Analysis of NVIDIA Stock Price History

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1.1 – Project Outline
The financial markets have long been a subject of intense study, with researchers continually seeking innovative theoretical frameworks to comprehend market behaviour. One such breakthrough hypothesis, gaining traction in recent years, is the Adaptive Markets Hypothesis (Lo, 2004). This hypothesis suggests that a blend of fundamental analysis, technical analysis, and behavioural analysis can yield significant insights into market dynamics. Concurrently, the resurgence of supervised Machine Learning (ML) has provided new avenues for predicting stock returns. The combination of the Adaptive Markets Hypothesis and ML techniques holds promise for enhancing stock return forecasting accuracy.

This project focuses on analysing the stock price of NVIDIA Corporation, with reference to its competitors in the semiconductor industry (namely INTEL, AMD, and QUALCOMM). The intention is to analyse various facets of NVIDIA's business decisions, earnings reports, and stock price history. The following key inquiries are the forefront of this report:

1.2 – Project Objectives
Objective 1: Historical Stock Price Trend Analysis
- What are the historical stock price trends for NVIDIA and its competitors?
- Are there any discernible patterns in the data?
- What insights can we gain from this data?

Objective 2: Impacts of Strategic Business Decisions
- Which strategic business decisions have facilitated such a significant rise in NVIDIA's stock price?
- How did these decisions impact the business and their stock price?

Objective 3: Forecasting Stock Prices:
- Which ML models are most accurate in forecasting time series stock prices?
- What is the feasibility and effectiveness of different ML models in such forecasting?
- How can prediction accuracy be improved in the future?

Section 2 – Background
NVIDIA Corporation, founded in 1993 by Jensen Huang, Curtis Priem, and Christopher Malachowsky, has risen to be a vanguard in the technological sphere, specifically in designing and manufacturing graphics processing units (GPUs), artificial intelligence (AI), and high-performance computing. Headquartered in Santa Clara, California, NVIDIA has evolved from pioneering the GPU in 1999 to revolutionize computer graphics and parallel computing, allowing for enhanced 3D graphics and a leap in the PC gaming market.

Their innovation didn't stop at gaming; NVIDIA's product line includes the GeForce series for gaming and professional visualization, and the Drive suite for autonomous vehicles, illustrating their industry leadership which has expanded to a workforce of 18,100 and a staggering annual revenue of $27 billion in 2022. With initiatives like CUDA, a GPU programming language introduced in 2004, NVIDIA has solidified its control over the GPU sector and committed to education by fostering GPU programming courses worldwide.

Despite facing accusations of inadequate disclosures regarding the impact of cryptocurrency mining on its gaming business by the SEC in 2022, NVIDIA has continued to thrive. The company opted to settle with a $5.5 million fine without confirming or contesting the allegations, a move that speaks to its agility in navigating the complex landscape of corporate governance.

Operating in four primary market segments—Gaming, Professional Visualization, Data Centre, and Automotive—NVIDIA has a robust product ecosystem encompassing GeForce, Quadro, Tesla, and Tegra processors. These are engineered not just for traditional gaming but also for the cutting-edge realms of AI, deep learning, and autonomous driving technologies. The company's investment in R&D has been

substantial, amounting to over $24 billion since its inception, significantly outstripping its closest competitor, AMD, which has been critical in maintaining its competitive edge.

NVIDIA's strategic diversification and adaptation to market trends have kept it at the forefront of the high-end GPU market. With a focus on digital transformation opportunities such as AI, data science, deep learning, and autonomous driving, NVIDIA continues to redefine its value proposition and maintain its position as a global leader.

Following its 2023 Q4 financial disclosures, NVIDIA Corporation has surged in value to become the third most valuable company in the United States. This surge highlights the market's recognition of NVIDIA's pivotal role in the ever-expanding AI sector and its solid financial performance

Section 3 – Exploratory Data Analysis (EDA)

Stock Price History & Moving Averages

In analysing NVIDIA's stock price history over the past five years, we observe a notable growth trajectory that signifies its robust market performance and investor confidence. Figure 1 - 5 Year Stock Prices & Moving Averages illustrates an overall ascending trend. We can observe with an initial peak in November 2021, followed by a trough in October 2022 from which the stock has continuously risen. These timeframes note 3 specific rallies in NVIDIA's stock price, with each characterised by different business decisions and political situations. The overall upward trend, despite periodic corrections, indicates NVIDIA's sustained growth and its pivotal role in driving the semiconductor industry forward, underpinned by the company's focus on cutting-edge technology and expanding product lines.

