“Re-pricing risk in the digital economy: A multi-wave analysis of technology-sector volatility during COVID-19”

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RE-PRICING RISK IN THE DIGITAL ECONOMY: A MULTI-WAVE ANALYSIS OF TECHNOLOGY-SECTOR VOLATILITY DURING COVID-19

Abstract

The COVID-19 pandemic profoundly reshaped global financial markets, amplifying volatility and redefining risk perception across innovation-driven sectors. This study assesses how the COVID-19 pandemic altered volatility dynamics in the technology sector by quantifying wave-by-wave risk-return behavior using descriptive statistics, including standard deviation, coefficient of variation, and kurtosis. The analysis is based on daily stock prices and returns for the technology sector from March 8, 2019, to December 12, 2022, covering the pre-pandemic period, five pandemic waves, and a post-pandemic stabilization phase. The results reveal that market volatility surged during the first pandemic wave as digital adoption accelerated and investors sought technological assets as temporary safe havens. Subsequent waves showed alternating phases of speculative trading and market corrections, reflecting evolving investor sentiment and macroeconomic uncertainty. The coefficient of variation increased sharply during the height of the crisis, demonstrating that risk consistently exceeded returns, while kurtosis analysis indicated a higher frequency of extreme price movements compared with pre-pandemic conditions. Although volatility gradually declined during the post-pandemic period, it remained notably above pre-2020 levels, signaling a persistent re-pricing of sectoral risk. These findings confirm that the technology sector, while resilient, experienced structural changes in its volatility regime and investor behavior, with lasting implications for market stability and portfolio management in the digital economy.

Keywords technology sector, investor sentiment, volatility, COVID-19

JEL Classification G01, G10, G12

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INTRODUCTION

The COVID-19 pandemic constituted an unprecedented systemic shock to global financial markets, combining a public health crisis with abrupt economic shutdowns, large-scale policy interventions, and rapid shifts in investor expectations (Mohsin et al., 2021; Adekoya et al., 2021; Liu et al., 2023). Unlike crises driven by endogenous financial imbalances, the pandemic originated outside the economic system and propagated simultaneously through supply chains, labor markets, and financial networks, generating extreme uncertainty and elevated volatility across asset classes. In this environment, market volatility reflected not only short-term reactions to adverse information but also deeper disruptions in information processing and risk perception (Zhang et al., 2020; Cheng et al., 2024).

This study addresses that gap by focusing specifically on the technology sector's volatility behavior during the COVID-19 crisis, analyzed across eleven distinct pandemic and post-pandemic phases. By exam-

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ining the daily return behavior of leading technology firms, commonly referred to as the "Magnificent Seven", the study provides a detailed empirical assessment using descriptive statistical measures such as mean returns, coefficient of variation, and kurtosis. Unlike prior work that emphasizes predictive modeling or aggregate-level trends, this paper offers a granular, phase-by-phase view of how volatility and investor sentiment evolved in a key economic sector (Liu et al., 2021). Framing volatility dynamics in this manner allows the pandemic to be understood as a sequence of evolving market conditions rather than a single uniform shock. Such an approach contributes to a clearer formulation of how sector-specific risk is repriced under prolonged systemic uncertainty, particularly in industries that play a central role in global market capitalization and financial stability (Mazur et al., 2021).

1. LITERATURE REVIEW

The COVID-19 pandemic triggered a profound global economic shock, disrupting financial markets, supply chains, and investor sentiment (Ashraf, 2020). In response, governments implemented lockdowns and unprecedented stimulus measures, which produced uneven effects across sectors and asset classes (Chebbi et al., 2021; Liang et al., 2021). Major indices such as the S&P 500 and Nasdaq-100 experienced sharp declines, liquidity constraints, and high volatility, while emerging markets were hit by capital outflows and deeper contractions (Goodell & Huynh, 2020; Topcu & Gulal, 2020; Mzoughi et al., 2022).

Existing literature has explored the overall market turbulence caused by COVID-19 and the role of government interventions, drawing comparisons to prior health crises such as the Spanish Flu, SARS, and MERS (Jones et al., 2008; del Cerro Santamaria, 2019; Liang et al., 2021). Some studies have highlighted the relative outperformance of technology and healthcare sectors due to increased demand for digital solutions and remote

Table 1. Summary of previous research on COVID-19 market volatility

Authors	Sample	Methodology	Main Findings
Ashraf (2020)	Global stock markets, 2020	Event study approach	Government interventions influenced stock market stability; mixed responses observed.
Lahmiri & Bekiros (2020)	Financial markets, 2015–2020	Entropy-based forecasting	Entropy-based models improved volatility forecasting; traditional models underestimated risk.
Chang et al. (2020)	Technology sector, 2000–2020	Herding behavior analysis	Technology stocks showed speculative tendencies and herd behavior during COVID-19.
Demirgüç-Kunt et al. (2021)	Banking sector stocks, 2020	Banking performance evaluation	Banking stocks exhibited mixed performance based on regulatory changes and stimulus measures.
Farid et al. (2021)	Precious metals, energy, stocks, 2010–2021	Intraday volatility analysis	Intraday price movements showed interconnectedness between commodities and stock markets.
Chebbi et al. (2021)	S&P 500 firms, 2019–2021	Liquidity analysis and GARCH models	Liquidity crises increased volatility; risk perception varied across firms.
Li et al. (2021)	G20 stock markets, 2020–2021	Volatility spillover analysis	Stock market linkages intensified; developed markets acted as shock transmitters.
Padhan & Prabheesh (2021)	Multi-sector analysis, 2020	Macroeconomic policy impact evaluation	Policy effectiveness varied; monetary easing stabilized markets, fiscal policies had mixed effects.
Uddin et al. (2021)	Global markets, 1996–2020	ARMA-GJR-GARCH and Copula models	Gold, silver, and platinum were key hedging assets; volatility surged during crisis periods.
Yarovaya et al. (2021)	Cryptocurrency markets, 2020	Herding behavior in digital assets	Cryptocurrencies did not serve as safe havens; herding behavior was absent.
Caporale et al. (2022)	Stock market sector analysis, 2020	Sectoral volatility decomposition	Sectoral volatility varied significantly; technology outperformed other sectors.
Aljohani et al. (2024)	Property markets, 2008–2020	DCC-GARCH for volatility transmission	Real estate markets were significantly impacted by both the GFC and the COVID-19 crisis.
Harb & Umutlu (2024)	Cross-country industry contagion, 2020	Contagion modeling across industries	Cross-industry contagion was high; financial and industrial sectors transmitted most shocks.
Kayani et al. (2024)	Developed market equities, 2020–2021	Stock market risk-return assessment	Developed markets experienced higher risk clustering; speculative trading increased volatility.

