Investigating the Correlation Between Tesla Stock Prices and Cryptocurrency Prices Using Pearson and Spearman Correlation Analysis (2010-2024)

Muhammad Iqbal[1,*], Syahril Efendi[2]

[1]Faculty of Science and Technology, Universitas Pembangunan Panca Budi, Indonesia

[2]Department of Computer Science, Universitas Sumatera Utara, Indonesia

ABSTRACT

This study investigates the correlation between Tesla's stock prices and the prices of the two leading cryptocurrencies, Bitcoin and Ethereum, from 2010 to 2024. By employing both Pearson and Spearman correlation analyses, the research identifies strong positive correlations between these assets, with Tesla-Bitcoin showing a Pearson coefficient of 0.76 and Tesla-Ethereum at 0.82. The Spearman correlations further validate these findings, indicating that Tesla's stock prices are significantly aligned with the movements of Bitcoin and Ethereum. The results suggest that similar market forces and investor sentiments influence both Tesla and these cryptocurrencies. This strong correlation implies that investors should be cautious when seeking diversification, as these assets tend to move together, potentially amplifying portfolio risk. The study's findings underscore the importance of considering cross-market dynamics in investment strategies and highlight the interconnectedness of traditional and digital financial markets. Future research could explore the relationships between other technology stocks and digital assets, as well as the evolving correlations in response to major market events.

Keywords Tesla, Bitcoin, Ethereum, Pearson correlation, Spearman correlation

INTRODUCTION

Financial markets play a crucial role in the global economy, providing a platform for the exchange of assets and enabling capital formation. Traditionally, these markets have been dominated by stocks, bonds, and other securities. In recent years, however, the financial landscape has undergone significant transformation with the advent of digital currencies, which have introduced a new dimension to investing and trading. This shift has led to the emergence of a more complex and interconnected financial ecosystem, where traditional and digital assets coexist and interact in various ways.

Digital currencies, particularly Bitcoin and Ethereum, have risen to prominence and have become integral parts of the financial markets. Bitcoin, often referred to as digital gold, was the first cryptocurrency to gain widespread acceptance and is renowned for its decentralized nature and limited supply. Ethereum, on the other hand, introduced the concept of smart contracts, allowing for more complex financial transactions and decentralized applications. Together, these digital currencies have garnered significant attention from investors, policymakers, and researchers, leading to a burgeoning interest in understanding their behavior and impact on traditional financial markets.

The rise of digital currencies alongside traditional stocks has created a unique

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Corresponding author
Muhammad Iqbal,
muhammadiqbal@dosen.pancabudi.ac.id

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financial environment. While stocks represent ownership in a company and are influenced by corporate performance, economic conditions, and market sentiment, digital currencies are largely driven by technological developments, regulatory changes, and macroeconomic factors. This dichotomy presents an intriguing opportunity to study the interactions between these two asset classes, especially considering their growing relevance in today's financial markets.

Understanding the correlations between traditional stocks and digital currencies is essential for several reasons. Firstly, it enables investors to diversify their portfolios by identifying assets that may move independently of each other, thus reducing overall risk. Secondly, these correlations offer insights into the dynamics of market behavior, highlighting potential spillover effects between traditional financial markets and digital currencies. Lastly, they provide critical information for policymakers and regulators who are tasked with developing frameworks that ensure market stability while fostering innovation in financial technologies.

The growing interest in the relationship between traditional stocks and digital currencies, particularly cryptocurrencies like Bitcoin and Ethereum, reflects the increasing integration of these markets. Empirical studies have shown significant interconnectedness, with evidence suggesting that the volatility of cryptocurrencies is influenced by stock market dynamics [1], [2]. This connection is further underscored by findings that cryptocurrency trading often overlaps with high-risk stock trading, indicating a shared investor base or common driving factors [3]. Such findings suggest that the relationship between these markets is complex, requiring a nuanced approach to both investment strategy and risk management.

The COVID-19 pandemic highlighted the importance of understanding these correlations, as the crisis revealed significant interlinkages between cryptocurrency and stock markets. For example, during the early months of 2020, cryptocurrencies were found to contribute to the volatility in stock markets, underscoring the potential for contagion across asset classes during periods of market stress [4]. This interconnectedness emphasizes the need for policymakers to develop comprehensive risk management strategies that account for the influences of both traditional and digital assets. Additionally, research into Bitcoin’s hedging capabilities, particularly its lack of correlation with major stock indices, suggests that it could serve as an effective risk mitigation tool alongside traditional safe-haven assets like gold [5]. As digital currencies continue to evolve, their impact on traditional banking systems presents new challenges, particularly in the context of regulatory ambiguity, which must be addressed to facilitate their integration into the broader financial ecosystem [6].

Investigating the correlations between different asset classes, such as traditional stocks and digital currencies, is essential for several stakeholders in the financial markets. For investors, these correlations can inform strategies that optimize risk and return profiles. By understanding how assets move in relation to one another, investors can make informed decisions about asset allocation and hedging. For instance, if a strong negative correlation exists between stocks and digital currencies, an investor might use digital currencies as a hedge against stock market downturns.

For market analysts and researchers, studying these correlations provides a deeper understanding of market behavior and the factors driving asset prices. This knowledge can lead to the development of more sophisticated models for predicting market movements and identifying investment opportunities. Additionally, it sheds light on the interconnectedness of financial markets, which is crucial for assessing systemic risk and financial stability.