The moving averages in Figure 1 provide further insights into this trend. The 50-day moving average (MA50) has frequently crossed above the 200-day moving average (MA200), signalling bullish 'Golden Cross' events, which are often interpreted as strong buying opportunities by market participants. Conversely, the instances where MA50 has dipped below the MA200, known as 'Death Crosses,' have been relatively short-lived, suggesting swift recoveries and enduring market faith in NVIDIA's stock.

In the context of NVIDIA's competitors, a comparative examination reveals certain distinctions. In Figure 1 AMD's stock price trajectory showcases significant resemblance to that of NVIDIA; however, the scale and consistency of NVIDIA's performance markedly outstrip AMD's. Intel and Qualcomm, meanwhile, showcase less pronounced growth trends. These differences in trend magnitude against competitors reinforces the narrative of NVIDIA's dominance within the semiconductor industry.

Growth Rate Statistics

The following references statistics listed in Table 1 - Stock Price Growth Statistics. The statistics provided reinforce NVIDIA's exceptional stock performance relative to its competitors. With a 5-year growth rate of 1895.16%, and a compound annual growth rate (CARGR) of 81.98%, NVIDIA's market valuation has significantly outpaced AMD (635.98% growth, 49.06% CAGR), Intel (negative growth), and Qualcomm (231.78% growth, 27.11% CAGR). These statistics reinforce the narratives discussed thus far, highlighting NVIDIA's sustained growth and market dominance, bolstered by strategic business decisions and resilience through various economic situations. NVIDIA's ascendancy in the market is a testament to its innovation and leadership within the semiconductor industry.

Correlation

Figure 2 - Stock Price Correlation Heatmap showcases that NVIDIA's stock price movements are positively correlated with its competitors, AMD, Intel, and Qualcomm. NVIDIA and AMD stock show the highest correlation at 0.76, suggesting that similar market forces may be driving the rise in both companies. These market forces will be later investigated in Section 4 – Analysis of Earnings Reports & Business Decisions.

Risk vs Expected Returns

The risk-return figures in Figure *3* - Expected Return vs Risk Plot underscores a fundamental principle in finance: higher risk typically correlates with the potential for higher returns. NVIDIA's position in this plot affirms this, exhibiting the highest risk as well as the highest expected return when compared against industry competitors. Interestingly, AMD presents a disproportionate risk-return profile, suggesting that its investors bear a higher risk relative to the expected return when compared to NVIDIA. This observation is

critical for machine learning models, which could integrate such disparities into more nuanced, adaptive forecasting algorithms that account for differing risk sensitivities across companies in the semiconductor industry.

Target Distributions & Target Statistics

The target distribution plot in Figure 4 - Stock Target Distributions offer a comprehensive view of each company's stock performance volatility. NVIDIA exhibits a daily return slightly higher than its industry competitors with a moderate magnitude of volatility. Notable, NVIDIA's distribution shows a positive skew, suggesting more days of gains than losses, and a higher kurtosis, indicating occasional extreme results. These statistics are reaffirmed in Table 2 - Stock Target Distribution Statistics. In contrast, AMD, while having similar mean returns, shows greater volatility, a lower skew, and less kurtosis, hinting at a higher relative risk-return profile as previously discussed.

Section 4 – Analysis of Earnings Reports & Business Decisions

4.1- Financial Performance Analysis

4.1.1 – Profitability Ratios

- Return on Equity (ROE): NVIDIA's ROE stands at an exceptional 91.46%, indicating the company's proficiency in generating profits from its equity. This level suggests that for every dollar of shareholders' equity, NVIDIA produces over ninety-one cents in profit, demonstrating a commendable deployment of shareholder capital.
- Return on Assets (ROA): The company's ROA is recorded at 38.55%, showcasing NVIDIA's capability to utilize its assets to generate substantial earnings. This ratio underscores the company's efficient asset management practices.
- Operating Margin: With an operating margin of 61.59%, NVIDIA demonstrates its ability to translate sales into operating income effectively. This margin reflects the company's solid pricing strategy and commendable control over production and operating costs.
- Net Profit Margin: NVIDIA's net profit margin, at 48.45%, indicates the company's success in converting a significant portion of its sales into actual profit, reinforcing its market leadership in terms of profitability.

4.1.2 – Liquidity Ratios

- Current Ratio: NVIDIA's current ratio, erroneously reported as a percentage, is indicative of the company's financial health, with enough liquid assets to cover short-term liabilities comfortably.
- Operating Cash Flow: The operating cash flow figure of $28.09 billion represents NVIDIA's robust cash-generating capability, a vital component for sustaining growth and operational excellence.
- Levered Free Cash Flow: The levered free cash flow of $19.87 billion is indicative of the company's capacity to generate cash after satisfying its debt obligations, further enhancing its investment appeal.