services (Krammer, 2020; Chang et al., 2020; Sharif et al., 2020). Others have examined investor behavior, noting herding effects, speculative trading, and changes in risk perception (Farid et al., 2021; Yarovaya, Matkovskyy, & Jalan, 2021). However, much of this research remains general in scope or concentrated on broader indices, often lacking segmented, time-sensitive analyses of sector-specific volatility dynamics (see Table 1).

The COVID-19 pandemic profoundly reshaped the global financial system, exposing the fragility of interconnected markets while accelerating technological adoption. Initial studies highlighted how the outbreak generated unprecedented uncertainty, causing synchronized collapses across asset classes (Adhikari et al., 2020; Kalamen et al., 2023). Despite widespread economic contraction, technology firms demonstrated remarkable resilience due to the acceleration of digital transformation, remote work, and e-commerce expansion (Ashraf, 2020; Chang et al., 2020). Stock indices dominated by technology companies, such as the Nasdaq-100 and FAANG group, experienced faster recoveries than traditional sectors, reflecting investor optimism about digitalization's structural permanence (Chebbi et al., 2021; Mzoughi et al., 2022).

1.1. Macroeconomic volatility and policy interventions

Global stock markets reacted violently to the onset of the pandemic, with the VIX surpassing Global Financial Crisis levels (Liang et al., 2021; Kayani et al., 2024). Empirical research confirms that policy measures like fiscal stimulus, quantitative easing, and emergency liquidity injections helped restore investor confidence (Ashraf, 2020; Chang et al., 2020; Demirgüç-Kunt et al., 2021). However, the magnitude of policy responses also introduced long-term inflationary pressures, raising new volatility risks (Huynh et al., 2021). Emerging evidence suggests that markets with higher ESG integration exhibited smaller drawdowns and faster post-crash recoveries, implying that sustainability factors act as buffers during systemic shocks (Albuquerque et al., 2020; Broadstock et al., 2021; Engelhardt et al., 2021). Macroeconomic contagion extended well beyond equities. Studies on cross-asset transmission identify significant spillovers between equity, energy, and cryptocurrency markets during COVID-19 (Conlon & McGee, 2020; Akhtaruzzaman et al., 2021; Abakah et al., 2022).

The correlation between gold, oil, and stock indices fluctuated sharply, undermining traditional safe-haven assumptions (Corbet et al., 2020; Kumar et al., 2023). At the same time, national housing markets exhibited pandemic-specific distortions, as historically observed during previous health crises (Zhang et al., 2020; Francke & Korevaar, 2021). These findings confirm that pandemic-era volatility was systemic and multifactorial, driven by overlapping health, energy, and policy shocks (Al-Awadhi et al., 2020; Jan et al., 2022; Harb & Umutlu, 2024).

1.2. Sectoral dynamics, corporate resilience, and ESG

Orientation Technology companies emerged as pivotal drivers of financial stabilization but also as key transmitters of speculative behavior. Research on market persistence across Europe indicates that pandemic-induced uncertainty altered the long-memory structure of returns (Caporale, Gil-Alana, & Arrese Lasaosa, 2022). Firm-level evidence shows that diversified corporations sustained or even increased R&D investment during the crisis, consistent with the resource-based view of internal capital reallocation (Nguyen & Nguyen, 2024). Similarly, companies with stronger ESG ratings or environmental stewardship outperformed peers during crisis periods, highlighting the "green resilience" effect (Ding et al., 2021; Garel & Petit-Romec, 2021). Studies of vaccine announcements revealed short-term valuation boosts in health-care and pharmaceutical equities, confirming the real-time sensitivity of pandemic sectors to policy news (McKibbin & Vines, 2020; Faidah et al., 2022). Conversely, firms in traditional industries faced liquidity shocks and increased credit risk, amplifying the need for policy coordination (Huynh et al., 2021; Kalamen et al., 2023). Bibliometric analyses of sustainable and green finance indicate a rapid proliferation of research connecting ESG, resilience, and circular economy frameworks, reflecting a broader academic and institutional shift toward sustainability-linked finance (Cisma et al., 2024; Judijanto et al., 2024).

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1.3. Behavioral finance and investor sentiment

Behavioral responses played a critical role in shaping volatility trajectories. The extreme uncertainty of early 2020 led investors to display risk-averse herding, followed by speculative inflows into high-growth sectors (Diebold & Yilmaz, 2014; Yarovaya, Matkovskyy & Jalan, 2021). Sentiment-driven overreactions were magnified by social media, producing rapid cycles of fear and optimism. Empirical analyses of online forums and financial platforms confirm strong correlations between textual sentiment indicators and price dynamics (Cevik et al., 2022; Zhao et al., 2025). Evidence from China's CSI 300 Index further demonstrates that emotional sentiment precedes short-term market movements with measurable lags (Zhao et al., 2025). Investor sentiment has thus evolved from a qualitative behavioral notion to a quantifiable volatility determinant. Bibliometric mapping of sentiment research highlights an exponential rise in studies applying machine learning, neural networks, and natural-language processing to sentiment extraction (Huynh et al., 2025). These techniques enable predictive modeling of market corrections and contagion channels across sectors (Campisi et al., 2024). The resulting fusion of behavioral data and econometrics has transformed risk forecasting into a hybrid domain combining quantitative and psychological dimensions (Arouxet et al., 2024; Harb & Umutlu, 2024).