Tesla, Inc. stands as a major player in the global stock market, influenced by a variety of factors, including its technological innovations, market dynamics, and external global events. Research has explored the correlation between Tesla's stock and other technology-based companies, shedding light on how global events like the Russia-Ukraine conflict can influence Tesla's stock price fluctuations [1], [7]. Moreover, understanding how Tesla's stock responds to interest rate policies and market news can provide deeper insights into the dynamic changes in its valuation [8], [9]. Additionally, Tesla's impact on the global energy landscape and its appeal to investors can offer valuable perspectives on its position within the broader stock market [7].

Tesla's rise as a pivotal entity in the global stock market has been marked by significant influence on investor behavior and broader market trends. Founded in 2003 with a focus on electric vehicles, Tesla, under the leadership of Elon Musk, has expanded into solar energy solutions and energy storage products, positioning itself at the forefront of the clean energy revolution. The remarkable growth of Tesla's stock (TSLA) reflects its innovative products, strategic market positioning, and Musk's charismatic leadership. However, this growth has also been accompanied by substantial volatility, driven by production milestones, regulatory developments, and Musk's influential presence on social media. For investors, understanding Tesla's stock performance is crucial to capitalizing on the company's growth potential while navigating the risks associated with its market fluctuations.

Bitcoin and Ethereum have revolutionized the financial landscape by introducing decentralized digital currencies that operate on blockchain technology. Bitcoin, created in 2009 by an anonymous entity known as Satoshi Nakamoto, was the first cryptocurrency and remains the most well-known and widely adopted. Its primary appeal lies in its decentralized nature, finite supply, and the promise of a secure, peer-to-peer transaction system that operates independently of traditional financial institutions. As a digital store of value, often referred to as "digital gold," Bitcoin has attracted a diverse array of investors, ranging from retail traders to institutional funds. The cryptocurrency's introduction marked a significant shift in financial paradigms, paving the way for the emergence of a new asset class [10], [11].

Ethereum, launched in 2015 by a team led by Vitalik Buterin, expanded the possibilities of blockchain technology beyond digital currency. Unlike Bitcoin, which was designed primarily as a decentralized payment system, Ethereum introduced the concept of smart contracts (self-executing contracts with the terms directly written into code). This innovation enabled the creation of Decentralized Applications (DApps) and positioned Ethereum as the backbone of the burgeoning Decentralized Finance (DeFi) ecosystem. As a result, Ethereum's native cryptocurrency, Ether (ETH), has become a critical asset for transactions within the network and has seen substantial appreciation in value [12], [13].

The evolution of both Bitcoin and Ethereum has been marked by significant milestones that have shaped the broader blockchain ecosystem. For Bitcoin, its growth from a novel experiment to a mainstream financial asset has been driven by its unique characteristics and the evolving dynamics of the cryptocurrency market [14]. Ethereum, on the other hand, has continuously innovated with updates such as the transition to a Proof-Of-Stake (PoS) algorithm in Ethereum 2.0, which aims to enhance scalability and user-friendliness [15]. The platform's ability to support over half a million transactions daily and deploy an average of 250 new smart contracts each day underscores its profound impact on the blockchain landscape, further solidifying its role in advancing decentralized finance and secure data sharing schemes [16], [17].

Both Bitcoin and Ethereum have shown significant price volatility, influenced by a myriad of factors including technological advancements, regulatory changes, market sentiment, and macroeconomic trends. Their roles as digital assets and the growing interest from both individual and institutional investors underscore the importance of analyzing their market behavior. Investigating the correlation between these leading cryptocurrencies and traditional stocks, such as Tesla, can provide valuable insights into the interconnected dynamics of modern financial markets.

The primary objective of this study is to explore the relationship between the stock prices of Tesla, Inc. (TSLA) and the prices of two leading cryptocurrencies, Bitcoin (BTC) and Ethereum (ETH), over the period from 2010 to 2024. Understanding this relationship is crucial as it can reveal insights into how traditional stock markets and digital currencies interact and influence each other. Given Tesla's prominent position in the stock market and the rapid rise of Bitcoin and Ethereum in the digital currency space, examining their correlation can provide valuable information for investors, analysts, and policymakers.

This investigation aims to determine whether the price movements of Tesla's stock exhibit any significant correlation with the price movements of Bitcoin and Ethereum. A positive correlation could indicate that these assets move in tandem, potentially driven by similar market forces or investor sentiments. Conversely, a negative correlation might suggest that these assets move inversely, offering diversification benefits to investors. This study seeks to quantify these relationships and provide a nuanced understanding of the interplay between these distinct asset classes.

To achieve the study's objective, Pearson and Spearman correlation analyses are employed. Pearson correlation measures the linear relationship between two variables, providing a coefficient that ranges from -1 to 1. A coefficient close to 1 indicates a strong positive linear relationship, while a coefficient close to -1 signifies a strong negative linear relationship. This method is suitable for capturing linear dependencies between Tesla's stock prices and the prices of Bitcoin and Ethereum.

Spearman correlation, on the other hand, assesses the rank-order relationship between two variables. Unlike Pearson correlation, Spearman correlation does not assume a linear relationship and is more robust to non-linear associations and outliers. This makes it a valuable complement to Pearson correlation, especially in the context of financial data, which often exhibit non-linear patterns and volatility. By employing both Pearson and Spearman correlation analyses,

this study ensures a comprehensive examination of the potential relationships between Tesla's stock prices and cryptocurrency prices.