4.1.3 – Debt Ratios

- Debt to Equity Ratio: At 25.73%, this ratio suggests that NVIDIA maintains a balanced approach towards financing its growth, utilizing a moderate level of debt in comparison to its equity.

4.1.4 – Market Ratios

- Earnings per Share (EPS): An EPS of $11.90 underscores NVIDIA's efficiency in profit generation per outstanding share, reinforcing investor confidence in the company's earnings potential.
- Price to Book Value Ratio: The high ratio of 45.85 indicates market recognition of NVIDIA's growth potential and possibly its vast intangible assets.
- Book Value per Share: Standing at $17.44, this ratio provides insights into the net asset value of NVIDIA per share, suggesting a stable financial base.
- Price to Earnings Ratio (P/E): A P/E ratio of 66.07 reflects the market's willingness to pay a premium for NVIDIA's earnings, which may be attributed to anticipated growth or a current market overvaluation.

4.2 – Strategic Business Decisions Analysis

NVIDIA has made several strategic decisions over the past five years that have solidified its market position:

- Diversification Strategy: NVIDIA has effectively broadened its focus from its traditional gaming sector to emergent areas like artificial intelligence, deep learning, and automotive technology, significantly diversifying its revenue sources.
- Research and Development (R&D): NVIDIA's sustained investment in R&D has been pivotal in maintaining its technological leadership, especially in graphics processing units (GPUs).
- Strategic Partnerships and Acquisitions: Collaborations with industry heavyweights and strategic acquisitions, such as Mellanox, have expanded NVIDIA's market presence and product portfolio.
- CUDA Platform Development: The advancement of the CUDA platform has facilitated the adoption of NVIDIA GPUs for a wide array of parallel processing tasks, including scientific computation and machine learning.
- Data Centre Expansion: NVIDIA's foray into the data centre sector has proven highly successful, capitalizing on the exponential growth of cloud computing and services.
- Gaming Industry Leadership: The consistent release of cutting-edge GPUs for gaming has helped NVIDIA maintain its dominance in this competitive market segment.

4.3 – Competitive Landscape and Market Position

NVIDIA operates in a highly competitive market, with key rivals including Intel, AMD, and Qualcomm. Despite the competition, NVIDIA has maintained a significant lead due to its:

- Innovative Product Line: NVIDIA's continuous innovation in GPUs and expansion into AI and deep learning have kept its offerings at the forefront of technology.
- Strategic Contracts: NVIDIA has secured lucrative contracts with various industry leaders, which, while their exact profitability is proprietary, are believed to be highly profitable given NVIDIA's financial metrics.
- Market Adaptability: NVIDIA's swift adaptation to market trends, such as the shift towards AI and deep learning, has given it a competitive edge.
- Brand Strength: NVIDIA's strong brand recognition and reputation for quality have contributed to its market leadership.
- Operational Efficiency: The company's impressive operating margins indicate a level of efficiency that many competitors struggle to match.

4.4 – Section Conclusions

In conclusion, NVIDIA's financial ratios reflect a company that is not only thriving in terms of profitability and liquidity but also strategically positioned for sustained growth. Its strategic business decisions have been instrumental in outpacing competitors and are likely to continue propelling the company forward in the semiconductor industry.

Section 5 – Describing the Data

The data used in this papers belongs to the period from 23/02/2019 to 23/02/2024 (5 years). All information was collected between 01/02/2024 and 23/02/2024. The data was collected from Yahoo Finance and contains the following variables:

- Date: Date of trading day.
- High: Highest Price of Stock on that day.
- Low: Lowest Price of Stock on that day.
- Open: Opening Price of Stock on that day.
- Close: Closing Price of Stock on that day.
- Volume: Number of shares or contracts traded in a security or an entire market during a given period.
- Adjusted Close: Adjusted closing price amends a stock’s closing price to accurately reflect that stock’s value after accounting for any corporate actions.

Section 6 – Predictive Analysis of NVIDIA Stock Price

Data and Preparation

We start by getting our data ready from Yahoo Finance, which covers the last four years of NVIDIA Corporation (NVDA) stock. This dataset encompasses daily metrics such as opening price, closing price, highest price, lowest price, and volume of shares traded for the specified timeframe. A series of essential feature engineering techniques are applied to each metric within the dataset. This includes the normalization of features, a critical step given that certain advanced gradient-boosting algorithms depend on distance measures and gradient-based optimization strategies for model construction and predictive accuracy. Furthermore, normalization facilitates the equitable comparison of error metrics (specifically, root mean squared error) across different models.

