movements were found to accurately resemble the dynamics within a share price, and investors and analysts began integrating this scientific concept into their work. We will use the parameters found through this analysis to procure future predictions for the movements of AMZN share price. Geometric Brownian Motion (GBM) predicts that the share price at future time in years, t , is given by:

$$S_t = S_0 e^{(r - \frac{1}{2}\sigma^2)t + \sigma W_t} \quad [1]$$

S_0 is the current share price, r is the annual drift, σ is the annual volatility, and W_t is called the Wiener process. This latter term generates the 'randomness' seen in GBM and can be implemented by a randomly selected value from a gaussian distribution about 0, with a standard deviation of 1.

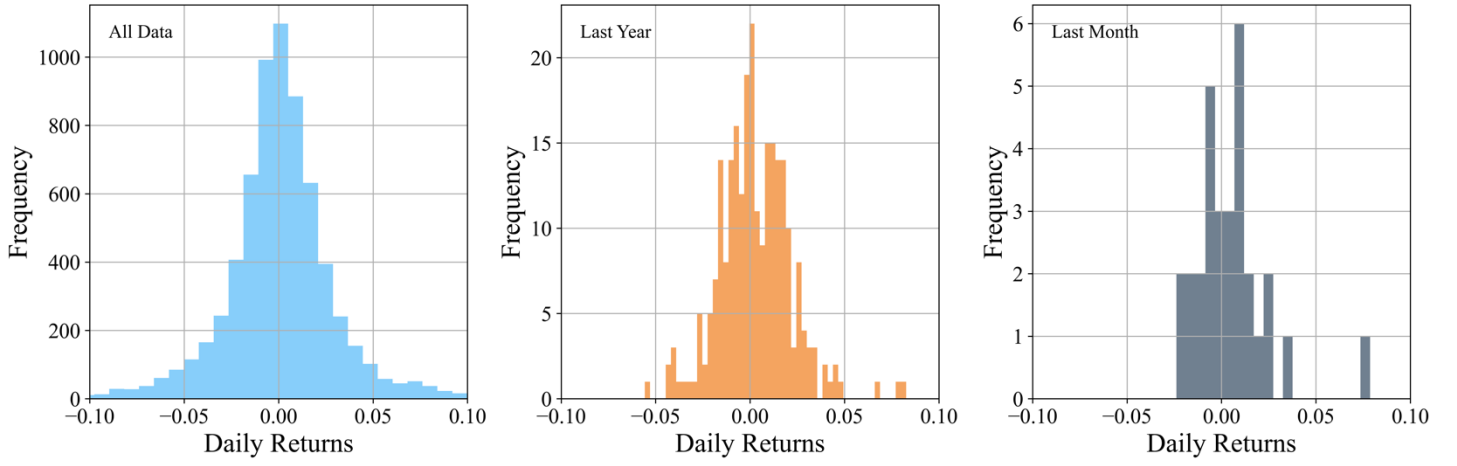


Figure [5]: Histograms of daily returns (\$) for AMZN stock. *Left*: Entire dataset from May 1997 to March 2024. *Centre*: March 2023 to March 2024. *Right*: February 2024 to March 2024. Looking from right to left, we can see a normal distribution appearing, which is to be expected as more data is compiled, providing greater confidence on the distribution seen.

To assess the pricing of options for AMZN, the Binomial Options Pricing Model (BOPM) will be deployed in this work, first discussed by William Sharpe in 1978.^[12] Binomial trees are created to predict different outcomes of the share, and their associated probabilities, given the assumption that the price can either go up by a factor of u , or down by a factor of d . The up and down factors are calculated as shown:

$$u = e^{\sigma\sqrt{\Delta t}} \quad [2]$$

$$d = \frac{1}{u} \quad [3]$$

Where σ is the volatility of the underlying asset, in our case, AMZN share, and Δt is the time duration between steps. Each step represents a time period, and the model iterates through these steps to determine the range of possible prices for the asset at each step. Using these potential prices, it predicts the future value of the underlying asset at some future time, allowing for an approximate price to be calculated for an option. It is not the most efficient model, with the analytical, calculus-driven, Black-Scholes-Merton model (BSM) being computationally faster. However, BOPM is far more versatile for dealing with a breadth of option styles, which is very useful as more exotic financial products are introduced into the markets. BSM works very well for ‘vanilla’ options such as European options but does not have the versatility of BOPM.