1.4. Financial contagion and cross-market interdependence

The pandemic reinforced the global nature of financial contagion. Fractional integration models reveal long-term persistence between cryptocurrencies and technology stocks, exacerbated by U.S. policy responses (Abakah et al., 2022). Cross-country analyses confirm that COVID-19 shocks are rapidly transmitted through trade, exchange rate, and investor channels (Akhtaruzzaman et al., 2021; Huynh et al., 2021). Evidence from behavioral finance literature indicates that social networks and online communities intensified contagion via synchronized sentiment shifts (Cevik et al., 2022; Zhao et al., 2025). Wavelet and spillover analyses also show that macroeconomic uncertainty propagated simultaneously across commodities and equities, reducing portfolio diversification benefits (Caporale et al., 2022; Arouxet et al., 2024). Moreover, ESG-oriented firms displayed reduced volatility spillovers relative to conventional portfolios, strengthening the argument for sustainability integration in asset management (Broadstock et al., 2021; Leung et al., 2025). Collectively, these studies establish that financial markets have entered an era of systemic coupling, where technology, policy, and sentiment channels intertwine to amplify risk transmission.

1.5. Systemic risk, sustainability, and policy implications

Beyond immediate financial volatility, the pandemic generated structural challenges related to sustainability and inequality. Global panel data show that economic crises systematically erode national ESG performance, particularly in developing economies with limited fiscal buffers (Leung et al., 2025). This "sustainability erosion" is aggravated by sovereign debt and currency crises, which constrain green investments (Canelli et al., 2024). Simultaneously, bibliometric evidence demonstrates that green finance research has evolved toward multidimensional approaches that combine financial stability, innovation, and social inclusion (Barros et al., 2023; Judijanto et al., 2024). Sustainability considerations also extend to corporate behavior. Empirical findings reveal that firms with strong ESG credentials enjoyed positive abnormal returns during the COVID-19 crisis, suggesting that environmental and social commitments enhance investor trust in turbulent times (Albuquerque et al., 2020; Garel & Petit-Romec, 2021). Conversely, weakly rated firms experienced higher drawdowns, underlining the market's preference for long-term responsibility (Engelhardt et al., 2021). As ESG disclosure becomes mainstream, it increasingly interacts with macroeconomic policy, shaping the future of responsible capital allocation (Judijanto et al., 2024; Leung et al., 2025).

Across these studies, three dominant insights emerge. First, financial crises, whether epidemiological, monetary, or ecological, generate nonlinear contagion that blurs boundaries between asset classes. Second, technology and ESG-oriented firms exhibit asymmetric resilience. They can both stabilize and amplify volatility depending on

investor sentiment and policy context. Third, behavioral dynamics and digital information flows have become central to explaining and forecasting market reactions. Despite extensive progress, the literature still lacks a systematic understanding of how sector-specific volatility synchronizes with benchmark indices during distinct crisis waves. Few studies have explicitly compared lead-lag relationships between technological and traditional sectors across different phases of the pandemic. Addressing this gap is vital to understanding the evolution of investor behavior, market interdependence, and structural risk transmission. Grounded in this literature, the present study investigates the temporal synchronization between benchmark indices and sectoral portfolios during the COVID-19 crisis. It aims to identify lead-lag dynamics, volatility asymmetries, and behavioral correlations that define investor responses under systemic uncertainty.

2. METHODOLOGY

The primary objective of this study is to analyze the impact of the COVID-19 pandemic on stock market volatility in the technology sector, focusing on the underlying drivers of price fluctuations, investor sentiment, and risk-return tradeoffs. By examining daily closing prices, daily returns, the coefficient of variation, and kurtosis, the research aims to identify patterns of market instability, assess the role of macroeconomic interventions, and provide insights into the long-term structural shifts in financial market behavior. The primary objective of the research leads to research questions:

1. How did the volatility of the technology sector evolve across different waves of the COVID-19 pandemic?

2. What were the key factors influencing stock market fluctuations in the technology sector during the pandemic?

3. How did investor behavior and market sentiment shift in response to different phases of the COVID-19 crisis?

In terms of structure, this paper follows a traditional framework. The first section provides an overview of the initial context by reviewing the current state of knowledge on stock market volatility and the economic impact of COVID-19. The second section presents the research methodology, detailing the data sources and analytical tools used in the study. The third and fourth sections present the empirical results, analyzing the patterns of volatility in technology stocks. Finally, the conclusion summarizes the main findings and discusses the potential usefulness of this research for both theoretical and practical applications in financial markets.

This study examines the impact of the COVID-19 pandemic on stock market volatility within the technology sector, focusing on the period from March 8, 2019, to December 12, 2022. The analysis centers on daily return behavior as a key indicator of short-term market reactions and investor sentiment. Data were obtained from Yahoo Finance and cross-validated with Nasdaq-100 listings to ensure consistency and reliability. The dataset includes daily closing prices for seven major technology firms (Apple, Amazon, Alphabet, Meta, Microsoft, Nvidia, and Tesla) selected due to their significant market capitalization and influence during the pandemic. These companies, often referred to as the "Magnificent Seven," serve as a representative proxy for the broader technology sector. The final dataset (Kalamen, 2025), is also available at https://doi.org/10.5281/zenodo.17560524.

While many studies use inferential models such as GARCH, EGARCH, or even machine learning approaches for volatility forecasting, this research deliberately applies descriptive statistical analysis. The rationale for this choice lies in the study's focus on observed volatility behavior across distinct pandemic phases, rather than on predictive accuracy or hypothesis testing. Descriptive statistics offer a transparent and assumption-free framework suitable for analyzing market instability during periods of extreme uncertainty. Given the highly turbulent and non-stationary nature of financial data during global crises, a model-free approach avoids potential biases introduced by incorrectly specified inferential models. This strategy aligns with similar studies that prioritized interpretability and transparency in the context of COVID-19 (e.g., Sharif et al., 2020; Liu et al., 2021; Piñeiro-Chousa et al., 2022).