Our predictive analysis on the NVDA stock is multi-faceted, encompassing both multiple-day time-series forecasts and single-day forecasts, with the latter category subdivided into forecasts utilizing static models and those updated with new data. The necessity for varied predictive approaches stems from the limitations posed by our input variables. As elucidated in Section 4, the NVDA stock experiences significant external influences that cannot be fully captured through numerical data alone. Consequently, our methodology prioritizes the precision of single-day forecasts, where the impact of external market dynamics is ostensibly minimized. Nonetheless, we persist in executing consecutive day forecasts to accentuate the 'noise' introduced by these external factors, thereby offering a holistic view of the stock's behaviour under varied conditions.

XGBoost Predictive Analysis

XGBoost, an abbreviation for Extreme Gradient Boosting, represents a distinguished machine learning algorithm within the boosting algorithm family. It employs a series of weak learners, specifically decision trees, progressively amalgamated into an ensemble. This methodology facilitates the elucidation and incorporation of intricate relationships present within the dataset into the ensemble framework, as each successive weak learner is seamlessly integrated. The algorithm operates iteratively, concentrating on rectifying the inaccuracies identified by preceding trees, thereby enhancing its comprehension of the dataset's overarching trends. Nonetheless, it is imperative to acknowledge its limitations in addressing the extensive external market fluctuations.

Our analytical process is delineated by the utilization of a training set, which serves as the foundation for model development, juxtaposed with a test set that delineates the predictive domain. The application of diverse predictive methodologies enables a thorough evaluation of the model's efficacy in forecasting outcomes for consecutive days. Notwithstanding, our analytical focus predominantly lies on single-day forecasts, wherein the model undergoes retraining with data from the newly anticipated day. The incorporation of this additional day's data does not substantially alter the model's fundamental insights into prevailing trends, thereby permitting the recurrent utilization of the model for forecasting multiple days, albeit with varying initial conditions.

Error Measures	Re-trained Model	Static Model
Mean-Squared-Error	0.00282	0.01556
Root-Mean-Squared-Error	0.05306	0.12472
Mean Absolute Error	0.04615	0.12189
R-Squared-Score	-3.02505	-21.23976

The Re-trained Model is more accurate and reliable because it assimilates the most recent actual stock prices, allowing it to adjust to the market's volatility and any new trends more effectively. Stock prices are influenced by numerous unpredictable factors, including market sentiment, news, economic indicators, and global events. Therefore, the frequent retraining with the latest data helps the model stay current with these influences. The Static Model, without the benefit of retraining, cannot adjust to new patterns as effectively.

Its predictions likely degrade over time as it moves further from the last training point, especially in the volatile and often non-linear environment of stock prices.

The Re-trained Model benefits from incorporating the most recent actual data into its training set, which likely helps it capture the latest trends and reduce error. The Static Model, without retraining, doesn't adjust to recent market changes, leading to larger prediction errors. The negative R^2 values for both models suggest that there may be issues with the underlying data or the model's assumptions. It's possible that the features used for predictions do not have a strong predictive relationship with the target variable, or the stock price movement is too random to be captured by the model. This indicates that the model is not complex enough to capture the volatility of the stock market effectively.

LSTM/RNN Predictive Analysis

An LSTM, or Long Short-Term Memory network, is a type of recurrent neural network (RNN) that is capable of learning long-term dependencies in data sequences. Stock prices are not random and often exhibit temporal patterns and dependencies. LSTMs can capture these patterns over time, which might be indicative of future movements. Financial markets are volatile and contain a lot of noise. LSTMs can help filter out noise and focus on the underlying trends in the data. LSTMs can integrate and learn from features across different time frames (e.g., daily, weekly, monthly stock prices), which is valuable for capturing both short-term fluctuations and long-term movements. However, it's important to note that while LSTMs can be powerful for capturing temporal dependencies, stock price prediction remains a challenging task due to the inherent uncertainty and influence of external factors that are difficult to predict or quantify (like market sentiment, geopolitical events, etc.).

This is suitable over a simple RNN as they suffer from short-term memory, the vanishing gradient problem, overfitting and noise sensitivity. They can handle input where the gap between the relevant context and the point of prediction is small. However, they struggle with long-term dependencies, which are common in stock price data.

Error Measures	RNN	LSTM	LSTM (% change)
Mean-Squared-Error	0.00323	0.00168	0.07817
Root-Mean-Squared-Error	0.05686	0.04096	0.27960
Mean Absolute Error	0.04899	0.03243	0.22046
R-Squared-Score	0.92666	0.96194	-2.98834

The LSTM model has outperformed the simple RNN in every metric. This is expected as LSTMs are specifically designed to remember long-term dependencies, which is crucial for time-series prediction like stock prices. MSE and RMSE are lower for the LSTM, suggesting that the LSTM predictions are closer to the actual values on average. The lower RMSE indicates that the LSTM has fewer large errors, which is important in financial contexts where large prediction errors can be very costly. The MAE is also lower for the LSTM, indicating that on average, the absolute errors are smaller. This again points to the LSTM's ability to capture the stock price movements more accurately than the simple RNN. The R^2 is higher for the LSTM, which means the percentage of variance explained by the model is higher. An R^2 closer to 1 indicates a model that can explain more variability of the response data around its mean.