2. COMPUTATIONAL DETAILS & DATA MANIPULATION

The data used within this study was collected from the ‘Yahoo! Finance’ page for AMZN.^[13] The date range for any listed stock can be selected and can be downloaded via CSV file. The data provided is Date,

Open price, High, Low, Close, Adjusted Close and Volume. The primary data that will be used in this research is Date and Adjusted Close. The exact date range for our dataset 15th May 1997 to 1st March 2024, with a daily frequency.

Data manipulation and analysis were carried out in Python, using the Pandas package to read-in, store and process the data. Pandas is one of the most widely used packages in Python for data science and big-data analytics.^[14] It is a powerful tool that is used widely across quantitative finance due to its efficiency and power for handling big datasets from numerous sources. Additionally, Pandas is well-equipped to handle time-series data, and for historic share price data, this is widely valuable due to the functions that can be utilised to manipulate and visualise the stock data. Python was used in the Spyder application interface, allowing for built-in plots and variable explorer. The Matplotlib Python package was used for data visualisation and to create all plots.

3. ANALYSIS

3.1 Daily Returns & Normal Distributions

To visually gauge the spread of daily returns over varying periods, histograms were plotted that display the spread results. Figure [5] shows the daily returns across the entire AMZN stock history, last year (03/2023 – 03/2024), and last month (02/2024 – 03/2024). A normal distribution was modelled to the entire dataset histogram, seen left in figure [5].

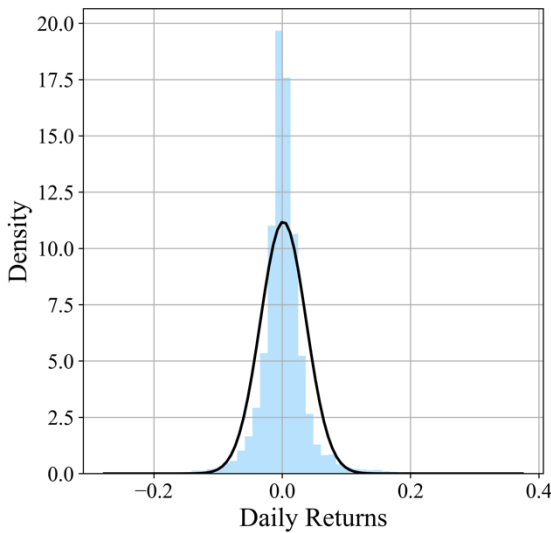


Figure [6]: Normal distribution modelled from histogram of daily returns over entire financial history of AMZN. Mean = 0.00174, Std = 0.0357. Normal distribution calculated using SciPy package.

This normal distribution was created using the mean and the standard deviation in the daily returns: $mean = 0.00174$, $std = 0.0357$. See figure [6] for the normal distribution fitted to the dataset. From a visual inspection, we can see large agreement with the daily return data, and the normal distribution modelled to it. In Appendix A, we discuss the limits of the normal distribution and its ability to successfully describe the AMZN share price data over this time window. The mean and standard deviations obtained from the fitted normal distribution were used to establish the annual drift and volatility seen in the AMZN share price. The annual drift was calculated to be 0.438, or 43.8%, and the annual volatility was 0.566, or 56.6%. The annual drift denotes the overall path of the share price, and the volatility is a measure of the noise, or fluctuations, seen across the path. The latter can be seen as the uncertainty, or risk, demonstrated within a share price's history. Using these parameters found from the normal distribution, and equation [1], we can generate future predictions on the performance of AMZN. We will consider 3 future predictions:

- The next quarter (3 months)
- The next 6 months
- The next year

Using equation [1] and these timeframes, potential future prices were calculated 10,000 times for each situation. The average and standard deviation for the values were found to gauge an accurate prediction with an uncertainty to quantify the confidence of the claim. Table [1] displays the predicted values and their uncertainties. We see an increase across all timeframes, which can be attributed to the very large growth

Amazon has experienced over its lifetime, clearly being shown in Figure [1].

Months Elapsed from 01/03/23	AMZN GBM Predicted Share Price (USD \$)
3	311.5 ± 191.8
6	299.1 ± 180.1
12	276.2 ± 168.6

Table [1]: Predictions of future share prices from GBM model, used often in BSM. With more months elapsed, the uncertainty on the prediction can be seen to drop. This can be attributed to the increase in data available for prediction.