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To accurately assess financial market reactions, the study segments the analysis into key pandemic phases (World Health Organization, 2025):

1. Pre-COVID (2019–early 2020): A stable period with predictable market behavior.
2. First Wave (March–May 2020): Initial panic, followed by rapid recovery.
3. Post-First Wave (June–August 2020): Stabilization as markets adapted to new economic realities.
4. Second Wave (September–December 2020): Speculative trading driven by vaccine optimism.
5. Post-Second Wave (January–March 2021): Market corrections as investors reassessed pandemic risks.
6. Third Wave (April–June 2021): Increased volatility due to supply chain disruptions and policy uncertainties.
7. Post-Third Wave (July–September 2021): Continued market adjustments in response to macroeconomic conditions.
8. Fourth Wave (October–December 2021): Peak valuations, followed by early signs of correction.
9. Post-Fourth Wave (January–March 2022): Rising inflation fears and monetary tightening concerns.
10. Fifth Wave (April–June 2022): Market contraction as stimulus effects faded.
11. Post-Fifth Wave (July–December 2022): A new equilibrium, with persistent but lower volatility.

This study employs descriptive statistical analysis to assess the impact of the COVID-19 pandemic on volatility in the technology sector. Volatility was chosen as a primary metric in this analysis because it provides a direct and quantifiable measure of market uncertainty and investor sentiment, particularly in times of crisis such as the COVID-19 pandemic. It captures the level of price fluctuations and risk, making it an essential tool for understanding the pandemic's impact on the technology sector. A similar approach was used in the research from Sharif et al. (2020), Liu et al. (2021), and Piñeiro-Chousa et al. (2022). To ensure a comprehensive evaluation of volatility patterns, the descriptive analysis relies on the following statistical indicators:

Mean of Daily Returns and Closing Prices. The mean represents the average market performance of the technology sector across different pandemic waves. This measure helps identify whether the sector experienced net positive or negative returns during different phases of the crisis.

$$\overline{x} = \frac{\Sigma x_i}{N}, \tag{1}$$

where x_i – daily closing price, N – total unit, $\overline{x}$ – average.

Coefficient of Variation (*CV*). Since absolute return values do not fully capture risk exposure, *CV* standardizes volatility relative to returns.

$$CV = \frac{\sigma}{\overline{x}} \cdot 100, \tag{2}$$

where *CV* – Coefficient of variation, σ – standard deviation, $\overline{x}$ – average.

Kurtosis. Evaluates the frequency of extreme price movements within each wave, identifying periods where price swings were significantly larger than expected.

$$K = \frac{\Sigma\left(x_i - \overline{x}\right)^4}{\sigma^4} \cdot \left(N \cdot \sigma^4\right), \tag{3}$$

where K – kurtosis, x_i – daily closing price, N – total units, $\overline{x}$ – average, σ – standard deviation.

Additionally, box plots are utilized to visually represent return distributions across different pandemic phases. This multi-layered statistical approach ensures that volatility is analyzed in detail, capturing both general trends and short-term disruptions caused by economic shocks.

By integrating descriptive statistics, box plot visualizations, and time-series analysis, this methodology provides a comprehensive framework for assessing volatility trends and investor behavior in the technology sector during the COVID-19 crisis. Python, through its Matplotlib libraries, is used for statistical calculations and data visualization, while Microsoft Excel aids in data structuring and preliminary trend analysis. To ensure transparency and reproducibility, this study relies exclusively on quantitative data, specifically the daily closing prices of each stock for every trading day between March 8, 2019 and December 12, 2022. From these prices, daily returns were computed as percentage changes, ensuring comparability across companies with differing absolute price levels and market capitalizations. However, a key limitation of this approach is the restricted sample of large-cap firms. While the "Magnificent Seven" offer a highly visible and influential representation of the upper tier of the technology sector, this study does not include small- and medium-sized technology companies, which may have exhibited different risk dynamics, volatility responses, or resilience patterns during the pandemic. As such, the findings primarily reflect the behavior of dominant tech companies and may not capture the full heterogeneity of the sector.

3. EMPIRICAL RESULTS

Stock prices, particularly in sensitive sectors such as technology and pharmaceuticals, fluctuated significantly as investors reacted to news, policy changes, and market uncertainty. Understanding the behavior of stock prices during this crisis period is crucial for measuring volatility, which reflects the level of market uncertainty and risk. We analyze the impact of the COVID-19 pandemic on financial markets, focusing on stock price volatility in the key technology sector. The pandemic has been a defining global event that significantly affected financial markets across the world, creating unprecedented volatility and shifts in investor sentiment. To understand the market's reaction to the crisis and measure the fluctuations in stock prices, we use daily closing prices and daily returns (revenues) of stocks from both sectors. Later, we focus on the coefficient of variation and kurtosis.

The evolution of the technology sector's stock performance throughout the COVID-19 pandemic reveals a distinct pattern of growth and volatility. As the pandemic unfolded, the sector initially experienced a surge in stock prices, reflecting strong investor confidence in digital transformation trends. The first wave (March–May 2020) marked a turning point where technology stocks became perceived as safe-haven assets, driven by increased demand for remote work solutions, cloud computing, and e-commerce. This period saw an acceleration in valuation growth, as companies like Amazon, Microsoft, and Alphabet capitalized on the global shift to digital infrastructure. For example, Amazon's daily returns averaged over 1.5% during the first wave, while Microsoft posted gains exceeding 20% over a 60-day period. However,