Section 7 – Conclusions & Future Improvements

In the assessment of predictive models for NVIDIA's stock price, a suite of machine learning approaches including a simple Recurrent Neural Network (RNN), Long Short-Term Memory (LSTM) networks, and XGBoost algorithms were employed. The evaluation of these models was grounded in a variety of error metrics, including Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), and the coefficient of determination (R^2 score).

Performance Evaluation

The LSTM model exhibited superior performance across several metrics when compared to its counterparts. Notably, it achieved a lower MSE, RMSE, and MAE, suggesting that its predictions were consistently closer to actual stock prices. The enhanced capability of the LSTM to accurately predict stock prices can be attributed to its architecture, which is adept at capturing long-term temporal dependencies, a characteristic particularly beneficial in the volatile domain of stock prices. The inclusion of technical indicators such as the Relative Strength Index (RSI) and various Exponential Moving Averages (EMA) in the feature set likely contributed to this improved performance by providing the model with additional relevant information that encapsulates market sentiment and trends.

Contrastingly, the simple RNN and XGBoost models, which were limited to basic stock attributes such as open, close, high, low, and volume, did not fare as well. The lack of sophisticated market indicators in their feature sets may be a contributing factor to their relatively poorer performance. This is supported by the apparent inability of these models to capture the more subtle dynamics that influence stock prices, as evidenced by their higher error rates.

Model Improvements

To further enhance the predictive accuracy of the models, an expansion of the feature set could be considered. This could include not only additional technical indicators but also macroeconomic factors, sentiment analysis from news sources, and social media, which could provide a more holistic view of the factors influencing stock prices. Additionally, fine-tuning the hyperparameters of the models, particularly for LSTM networks, could yield improvements in performance. This hyperparameter optimization should be methodical, leveraging approaches like grid search or random search to systematically explore the parameter space.

Data Considerations

Regarding data improvements, the incorporation of more granular data, such as intraday prices, could potentially provide models with a more detailed picture of stock movements, at the cost of requiring more sophisticated noise filtering techniques to manage the increased volatility present at these shorter time scales. Furthermore, ensuring data quality by mitigating issues like missing values, outliers, and ensuring alignment between different data sources would be critical in maintaining the integrity of the model's input, thus enhancing its predictive capabilities.

Conclusion

In conclusion, the LSTM model, augmented with a comprehensive set of technical indicators, stands out as the most effective tool for predicting NVIDIA's stock price among the models evaluated. Its proficiency in handling time-series data and its ability to incorporate a wide array of features make it a formidable model for this task. Nonetheless, there remains room for enhancement, particularly in terms of feature selection and model tuning, which could provide even more precise predictions. As the landscape of financial data analytics continues to evolve, the iterative refinement of models and data strategies will remain a cornerstone of successful stock price forecasting.