From taking the predictions laid out in table [1], we can see that AMZN is due for large growth across the next year, and especially the next quarter, inclining the opinion that it would be a safe investment for medium-long length investments. However, we do see large amounts of volatility, visually in figure [1] and also in the uncertainties on our predictions from GBM. These high values present doubt on shorter term investments. High volatility is highly risky when planning for short-term investments due to the fluctuating nature of the share price. At these short timeframes, you are not guaranteed to reap the benefits of a large, positive drift value. The history of Amazon also provides confidence in the prospects of the share price, as their growth shows no signs of slowing. As said prior, they made \$574.8 billion in 2023, an almost 12% increase from 2022.^[15] This growth can be seen in Figure [4].

3.2 Hypothetical Investment

A worthy comparison is to investigate the percentage change on the AMZN share price since the IPO in 1997. With a starting price of \$0.098, and a closing price of \$178.22 at the end of the dataset, we see a 182,011% increase across this time window. To assist in conceptualising this % change, we will gauge the return of investment (ROI) if £1 million (\$1.251 million) was invested when Amazon first went public and compare it to the earnings gained if that capital was in a standard bank account following the latest 'Secured Overnight Financing Rates' (SOFR) rates.^[16]

On 1st March 2024, this \$1.25 million investment would be worth \$2.28 billion, an immeasurable profit. However, this investment was not always profitable. A week after the IPO, the share price had dropped to \$0.069, leading to the investment being \$891,451 (29% loss). This is the minimum value during the investment. The share price began showing substantial growth from 2010, with an eventual maximum share price of \$186.6 on 8th July 2021. The investment would have a value of \$2.38 billion on this date (190,400% profit). These calculations do not consider dividends

earnings. Alternatively, let's assess the profit gathered if the \$1.25 million was placed into a bank account, instead of AMZN stock. Using the current 6-month SOFR rate of 5.39%, we can establish the earnings on the investment between 1997 to 2024. In 2024, the \$1.25 million would be worth \$5.36 million, with an ROI of 327%. Comparing the percentage growths on the investment in AMZN stock or bank account, we can see that there is a far greater ROI from the Amazon investment. However, the AMZN investment did not show profitable growth for at least 10 years, which would evidently cause doubt upon the share price. The 182,000% growth of AMZN stock could not have been predicted, and many would have claimed that the money would have been more lucrative within a standard bank account.

However, for future investments, Amazon is a very safe choice due to its large-scale business that has reach across numerous markets, such as retail, cloud computing (AWS), groceries (WholeFoods), and live streaming (Twitch streaming). As of January 2024, Amazon Prime, their subscription service, has over 200 million members that is seemingly still growing despite numerous price raises.^[17] With this insight, AMZN is a great choice for future investments, especially mid-long investments that intend to sell in months and years, and not days or weeks. This is primarily due to the large drift and overall path taken by the stock over longer time periods, but the volatility is rather high and could cause losses for shorter investments.

3.3 AMZN Options Pricing: Binomial Model

Options are a commonly bought derivative that allows for more control on investments, allowing the owner to buy (call)/sell (put) their underlying asset at a certain time in the future, or certain strike price. These options can be purchased from various brokers. As discussed earlier, a commonly used method by these brokers to price options is the Binomial Tree Model.^[12] This is achieved by calculating prospective prices for the stock after certain timesteps, and then going back through the nodes to establish the pricing of the options. The price of an option is heavily reliant on the underlying asset the probabilities of it going up or down. We will calculate the pricing of 2 options:

- European Long Call Option
- European Long Put Option

European options can only be exercised at their specified expiry date, where the underlying asset will be bought or sold for a prearranged (strike) price, K .^[18] As opposed to American options, where they can be exercised at any time before the expiration date. We are assessing a 'long' position, describing the

purchasing of a call or put option. Our calculations of the option prices will consist of a 2-step, 2-month binomial tree, resulting in upward (u) and downward (d) movement factors seen in equations [2] and [3]:

$$u = 1.178$$

$$d = 0.849$$

These factors were calculated using the volatility found on the AMZN stock in section 3.1. The probability of an upwards movement^[19] is calculated via:

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

With r being the current 6M SOFR rate discussed earlier, 5.39%,^[16] we get a probability of upwards movements:

$$p = 0.473 \text{ or } 47.3\%$$

The binomial tree was constructed by using the latest AMZN adjusted closing price (1st March 2024) of \$178.22. From this value, the strike prices were 10% above (for call option) or 10% below (for put option). The 2-step binomial tree can be seen in Appendix B. From this tree, the options prices were calculated by deducing the payoff at each node, given an upward or downward movement, tracing back to the original node, representing the original share price.