Literature Review

Historical Performance and Significance of Tesla's Stock

Tesla's stock has been marked by significant volatility and growth, reflecting its transformative impact on the Electric Vehicle (EV) market and its ability to capture investor sentiment. Since its founding in 2003, Tesla has evolved from a niche EV manufacturer into a dominant force in the automotive and clean energy sectors. This evolution is mirrored in its stock performance, which has experienced substantial increases, particularly during periods of innovation and market expansion. A notable surge occurred in 2020, driven by heightened investor enthusiasm and the company's strong performance in the EV market [18]. This growth was further supported by Tesla's continuous innovation and expansion of its product line, attracting considerable investor interest. However, this success is tempered by the volatility inherent in the tech and automotive sectors, driven by factors such as technological advancements, production milestones, and competitive pressures [19].

Tesla's stock holds significant importance due to its leadership in the EV market, positioning it as a barometer for the industry's overall health. The company's relentless innovation and expanding market share have made it a focal point for investors keen on sustainable energy opportunities [18]. Broad interest in Tesla's stock, from institutional investors to retail traders, is fueled by its reputation for innovation and its perceived potential for long-term growth [20]. Despite facing increasing competition in the EV market, Tesla's stock has shown resilience, even in the face of external factors like economic conditions and global market trends. For instance, changes in interest rates by the Federal Reserve have been shown to have minimal direct impact on Tesla's stock, highlighting its resilience amidst broader macroeconomic changes [8]. Tesla's ability to navigate these challenges and capitalize on growth opportunities will continue to play a critical role in shaping its historical and future performance.

Overview of Bitcoin and Ethereum in the Cryptocurrency Market

Bitcoin and Ethereum stand as the two leading cryptocurrencies, each playing a unique role in the digital currency ecosystem [21], [22]. Bitcoin, introduced in 2009 by the pseudonymous Satoshi Nakamoto, was the first cryptocurrency to implement a decentralized ledger system using blockchain technology. Bitcoin's fixed supply of 21 million coins and its role as a digital store of value have earned it the moniker "digital gold." Its price has experienced dramatic swings, influenced by factors such as regulatory developments, macroeconomic trends, technological upgrades, and speculative trading. Bitcoin's mainstream adoption has grown, with increasing acceptance as a payment method and a legitimate asset class for institutional investors.

Ethereum, launched in 2015 by Vitalik Buterin and his team, revolutionized the cryptocurrency space by introducing the concept of smart contracts. These programmable contracts run on the Ethereum blockchain, enabling a vast array of DApps and DeFi platforms. Ethereum's native currency, Ether (ETH), is used to facilitate transactions and computational services on the network. The flexibility and broad application of Ethereum have made it the foundation for

numerous blockchain-based innovations. Similar to Bitcoin, Ethereum's price has exhibited substantial volatility, driven by network upgrades, DeFi growth, and overall market sentiment [23], [24].

Both Bitcoin and Ethereum have established themselves as critical components of the cryptocurrency market, attracting attention from a diverse set of stakeholders, including individual investors, institutional players, and regulators. Their significant price volatility and market behavior offer valuable insights into the functioning and dynamics of digital currencies. Investigating the relationships between these cryptocurrencies and traditional stocks, such as Tesla, can provide a deeper understanding of the interconnectedness and potential correlations within modern financial markets. This research aims to bridge the knowledge gap by analyzing the interplay between these distinct yet increasingly intertwined asset classes.

Pearson Correlation Coefficient

The Pearson correlation coefficient, often denoted as (r), measures the strength and direction of the linear relationship between two continuous variables [25], [26]. It is calculated using the formula:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2]}\sqrt{[n\sum y^2 - (\sum y)^2]}} \quad (1)$$

In this formula, (n) represents the number of paired observations, (x) and (y) are the individual data points for the two variables being compared, and (\sum) denotes the summation operator. The numerator of the formula captures the covariance between the variables, while the denominator normalizes this value by the product of their standard deviations, ensuring the coefficient remains within the range of -1 to 1.

A Pearson correlation coefficient close to 1 indicates a strong positive linear relationship, meaning that as one variable increases, the other variable tends to increase as well. Conversely, a coefficient close to -1 signifies a strong negative linear relationship, where an increase in one variable corresponds to a decrease in the other. A coefficient around 0 implies no linear relationship between the variables. The Pearson correlation is widely used due to its simplicity and effectiveness in capturing linear associations, but it is sensitive to outliers and assumes a linear relationship between the variables.

Spearman Rank Correlation Coefficient

The Spearman rank correlation coefficient, denoted as (\rho) (rho), measures the strength and direction of the monotonic relationship between two ranked variables. It is given by the formula:

$$\rho = 1 - \frac{6\sum d^2}{n(n^2 - 1)} \quad (2)$$

Here, (d_i) represents the difference between the ranks of each pair of observations, and (n) is the number of observations. Unlike Pearson's correlation, Spearman's correlation does not assume that the relationship between the variables is linear or that the data are normally distributed. Instead,

it assesses how well the relationship between two variables can be described using a monotonic function.

A Spearman correlation coefficient close to 1 indicates a strong positive monotonic relationship, where an increase in one variable consistently corresponds to an increase in the other variable. A coefficient close to -1 signifies a strong negative monotonic relationship, where an increase in one variable corresponds to a decrease in the other. A coefficient around 0 suggests no monotonic relationship. Spearman's correlation is particularly useful when dealing with ordinal data or when the assumptions of Pearson's correlation are not met, such as in the presence of outliers or non-linear relationships.