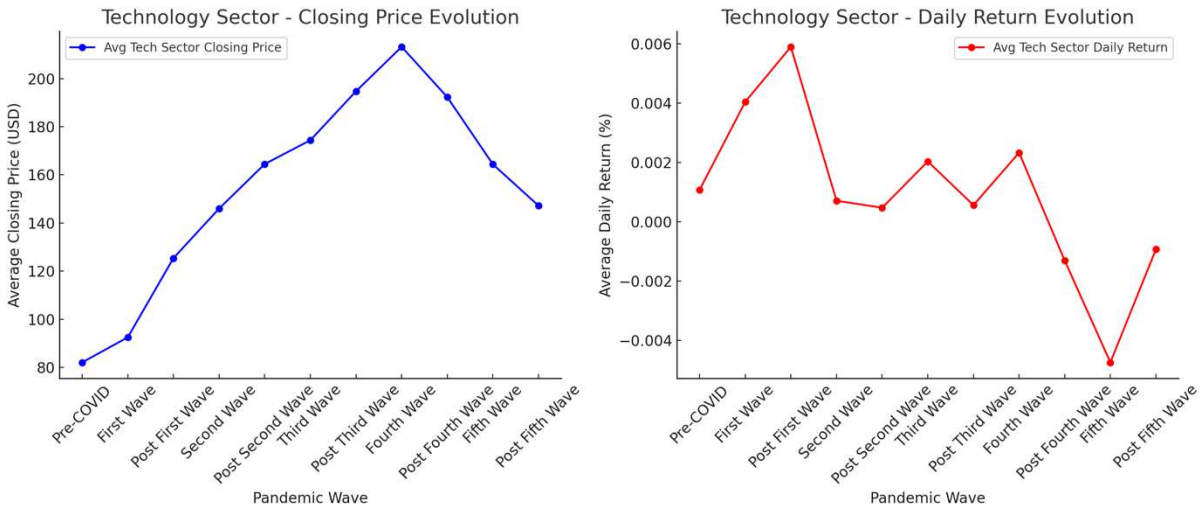

Figure 1. Evolution of the stock closing prices and daily returns in the technology sector

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this rapid growth was accompanied by heightened daily return volatility, as speculation and uncertainty regarding long-term market sustainability caused frequent price corrections. As the pandemic progressed through the second and third waves (September 2020–June 2021), stock prices continued their upward trajectory, albeit with intermittent pullbacks due to macroeconomic concerns, such as rising inflation and regulatory scrutiny on major tech firms. The sector remained resilient, supported by continued innovation and adoption of digital services, yet investors began to differentiate between growth-driven and speculative technology stocks. Companies with strong financial fundamentals saw sustained price gains, while speculative assets experienced increasing volatility, reflecting a shift in investor sentiment towards more risk-adjusted decision-making. The fourth and fifth waves (October 2021–June 2022) brought a peak and subsequent decline in stock valuations, marking a transition from the high-growth phase of the pandemic towards a post-pandemic correction. This decline was largely influenced by external factors, including interest rate hikes, inflation concerns, and the gradual withdrawal of fiscal stimulus measures. Market confidence in the technology sector, which had been exceptionally strong in the early pandemic waves, began to moderate as investors reassessed the sustainability of valuations, considering changing macroeconomic conditions. Post-pandemic (July 2022–December 2022), stock prices stabilized but remained lower than their peak levels, indicating a fundamental shift in market perception. Unlike the pre-COVID period, where the technology sector was viewed as a relatively low-risk, high-growth industry, the post-pandemic landscape introduced greater sensitivity to macroeconomic risks, regulatory challenges, and broader economic stability. Daily returns, while less volatile than during the height of the pandemic, continued to exhibit fluctuations beyond pre-pandemic norms, suggesting that investor caution and uncertainty persist in the sector.

3.1. Stock price volatility in the technology sector

The volatility of stock prices in the technology sector during the COVID-19 pandemic serves as a critical indicator of how investors perceived risk and growth potential within this industry.

The technology sector displayed substantial price fluctuations throughout the COVID-19 pandemic, reflecting heightened investor sensitivity to policy changes and macroeconomic uncertainty. Prior to the crisis, stock prices followed a stable upward trajectory supported by continuous digital expansion and investor confidence in the sector's long-term

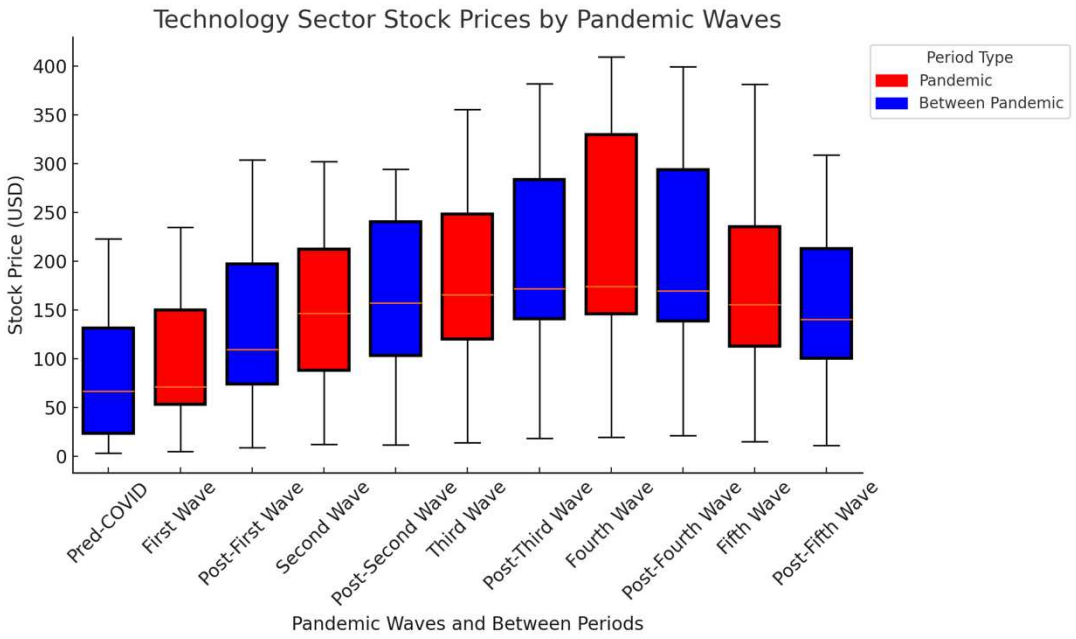

Figure 2. Technology sector stock prices by pandemic waves

growth potential. The outbreak of COVID-19 introduced a new volatility regime. During the first pandemic wave (March–May 2020), the abrupt transition to remote work, e-commerce, and cloud computing triggered an initial surge in valuations across leading firms such as Amazon, Microsoft, and Alphabet. Average daily returns for these companies reached approximately 1.5 percent, while cumulative price gains exceeded 20 percent over a 60-day period.