Section 8 – Appendix

Figure 1 - 5 Year Stock Prices & Moving Averages

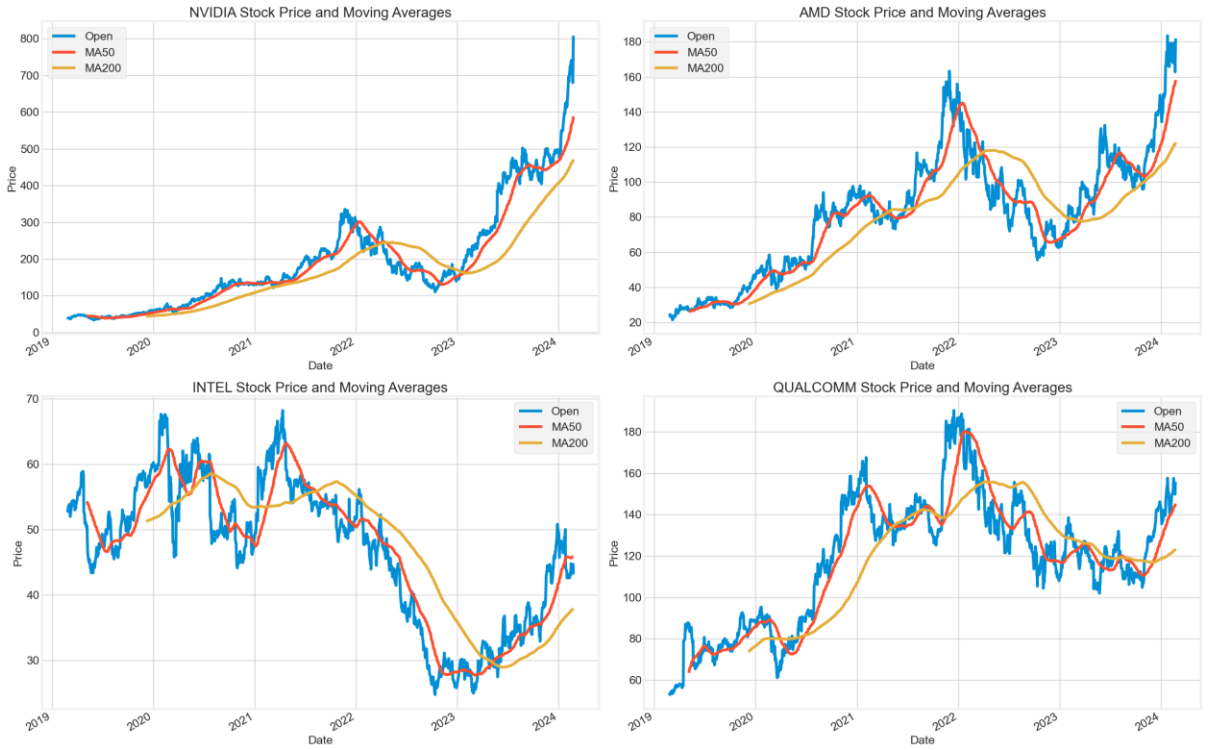


Table 1 - Stock Price Growth Statistics

Statistic	NVIDIA	AMD	Intel	Qualcomm
Current price ($)	785.38	181.86	42.98	154.75
Price 5 Years Ago ($)	39.36	24.71	46.47	46.64
5Y Growth Rate (%)	1895.16	635.98	-7.51	231.78
CAGR (%)	81.97	49.06	-1.55	27.11