Explanation of the Significance and Interpretation of These Coefficients

The significance of the Pearson and Spearman correlation coefficients lies in their ability to quantify the degree of association between two variables. These coefficients provide a single numerical value that summarizes the nature of the relationship, facilitating comparison and analysis across different datasets and contexts.

Interpreting these coefficients involves understanding both their magnitude and sign. A positive coefficient indicates that the variables tend to increase together, while a negative coefficient suggests that one variable tends to decrease as the other increases. The closer the coefficient is to either -1 or 1, the stronger the relationship. Conversely, a coefficient near 0 indicates a weak or no relationship.

In the context of this study, Pearson and Spearman correlation analyses will help determine the extent to which Tesla's stock prices move in relation to Bitcoin and Ethereum prices. A significant correlation could imply potential co-movement driven by common market factors, investor behavior, or external economic influences. Understanding these relationships can provide valuable insights for investors and analysts, helping them make more informed decisions regarding asset allocation and risk management in portfolios that include both traditional stocks and digital currencies.

Methodology

The research method for this study consists of several steps to ensure a comprehensive and accurate analysis. The flowchart in figure 1 outlines the detailed steps of the research method.

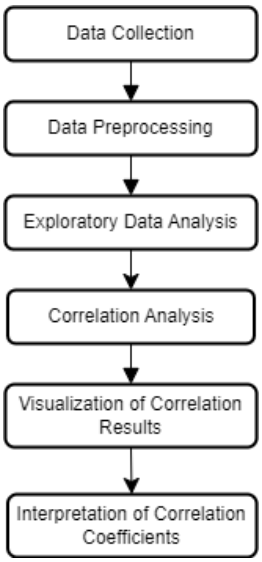

Figure 1 Research Method Flowchart

Data Collection

The Tesla stock market dataset provides a comprehensive record of Tesla, Inc.'s daily stock prices from June 29, 2010, to June 1, 2024. This dataset is sourced from Yahoo Finance, a widely recognized and reliable source of historical market data. The dataset includes key financial metrics that capture Tesla's market performance daily, making it a valuable resource for analyzing the stock's behavior over time.

The dataset comprises seven columns: Date, Open, High, Low, Close, Adj Close, and Volume. The 'Date' column, stored as an object type, records the specific trading day for each entry. The 'Open', 'High', 'Low', 'Close', and 'Adj Close' columns, all of which are in float64 format, represent the stock's opening price, the highest price during the trading session, the lowest price during the session, the closing price, and the adjusted closing price, respectively. The adjusted closing price accounts for corporate actions like stock splits and dividends, offering a more accurate reflection of the stock's value. The 'Volume' column, an int64 type, captures the total number of shares traded on the respective date. This dataset's detailed structure enables a thorough analysis of Tesla's stock trends and market dynamics over a significant period.

The BTC-ETH price dataset contains historical daily price data for two leading cryptocurrencies, BTC and ETH, spanning from January 1, 2014, to June 1, 2024, for Bitcoin, and from January 1, 2017, to June 1, 2024, for Ethereum. Like the Tesla dataset, this data is also sourced from Yahoo Finance, ensuring consistency in the data quality and integrity across the assets being analyzed.

The dataset is structured into seven key columns for each cryptocurrency: Date, Open, High, Low, Close, Adj Close, and Volume. The 'Date' column, similar to the Tesla dataset, is an object type that records the specific day for each entry. The 'Open', 'High', 'Low', 'Close', and 'Adj Close' columns are all float64 types, representing the opening price, highest price, lowest price, closing price, and adjusted closing price of Bitcoin and Ethereum on each respective day. The

'Volume' column, an int64 type, indicates the total number of units traded during that day. These columns collectively provide a detailed view of the daily price fluctuations and trading volume for Bitcoin and Ethereum, facilitating a robust comparative analysis between these cryptocurrencies and Tesla's stock prices.

Together, the Tesla stock market dataset and the BTC-ETH price dataset offer a rich foundation for exploring the correlations between traditional stock market assets and digital currencies. The consistent structure and reliable sourcing of these datasets allow for precise and meaningful statistical analysis, particularly when investigating the relationships between the market movements of Tesla, Bitcoin, and Ethereum over the specified period.

Data Preprocessing

Effective data preprocessing is essential for ensuring that the datasets are in a suitable format for analysis. The initial step involves loading the datasets for Tesla, Bitcoin, and Ethereum, followed by converting the 'Date' columns in each dataset to a standardized datetime format. This standardization allows for seamless merging of the datasets based on the 'Date' column, which is critical for aligning the data across the different asset

Given that the datasets contain key financial metrics such as opening prices, closing prices, and trading volumes, maintaining data integrity during merging is paramount. After ensuring that all datasets share the same time format, they are merged on the 'Date' column. The merged dataset includes columns specifically for Tesla’s closing prices, Bitcoin’s closing prices, and Ethereum’s closing prices, which are the primary focus of the correlation analysis.

Handling missing values is a crucial part of the data preprocessing phase to prevent inaccuracies in the subsequent analysis. An examination of the datasets revealed that there were no missing values in the Tesla, Bitcoin, or Ethereum datasets, which is beneficial as it eliminates the need for complex imputation methods. However, as a precautionary step to ensure data continuity, a forward fill method was applied. This method propagates the last valid observation forward to fill any gaps, though in this case, it was not necessary due to the absence of missing data.