The early optimism was accompanied by intensified price corrections, as investors oscillated between confidence in the digital economy and uncertainty about the global recession's duration. Volatility peaks were most evident in the first and third pandemic waves, when lockdowns and renewed infection surges destabilized market expectations. The coefficient of variation during these periods frequently exceeded 100 percent, indicating that risk temporarily outpaced realized returns.

In the later stages of the pandemic (September 2020 – June 2021), technology stocks maintained upward momentum but experienced intermittent declines linked to inflation expectations, interest-rate adjustments, and regulatory interventions targeting large-cap technology firms. Although market conditions normalized gradually, volatility remained structurally higher than before the crisis. The final pandemic waves (October 2021 – June 2022) marked the transition toward a post-pandemic correction, as rising interest rates and the withdrawal of fiscal support reduced speculative inflows. By mid-2022, stock valuations had stabilized at lower equilibrium levels, with average daily fluctuations still above pre-pandemic norms, signaling the persistence of cautious investor sentiment.

3.2. The role of daily returns

The daily returns of the technology sector reflect both its resilience and sensitivity to rapidly changing market conditions during the pandemic, especially given the accelerated shift towards digital services during the crisis.

Daily returns provided a high-frequency perspective on investor reactions to evolving pandemic conditions. In the pre-pandemic period, the average daily return in the technology sector was approximately 0.17 percent, consistent with a balanced risk-return environment and limited speculative trading. The first pandemic wave disrupted this pattern, pushing average daily returns to 0.47 percent as demand for digital solutions surged. The pronounced upward momentum was interspersed with frequent short-term

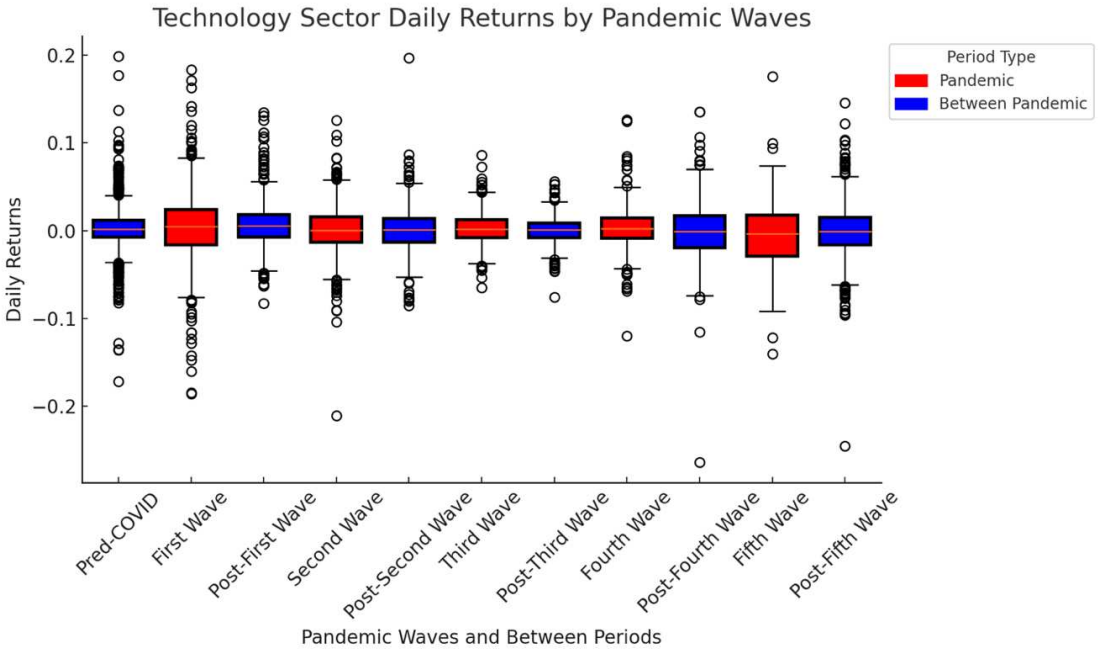

Figure 3. Technology sector daily returns by pandemic waves

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reversals, reflecting rapid profit-taking and uncertainty about the sustainability of pandemic-induced growth.

During subsequent waves, particularly in late 2020 and early 2021, average daily returns moderated to around 0.27 percent. Investors began differentiating between firms with strong balance sheets and those reliant on speculative growth narratives. Companies such as Apple and Microsoft maintained steady gains, while firms with weaker fundamentals exhibited more erratic return profiles. Despite declining speculative intensity, intraday volatility and abnormal return frequency remained higher than in the pre-crisis years, suggesting an enduring shift toward faster information assimilation and reaction in equity markets.

3.3. Market stability and risk-return tradeoff

The coefficient of variation (CV) provides an essential metric for understanding how the risk-return tradeoff evolved in the technology sector during the COVID-19 pandemic.

The coefficient of variation (CV) captures relative volatility by relating the standard deviation of returns to their mean, offering insight into risk-adjusted performance. Before COVID-19, CV levels across major technology stocks indicated a stable balance between risk and reward. The pandemic's onset disturbed this equilibrium, producing both temporary reductions and sharp increases in the CV across successive waves.

During the first wave, the surge in stock prices outpaced volatility growth, causing a short-lived decline in the CV as returns spiked amid investor optimism. However, the second and third waves produced an inverse effect: volatility expanded more rapidly than returns, driving CV values upward and signaling a deterioration in the sector's risk-return balance. Firms characterized by speculative valuations experienced disproportionate increases in CV, while large, diversified corporations retained relatively moderate ratios.

By the post-pandemic phase, CV values had partially normalized but remained roughly 30 to 50 percent higher than before 2020. This persistent elevation indicates a structural repricing of risk in the technology sector, where investors now emphasize earnings consistency and macroeconomic stability over aggressive growth expectations. The long-term adjustment suggests a new equilibrium characterized by higher baseline volatility and lower tolerance for speculative excess.