Figure 2 - Stock Price Correlation Heatmap

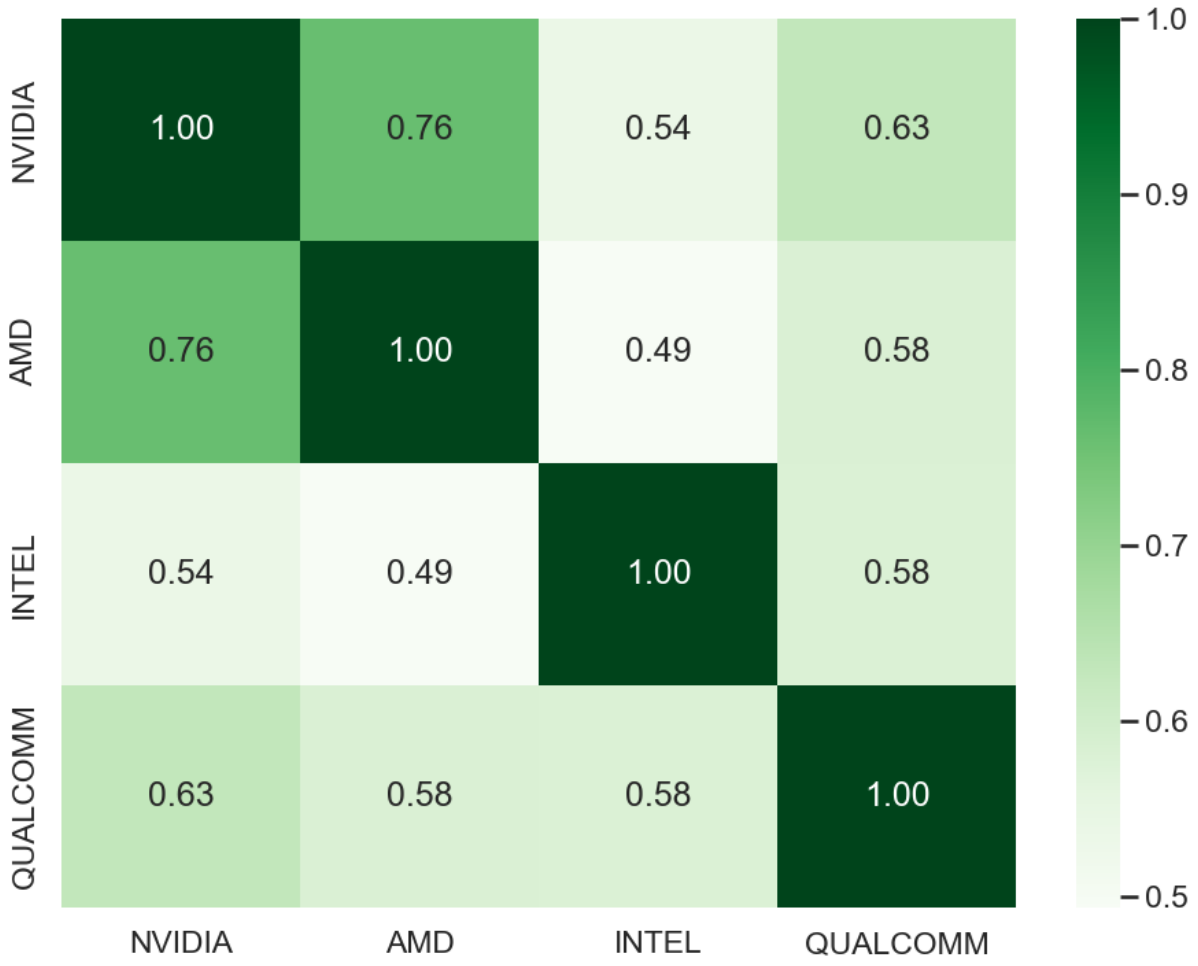
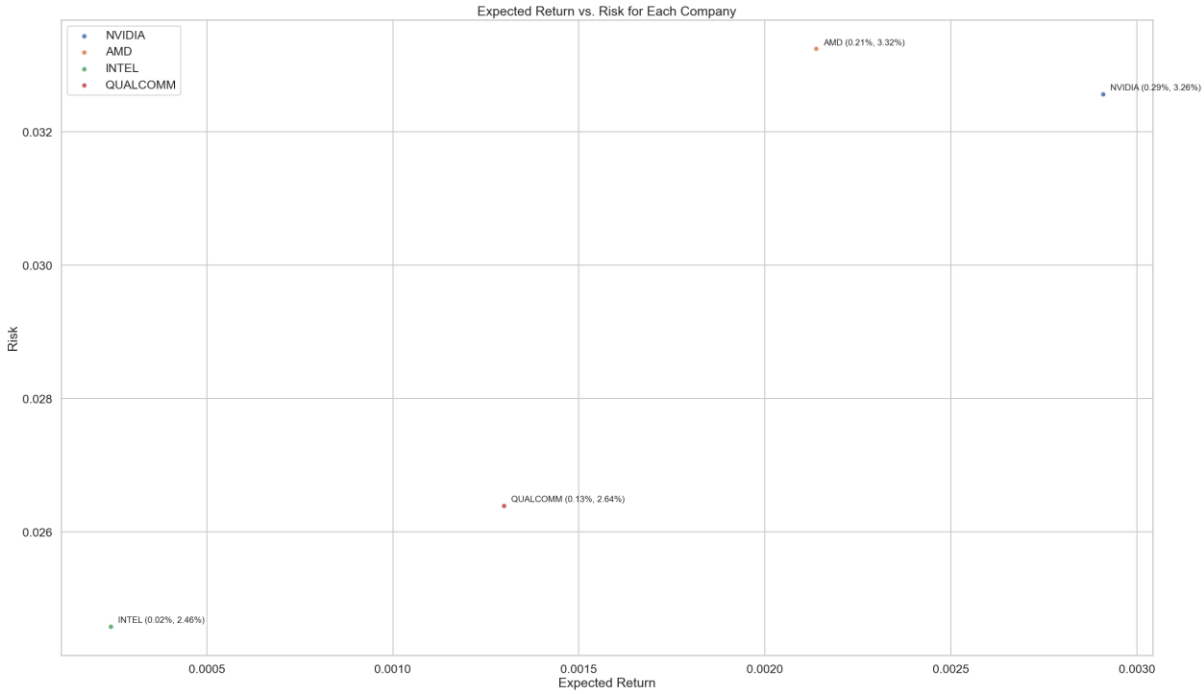


Figure 3 - Expected Return vs Risk Plot



Note: In this plot, "Risk" is defined as the (estimated) standard deviation of a stock's daily return and "Expected Return" is defined as the stock's average daily return.