After addressing potential missing values, the next step involved aligning the dates across the datasets. Aligning the dates is critical because discrepancies in the trading days between traditional stock markets and cryptocurrency markets can lead to misalignment in the data. Once the dates were aligned, the datasets were successfully merged, resulting in a comprehensive dataset with synchronized closing prices for Tesla, Bitcoin, and Ethereum. This merged dataset forms the foundation for the subsequent analysis and ensures that all relevant data points are accurately aligned over the study period.

The merged dataset preview indicates successful integration, with columns for Tesla, Bitcoin, and Ethereum closing prices, each aligned by date. The dataset provides a robust basis for exploring the correlations between Tesla’s stock prices and the prices of the two leading cryptocurrencies, facilitating a thorough and reliable analysis.

Exploratory Data Analysis (EDA)

Descriptive statistics are a fundamental step in understanding the basic

properties of the dataset. For this analysis, we calculated the mean, median, and standard deviation of the closing prices of Tesla, Bitcoin, and Ethereum. These statistical measures provide insights into the central tendency and dispersion of the data, which are essential for understanding the distribution and volatility of each asset over time.

The mean represents the average closing price for each asset during the specified period, giving a general idea of the typical value. The median, which is the middle value when the prices are ordered, offers a robust measure of central tendency that is less sensitive to outliers compared to the mean. The standard deviation quantifies the amount of variation or dispersion from the mean, indicating how spread out the prices are. A higher standard deviation suggests that the asset has experienced significant price fluctuations, which is often the case with cryptocurrencies like Bitcoin and Ethereum.

Visualization plays a crucial role in EDA, as it allows us to observe patterns, trends, and potential anomalies in the data that may not be evident from summary statistics alone. In this study, time series plots were created for the closing prices of Tesla, Bitcoin, and Ethereum to visualize their behavior over the period from 2010 to 2024. These plots in figure 2 illustrate how the prices of each asset have evolved, highlighting periods of growth, decline, and volatility.

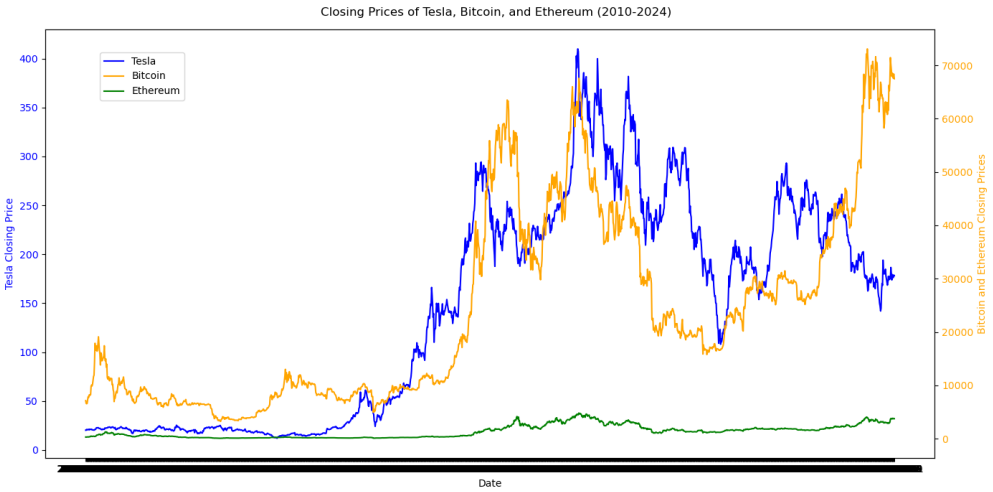

Figure 2 Closing Price of TSLA, BTC and ETH 2010-2024

To enhance the clarity of the trends, a rolling average was also computed and plotted. The rolling average smooths out short-term fluctuations and highlights longer-term trends by averaging the closing prices over a specified window, such as 30 days. This technique is particularly useful for identifying underlying patterns in the data that may not be immediately apparent in the raw time series. The rolling average plots for Tesla, Bitcoin, and Ethereum provide a clearer picture of their price movements and allow for a more nuanced comparison of their respective trends over the study period.

The visualizations, including both the time series plots and rolling average plots, reveal significant insights into the behavior of these assets. Tesla's stock prices show notable peaks and troughs, reflecting the company's growth phases and market volatility. Bitcoin and Ethereum exhibit similar characteristics, with Bitcoin showing substantial price surges and corrections, while Ethereum

demonstrates more moderate but consistent growth. These visualizations set the stage for the subsequent correlation analysis, which will quantitatively assess the relationships between these assets.

Correlation Analysis

To understand the relationships between Tesla's stock prices and the prices of Bitcoin and Ethereum, we performed correlation analysis using both Pearson and Spearman correlation coefficients. The Pearson correlation coefficient measures the linear relationship between two continuous variables, while the Spearman correlation coefficient assesses the monotonic relationship between two ranked variables. These two approaches provide complementary insights into the nature of the correlations.

For the Pearson correlation, the analysis yielded a coefficient of 0.76 between Tesla and Bitcoin prices, indicating a strong positive linear relationship. This suggests that, generally, as Bitcoin prices increase or decrease, Tesla's stock prices tend to follow in the same direction. The correlation between Tesla and Ethereum was even stronger, with a Pearson coefficient of 0.82, further emphasizing the alignment between Tesla's stock movements and the cryptocurrency market. Similarly, the Spearman correlation coefficients were 0.80 for Tesla-Bitcoin and 0.79 for Tesla-Ethereum, consistent with the Pearson results and highlighting a significant positive monotonic relationship between these assets. The p-values for both Pearson and Spearman correlations were effectively zero, indicating that these correlations are statistically significant.