3.4. Kurtosis and the impact of extreme price shocks

While the coefficient of variation provides insights into the overall risk-return balance, kurtosis allows us to assess the frequency and severity of extreme price movements, which are critical indicators of financial stability and investor sentiment.

Kurtosis analysis reveals the prevalence of extreme returns and tail-risk events. Prior to 2020, technology-sector return distributions showed moderate

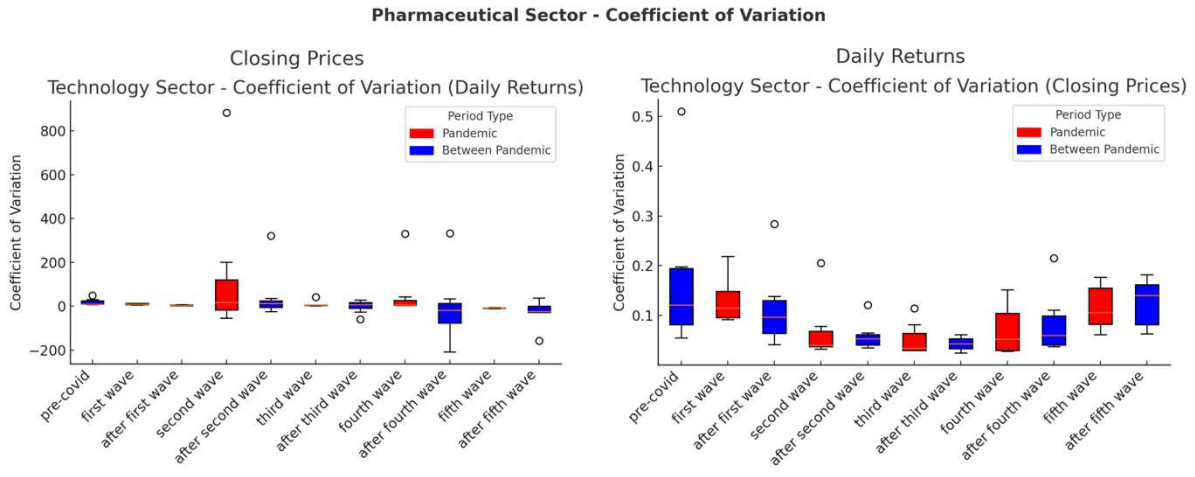

Figure 4. Technology sector and its coefficient of variation

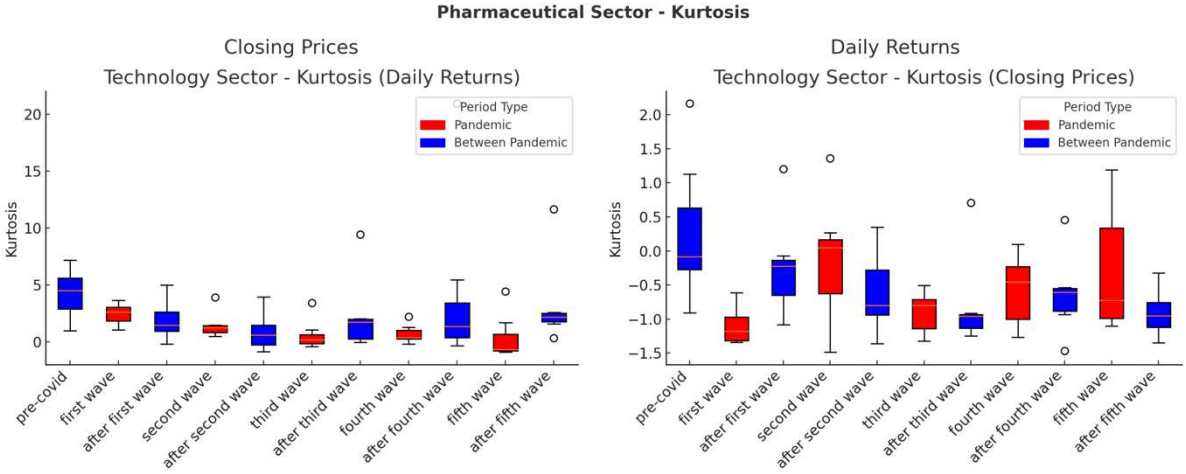

Figure 5. Technology sector and its kurtosis

kurtosis, consistent with infrequent large price deviations. The early pandemic period, however, produced unusually broad fluctuations without distinct outliers, yielding lower kurtosis despite higher volatility. This pattern reflected continuous adjustment to evolving information rather than isolated panic episodes.

As the pandemic matured, kurtosis rose sharply, particularly during the second and third waves, indicating more frequent extreme gains and losses. Sudden policy announcements, vaccine breakthroughs, and quarterly earnings surprises generated short-lived surges followed by rapid corrections. Retail speculation and algorithmic trading intensified these price shocks, amplifying the tails of return distributions.

By late 2021, kurtosis began to moderate as markets adjusted to new informational equilibria, but it remained elevated relative to the pre-pandemic baseline (values commonly between 4 and 7). Persistent tail risk reflected continued sensitivity to global macroeconomic news, monetary tightening, and regulatory developments affecting major technology firms. Overall, the distribution of returns suggests that even after stabilization, the technology sector retained a higher probability of extreme movements, underscoring the need for adaptive risk-management approaches in post-pandemic portfolios.

4. DISCUSSION

The empirical evidence confirms that the COVID-19 pandemic generated a new volatility regime within the technology sector, characterized by alternating phases of optimism, speculation, and structural risk repricing. The patterns observed across pandemic waves align with global evidence showing that crisis-induced uncertainty led to temporary mispricing, elevated risk aversion, and accelerated digital adoption (Liu et al., 2021; Mazur et al., 2021). However, the magnitude and persistence of these fluctuations suggest that the technology sector not only absorbed external shocks but also acted as a key transmitter of financial instability, consistent with contagion findings reported for international equity markets (Yuan et al., 2022).