From this model, the European Long Call Option price was \$11.32, and the European Long Put Option price was \$8.77. With these prices, the payoff and profit/loss were plotted against the price of the AMZN share. Figure [7] shows the profit for the call option, and figure [8] is the put option equivalent.

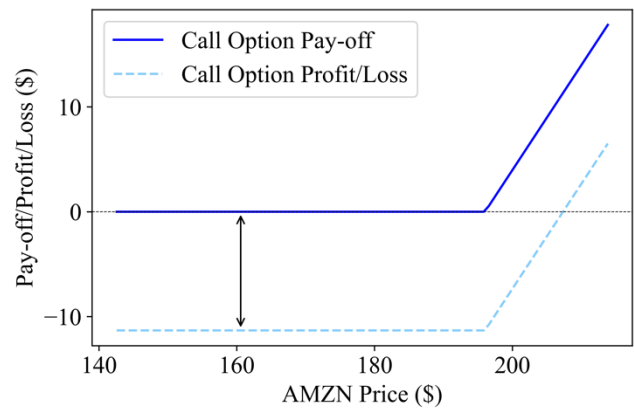


Figure [7]: Profit/Loss and pay-off for the European Long Call Option, with an expiration time of 2 months, and strike price of 10% above starting price (\$178.22). The arrow represents the price of the option.

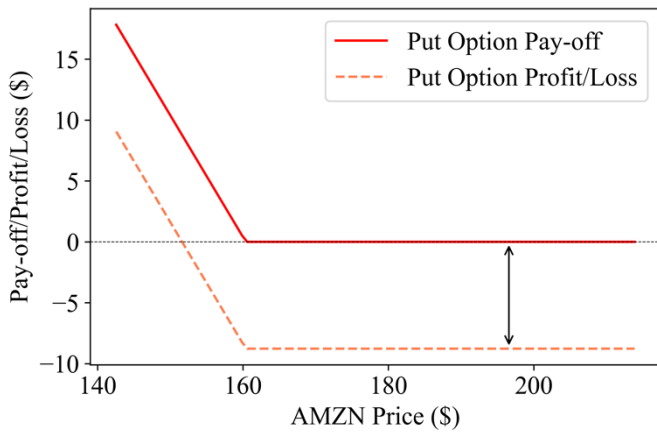


Figure [8]: Profit/Loss and pay-off for the European Long Put Option, with an expiration time of 2 months, and strike price of 10% below starting price (\$178.22). The arrow represents the price of the option.

In figure [7], the investment has no profit/loss (breakeven) when the share price equals to the strike price + the price of the option. As the share price grows from here, we see larger profit. The strike price can be identified at the point when both pay-off and profit/loss show non-zero gradient. The same is true for the put option pay-off seen in figure [8].

3.4 Stocks vs Options: Potential Investments

Investing in AMZN stocks allows for potential long-term profit, on the timescale of years. Amazon has showed very strong long-term growth over its lifetime, especially in the last decade, see figure [1]. For that reason, a safe investment strategy would be to invest in AMZN on a long-term basis, with the plan to sell 2-5 years. As the business expands, your investment and portfolio would grow with it, earning substantial profit. The confidence in the future movements of the Amazon share price is strongly in the favour of upwards movements, making this a safe investment, with a high chance of accumulating more capital than if the money was placed in a savings account.

However, AMZN has historically showed relatively large fluctuations and volatility, especially in the last 5 years, following a large increase from the COVID-19 pandemic, see figure [3]. It featured a period of volatility, without a prevalent increase or decrease. This uncertainty casts doubt upon many investors, opting to not purchase new stocks. However, long put options are a good investment during these periods. These options allow for the owner to sell their stocks at a predetermined price, providing protection against downward turns in the share price. In periods of volatility, seen following the COVID-19 pandemic, hedging options such as this is a safe investment.

Alternatively, long call options are a strategy to capitalize on Amazon's potential upward motion while managing risk. Investors can limit their downside risk while maintaining exposure to the upside potential of the stock.

A combination strategy of investing in stocks and options is a common way investors can maximize their profit. With the history of AMZN share price, building a strong core of shares allows long-term profit and growth that can be visually and mathematically predicted, as seen by the analysis in this report. Alongside this, long put options can be bought to provide security on investments if the share price shows volatility or a downward path. The investor would be able to sell their shares at a predetermined price, mitigating risk if the downward trend continued. This hedging strategy is used often due to the protection it provides on investments, enduring periods of volatility. This is highly useful for AMZN shares as it features strong historic growth, but also windows of high volatility.