To visually represent the relationships between Tesla, Bitcoin, and Ethereum prices, a correlation matrix was constructed and visualized using a heatmap. The heatmap, shown in figure 3 and figure 4, provides a clear and intuitive way to observe the strength and direction of correlations between the assets, with color intensity corresponding to the magnitude of the correlation coefficients.

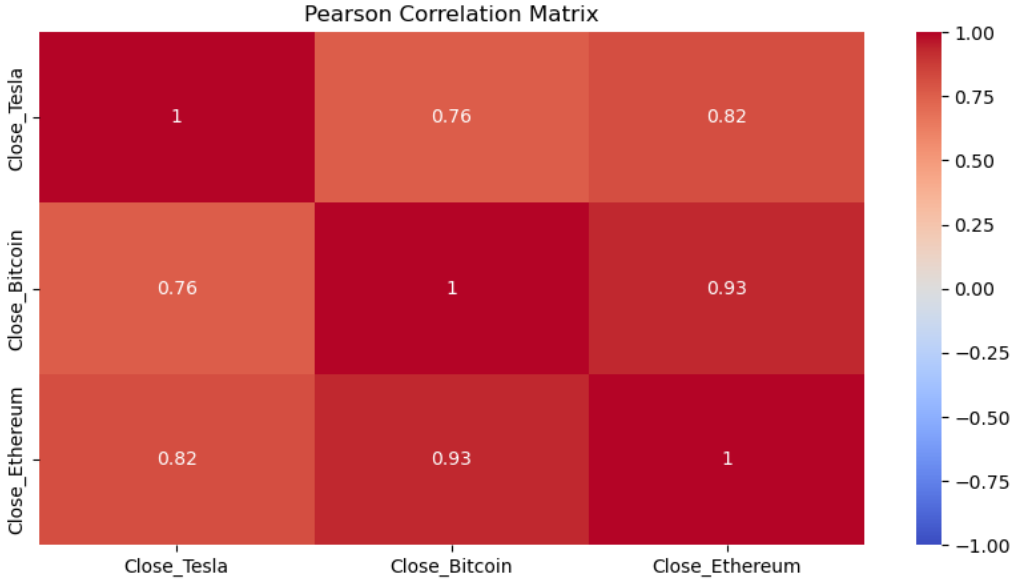

Figure 3 Pearson Correlation Heatmap

In the Pearson correlation heatmap, the relationship between Tesla and Bitcoin was indicated by a correlation coefficient of 0.76, shown by a moderately strong

color intensity. The correlation between Tesla and Ethereum was even more pronounced, with a coefficient of 0.82, indicated by a stronger color intensity. The heatmap also highlighted the very strong correlation between Bitcoin and Ethereum, with a Pearson coefficient of 0.93. This suggests that while Tesla is strongly correlated with these cryptocurrencies, Bitcoin and Ethereum are even more closely related to each other.

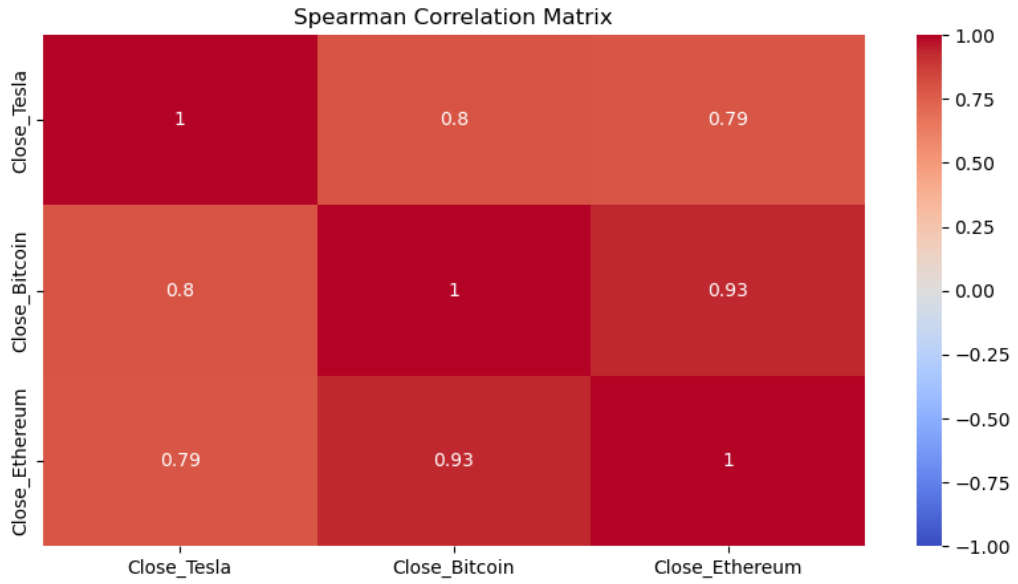

Figure 4 Spearman Correlation Heatmap

Similarly, the Spearman correlation heatmap reflected comparable relationships, with slightly different values due to the rank-based nature of Spearman's correlation. The visual representation confirms that Tesla's stock prices have a significant correlation with Bitcoin and Ethereum, reinforcing the numerical findings from the correlation coefficients. These visual tools, along with the statistical analysis, provide a comprehensive view of the interconnectedness between traditional stocks and cryptocurrencies, offering valuable insights for investors and analysts looking to understand the dynamics of these markets.