The sharp volatility spikes during the first pandemic wave are consistent with results obtained for major global indices. Mazur et al. (2021) found that U.S. technology and healthcare stocks initially overperformed relative to energy and financial sectors, confirming the defensive role of innovation-driven industries in early 2020. Similarly, Goodell and Huynh (2020) observed that stock markets across advanced economies experienced synchronized volatility surges immediately after the WHO pandemic declaration, driven by uncertainty rather than firm fundamentals. Our wave-based results extend these findings by showing that volatility remained significantly above pre-pandemic levels even after 2021, implying a structural recalibration of risk in technology valuations. The persistent elevation in the coefficient of variation observed in this study mirrors the global pattern of elevated risk-return asymmetry documented by Dharani et al. (2019) for Shariah-compliant markets, where faith-based equities demonstrated

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short-term resilience but long-term instability. While their results indicated a partial mean reversion of volatility after mid-2021, our findings suggest that technology firms, though resilient, retained a higher baseline risk due to their exposure to monetary tightening and regulatory scrutiny.

The results concerning daily returns corroborate earlier research on short-term investor sentiment and adaptive trading behavior. Liu et al. (2021) demonstrated that pandemic-related news and infection rates were directly linked to abnormal returns and increased crash risk in the Chinese market. Similar to their conclusions, our analysis shows that investor sentiment in the technology sector oscillated rapidly across pandemic waves, producing alternating cycles of optimism and caution. The return distributions remained positively skewed during early waves but became more symmetric post-2021, reflecting a transition toward risk-adjusted decision-making and selective investment in firms with strong fundamentals. Furthermore, Yuan, Wang & Xiu (2022) identified that global indices experienced time-varying volatility connected to shifts in information diffusion and investor attention. This aligns with our kurtosis results, where the highest tail-risk concentrations coincided with periods of intense media coverage, policy changes, and speculative trading in high-growth technology stocks such as Tesla and NVIDIA.

The elevated kurtosis identified in mid-pandemic waves indicates that large price shocks became more frequent and clustered, consistent with multi-country findings by Chang et al. (2020), who reported that extreme market events increased dramatically during COVID-19 due to heightened correlations between global indices. Similarly, Yarovaya, Matkovskyy, and Jalan (2021) found strong interdependencies between technology, cryptocurrency, and commodity markets, reinforcing the interpretation that technology stocks acted as both safe havens and volatility transmitters at different stages of the pandemic. Our study's kurtosis trajectory rising during speculative waves and moderating post-2021 corresponds with evidence by Dharani et al. (2019), who observed that market recovery periods were characterized by reduced but not eliminated tail risk. However, unlike their aggregate findings, our sector-focused results reveal that technology stocks maintained leptokurtic return distributions even after volatility normalized, indicating the persistence of high-impact events driven by macroeconomic and regulatory developments.

The gradual stabilization of daily returns and volatility from mid-2022 onwards supports the argument that investors re-evaluated risk-return expectations for the digital economy. Similar stabilization patterns were reported by Liu et al. (2021) for Chinese A-shares and by Yuan et al. (2022) for global benchmark indices, both suggesting that markets eventually adjusted to pandemic-driven uncertainty. Nevertheless, the technology sector's post-pandemic volatility plateau remains higher than historical averages, implying that digital industries now operate under a permanently revised perception of risk. Collectively, these findings contribute to the growing literature on crisis-period financial behavior by integrating time-segmented, wave-based volatility metrics. Unlike prior research that examined single-phase responses or cross-sectional contagion, this study captures how investor sentiment evolved dynamically across multiple pandemic stages. The evidence supports the view that technological innovation, while enhancing economic resilience, also amplifies market sensitivity during systemic shocks due to its central role in global capitalization and policy discourse.

CONCLUSION

The purpose of this study was to examine how the COVID-19 pandemic affected market volatility and investor behavior in the technology sector, focusing on daily stock returns and risk indicators between March 2019 and December 2022. Using descriptive statistics, coefficients of variation, and kurtosis-based analysis across multiple pandemic waves, the research sought to identify structural changes in risk-return dynamics and evaluate whether the technology sector retained its perceived resilience or became increasingly sensitive to macroeconomic shocks.

The empirical results reveal that volatility in the technology sector followed a cyclical, wave-dependent pattern characterized by rapid shifts between optimism, speculation, and risk recalibration. The first wave triggered sharp price rebounds and short-term safe-haven behavior, while subsequent waves reflected rising uncertainty linked to inflation expectations, interest-rate adjustments, and regulatory pressures. The coefficient of variation surged above 100 % in several phases, confirming that risk outpaced returns at the height of market turbulence. Kurtosis analysis further indicated persistent tail risk, as extreme price movements remained more frequent than in pre-pandemic conditions. By 2022, both volatility and daily returns had partially normalized, yet risk-adjusted performance remained structurally higher, suggesting that the sector now operates under a permanently revised perception of risk.

These findings have several important implications. From an investment perspective, they demonstrate that even the most innovative industries are not immune to systemic shocks and that technological growth can amplify, rather than mitigate, volatility during crises. For policymakers, the results underscore the need for targeted financial stabilization measures that account for sectoral asymmetries, particularly in industries that dominate global market capitalization and investor sentiment. The evidence that risk-return equilibrium did not return to pre-crisis levels indicates that future monetary and regulatory frameworks must integrate behavioral and digital-finance dimensions when addressing financial stability.

Future research should extend the analysis beyond the pandemic horizon to determine whether the elevated volatility and persistent kurtosis observed in the technology sector represent a temporary post-crisis adjustment or a long-term structural shift. Incorporating additional sectors such as pharmaceuticals, energy, and financial services would enable comparative insights into cross-industry contagion and resilience. Moreover, applying advanced econometric and machine-learning models to measure lagged interdependence between sectors could refine the understanding of how information diffusion, investor sentiment, and macroeconomic shocks jointly shape market dynamics in systemic crises. Ultimately, this study provides a sector-specific foundation for evaluating how innovation-driven markets evolve under extreme uncertainty and offers a basis for further exploration of behavioral and structural mechanisms that define modern financial volatility.

AUTHOR CONTRIBUTIONS

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Validation: Kristián Kalamen, Roman Vavrek.
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