Figure 4 - Stock Target Distributions

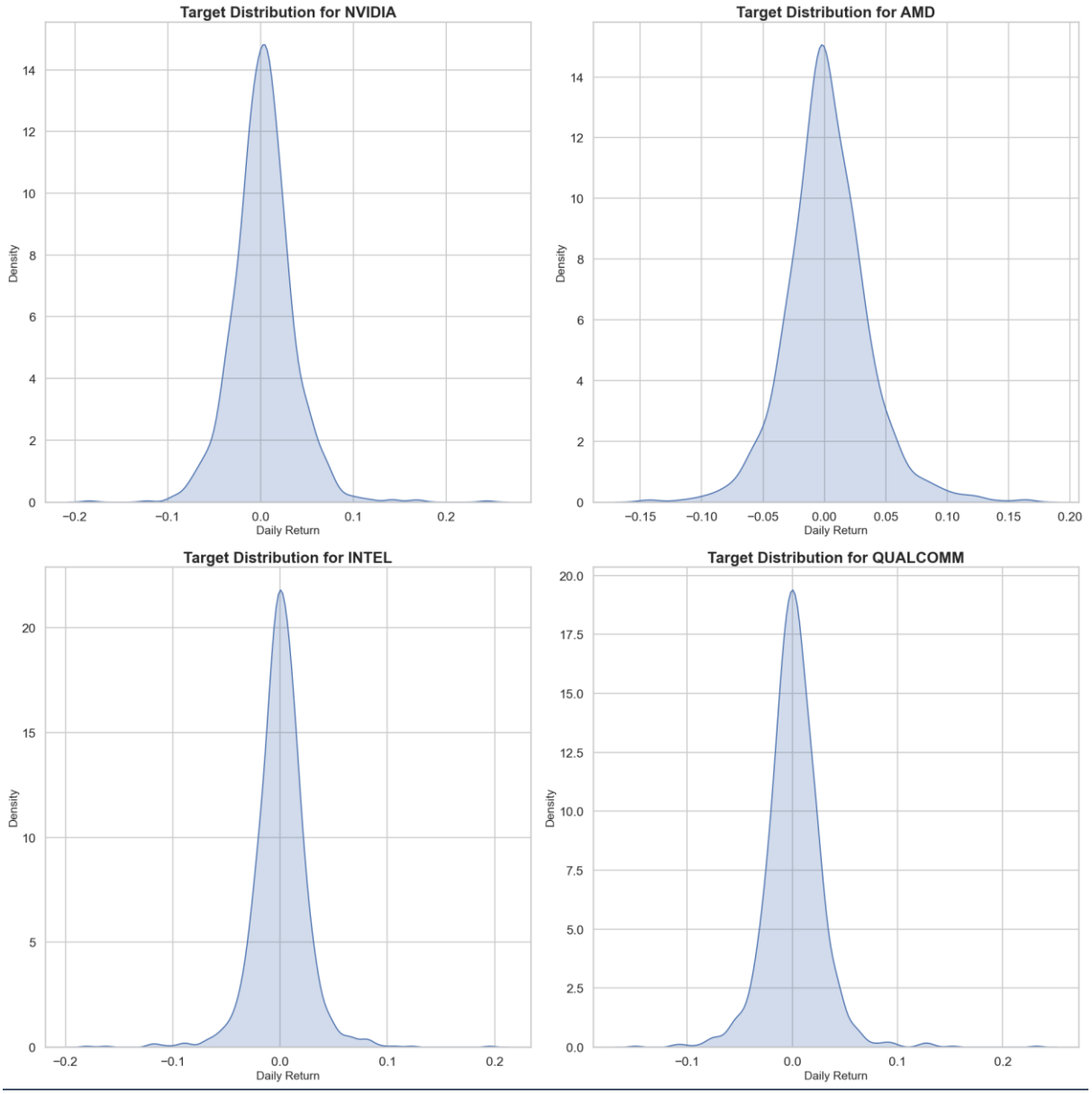


Table 2 - Stock Target Distribution Statistics

Statistic	NVIDIA	AMD	Intel	Qualcomm
Mean	0.00291	0.00211	0.00024	0.00130
Median	0.00294	0.00048	0.00042	0.00090
S.D.	0.03256	0.03325	0.02458	0.02639
Skewness	0.49750	0.33541	-0.25060	0.70234
Kurtosis	4.75544	2.46142	9.52262	8.46165

Table 3 - NVIDIA Profitability Ratios

Return on Equity (ROE)	91.46%
Return on Assets (ROA)	38.55%
Operating Margin	61.59%
Net Profit Margin	48.45%

Table 4 - NVIDIA Liquidity Ratios

Current Ratio	4.17%
Operating Cash Flow	$28.09 billion
Levered Free Cash Flow	$19.87 billion

Table 5 - Debt Ratios

Debt to Equity Ratio	25.73%

Table 6 - Market Ratios

Earnings per Share (EPS)	$11.90
Price to Book Value Ratio	45.85
Book Value per Share	$17.44
Price to Earnings Ratio (P/E)	66.07

Section 9 – References

Ratios and Shit from:

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