4. CONCLUSIONS

In this report, quantitative and qualitative analysis was performed to assess the historic trends of Amazon and its share price. Events in the company's history, such as major acquisitions or earnings reports were investigated to see their impact on the share price and how it affected the company's growth. Overall, AMZN shows immense growth, with an ROI of 180,000% since the IPO to now. Despite this, the share price has shown signs of volatility, with the most notable example being during the COVID-19 pandemic, where major fluctuations were seen between 09/2020 and 04/2022.

The dramatic growth prompts the recommendation of purchasing shares in AMZN. Based upon plans discussed by the company and the reliance of many people on the retail and delivery service provided by Amazon, it shows no signs of slowing down. Alternate online retail companies have emerged in the past few years such as Alibaba^[20] and Temu,^[21] but these are far more active in Eastern countries, and Amazon still holds the monopoly on the West when it comes to online retail. However, risk has emerged in last few years with the exponential growth slowing down and fluctuations being seen. This leads to the recommendation of long pull options, providing a risk mitigation strategy that protects the investor from suffering losses if large fluctuations are seen, or there is a downward trend. A combination strategy, consisting of shares and put options, is a method of hedging their investments, providing the profits and benefits if AMZN behaves as it has historically, but protects against high volatility.

Investment strategies depend on the investor's motivations and their appetite for profit, risk tolerance and timescales. For that reason, numerous factors should be considered before conducting any sort of investment or hedging. The analysis in this report has been tailored as a general overview of the AMZN share, its historic performance and future predictions. By finding quantitative factors that describe the dynamics and trends seen in the share price, simulations have been run to predict the most likely

path taken by the share and how it will develop with the market. The predicted value for the end of the next quarter is $\$311.5 \pm 191.8$, and in 12 months, $\$276.2 \pm 168.6$. The uncertainties on these prediction values are relatively high, stemming from the high volatility of AMZN (43.8%). Due to this, the investment recommendations should not be taken as direct advice without consulting other sources.

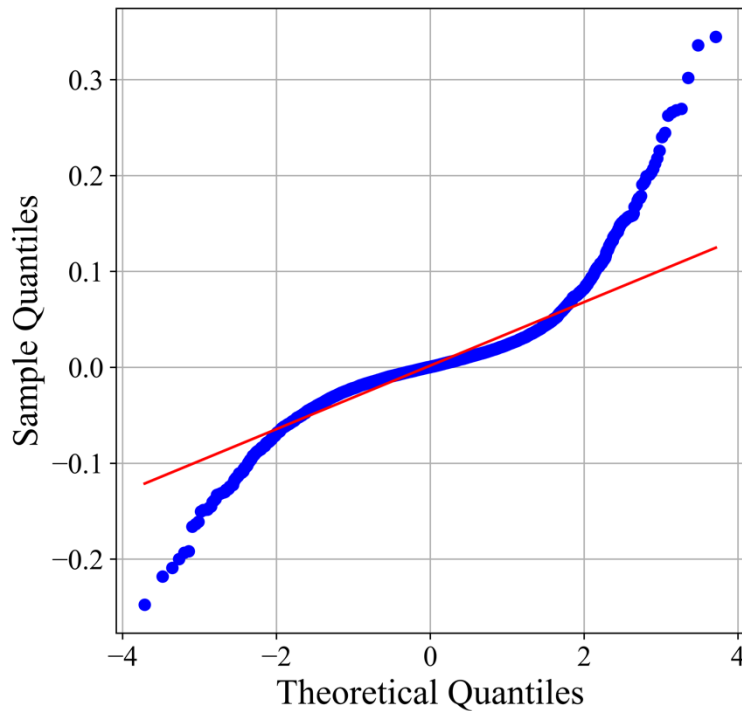
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APPENDIX

APPENDIX A: Quantile-Quantile plot (Q-Q): Designed to show the residuals of a dataset from a normal distribution.

The blue points are the daily returns of AMZN share price from the May 1997 IPO to March 2024. The red line shows the expected value from a normal/gaussian distribution.



APPENDIX B: Binomial Tree for Options Pricing – 2-month 2-step tree that shows the pay-off for each eventuality for call and put options.