Results and Discussion

Correlation Analysis

The correlation analysis between Tesla's stock prices and the prices of Bitcoin and Ethereum yielded significant insights into the relationships between these assets over the period from 2010 to 2024. Both Pearson and Spearman correlation coefficients were calculated to capture the linear and monotonic relationships, respectively.

The Pearson correlation coefficient between Tesla and Bitcoin was found to be 0.76, indicating a strong positive linear relationship. This suggests that as Bitcoin's price increases or decreases, Tesla's stock price tends to move in the same direction, albeit not perfectly. The correlation between Tesla and Ethereum was even stronger, with a Pearson coefficient of 0.82, highlighting a very strong positive correlation. This implies that Tesla's stock price is more

closely aligned with Ethereum than with Bitcoin, though both cryptocurrencies exhibit significant correlation with Tesla. These findings are supported by p-values effectively equal to zero, indicating that the observed correlations are statistically significant and unlikely to have occurred by chance.

The Spearman correlation coefficients, which measure the strength and direction of the monotonic relationship between the ranked data, provided further validation of these relationships. The Spearman correlation between Tesla and Bitcoin was 0.80, slightly higher than the Pearson coefficient, suggesting that the overall trend in their price movements remains consistent even when considering rank-based relationships. The Spearman correlation between Tesla and Ethereum was 0.79, closely aligning with the Pearson result. These Spearman correlations reinforce the conclusion that Tesla's stock price has a significant and consistent positive relationship with both Bitcoin and Ethereum, regardless of whether the relationship is strictly linear.

The heatmap of the correlation matrix visually represents the strength and direction of the relationships between Tesla's stock prices and the prices of Bitcoin and Ethereum. In this heatmap, the color intensity corresponds to the magnitude of the Pearson correlation coefficients, ranging from -1 to 1. Strong positive correlations are indicated by deep red colors, while weaker or negative correlations would appear in lighter shades or cooler colors.

The heatmap clearly shows a strong positive correlation between all pairs of assets. Tesla's closing prices are strongly correlated with both Bitcoin (0.76) and Ethereum (0.82), as depicted by the robust color intensity. Additionally, the correlation between Bitcoin and Ethereum is even stronger, with a coefficient of 0.93, underscoring the close relationship between the two leading cryptocurrencies. This visual representation confirms the numerical findings and provides an intuitive understanding of the relationships among these assets.

This table 1 presents the Pearson and Spearman correlation coefficients for the relationships between Tesla, Bitcoin, and Ethereum, along with their corresponding p-values. The high correlation coefficients between Tesla and the two cryptocurrencies indicate strong relationships, with Pearson and Spearman values both supporting the conclusion of significant positive correlations. The p-values are effectively zero across all pairs, reinforcing the statistical significance of the observed correlations. This table succinctly summarizes the key findings from the correlation analysis, providing a clear and accessible overview of the relationships between these assets.

Table 1 Tesla, Bitcoin and Ethereum Correlation Coefficient

Pair of Assets	Pearson Correlation	Spearman Correlation	p-value (Pearson)	p-value (Spearman)
Tesla - Bitcoin	0.76	0.80	6.64e-317	0.0
Tesla - Ethereum	0.82	0.79	0.0	0.0
Bitcoin - Ethereum	0.93	0.93	0.0	0.0

These visualizations and tables collectively offer a comprehensive view of the relationships between Tesla, Bitcoin, and Ethereum, combining statistical rigor

with intuitive visual representations. Together, they underscore the strong correlations among these assets, providing valuable insights for investors, analysts, and researchers interested in the interplay between traditional stocks and cryptocurrencies.

Discussion

The correlation coefficients calculated in this study provide significant insights into the relationships between Tesla's stock prices and the prices of Bitcoin and Ethereum over the period from 2010 to 2024. The Pearson correlation coefficients reveal strong positive linear relationships, with Tesla's stock price showing a correlation of 0.76 with Bitcoin and 0.82 with Ethereum. These values suggest that movements in the prices of Bitcoin and Ethereum are closely mirrored by movements in Tesla's stock price. The slightly higher correlation with Ethereum may indicate a stronger alignment between Tesla's market behavior and Ethereum's, perhaps due to shared investor demographics or similar underlying economic factors.

The Spearman correlation coefficients, which capture the rank-order relationships, further validate these findings, with coefficients of 0.80 between Tesla and Bitcoin, and 0.79 between Tesla and Ethereum. These high Spearman coefficients suggest that the overall trends in the relative ranking of Tesla's stock prices and the cryptocurrency prices are consistent, even if the exact price movements are not perfectly linear. The close alignment between the Pearson and Spearman coefficients indicates that the relationships are robust across different measures of association, reinforcing the conclusion that Tesla's stock is significantly correlated with these leading cryptocurrencies.

The strong correlations observed in this study align with notable trends and patterns in the financial markets during the period analyzed. Tesla's stock price experienced substantial growth and volatility, particularly during periods of heightened interest in renewable energy and electric vehicles. Similarly, Bitcoin and Ethereum have seen dramatic price fluctuations, driven by factors such as regulatory developments, technological advancements, and shifts in investor sentiment. The observed correlations suggest that Tesla's stock may have been influenced by similar macroeconomic factors affecting the cryptocurrency markets, such as global economic conditions, investor risk appetite, and technological innovations.

Moreover, the slightly stronger correlation with Ethereum could be attributed to the increasing relevance of blockchain technology in industries beyond finance, including energy, where Tesla is a key player. Ethereum's focus on smart contracts and decentralized applications may resonate with Tesla's innovative business model, which emphasizes technological disruption and future-oriented investments. This alignment could explain why Tesla's stock price appears more closely tied to Ethereum than to Bitcoin, despite Bitcoin's dominance in the cryptocurrency market.

The findings of this study contribute to the growing body of literature examining the relationships between traditional financial assets and digital currencies. Previous research has often focused on the correlations between various cryptocurrencies or between cryptocurrencies and broader stock indices. The strong positive correlations observed in this study are consistent with previous findings that suggest increasing interconnectedness between traditional and

digital financial markets. However, this study's focus on Tesla—a single, highly innovative company—provides a more nuanced perspective, highlighting how specific firms with strong technological and future-oriented profiles might exhibit stronger correlations with cryptocurrencies compared to broader market indices.

This study's results are also in line with the literature that emphasizes the role of investor sentiment and speculation in driving both cryptocurrency and stock prices. The strong correlations suggest that Tesla's stock, much like Bitcoin and Ethereum, may be subject to speculative trading and investor behaviors that transcend traditional market fundamentals. This aligns with studies that have identified sentiment-driven trading as a significant factor in both markets, particularly during periods of rapid price growth or decline.

The significant correlations between Tesla's stock prices and cryptocurrency prices have important implications for investors and market analysts. For investors, understanding these relationships can inform portfolio diversification strategies. The strong positive correlations suggest that holding both Tesla stock and cryptocurrencies like Bitcoin and Ethereum in the same portfolio may not provide the diversification benefits typically sought by investors. Instead, these assets appear to move in tandem, potentially amplifying both gains and losses depending on market conditions.

For market analysts, these findings underscore the importance of considering cross-market influences when evaluating asset prices. The alignment between Tesla and cryptocurrencies like Ethereum suggests that factors driving the cryptocurrency market could also impact specific technology stocks, particularly those involved in innovative or disruptive industries. Analysts might, therefore, need to account for developments in the cryptocurrency market when forecasting the performance of companies like Tesla, as well as the broader tech sector.

Conclusion

This study investigated the correlation between Tesla's stock prices and the prices of the two leading cryptocurrencies, Bitcoin and Ethereum, over the period from 2010 to 2024. The analysis revealed strong positive correlations between these assets, with Pearson correlation coefficients of 0.76 for Tesla-Bitcoin and 0.82 for Tesla-Ethereum. The Spearman correlation coefficients were similarly high, confirming the robustness of these relationships across different measures of association. These findings indicate that Tesla's stock price movements are closely aligned with those of Bitcoin and Ethereum, suggesting a significant interplay between traditional stock markets and cryptocurrency markets. The significance of these correlations cannot be overstated. The statistical analysis demonstrated that these correlations are highly significant, with p-values effectively equal to zero, ruling out the possibility that these relationships are due to random chance. The results suggest that Tesla's stock price behavior is influenced by similar market forces as those driving Bitcoin and Ethereum prices, reflecting broader trends in investor sentiment, market speculation, and macroeconomic conditions that affect both traditional and digital assets. The findings of this study have important implications for investment strategies and market analysis. For investors, the strong correlations between Tesla's stock prices and cryptocurrency prices

highlight the need for caution when seeking to diversify portfolios with these assets. Since these assets tend to move together, holding them in the same portfolio may not provide the diversification benefits traditionally expected from combining different asset classes. Instead, these correlations suggest that investors may experience amplified gains or losses, depending on the direction of the market. For market analysts, these findings underscore the importance of considering cross-market dynamics when evaluating the performance of specific stocks or cryptocurrencies. The strong alignment between Tesla's stock and cryptocurrencies like Ethereum suggests that factors driving the cryptocurrency market (such as technological innovation, regulatory changes, and shifts in investor sentiment) could have a direct impact on the stock prices of innovative companies like Tesla. Analysts must therefore integrate cryptocurrency market analysis into their broader financial models to provide more accurate forecasts and investment recommendations. While this study provides valuable insights into the correlation between Tesla's stock prices and cryptocurrency prices, it also opens up avenues for further research. Future studies could expand on these findings by exploring the relationships between other technology stocks and cryptocurrencies, or by examining the role of other macroeconomic variables in shaping these correlations. Additionally, research could investigate how the correlations between traditional stocks and digital currencies evolve over time, particularly in response to major market events or technological advancements. Another promising area for future research is the exploration of the correlations between different types of digital assets, such as stablecoins or emerging cryptocurrencies, and traditional financial assets. As the cryptocurrency market continues to diversify and mature, understanding how different types of digital assets interact with traditional markets will be crucial for developing more sophisticated investment strategies and risk management approaches. Ultimately, this research contributes to the broader understanding of the increasingly interconnected nature of global financial markets, where the boundaries between traditional and digital assets are becoming ever more fluid.

Declarations

Author Contributions

Conceptualization: M.I., S.E.; Methodology: M.I., S.E.; Software: M.I.; Validation: S.E.; Formal Analysis: M.I.; Investigation: M.I.; Resources: S.E.; Data Curation: M.I.; Writing – Original Draft Preparation: M.I.; Writing – Review and Editing: M.I., S.E.; Visualization: M.I.; All authors have read and agreed to the published version of the manuscript.

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The data presented in this study are available on request from the corresponding author.

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