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Navigating Global Stock Volatility with The Integration of GARCH-VECM Models in The Disruption Era

Melan Rena*, Faizul Mubarok, Andi Harmoko Arifin
Financial Management, Terbuka University, Jakarta, Indonesia

*E-mail corresponding author: rena.alexanderzz@gmail.com

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Abstract *- The global advertising industry is undergoing structural transformation amid rapid digital disruption and economic uncertainty. This study examines the impact of technological disruption including the adoption of artificial intelligence (AI), big data, and automated advertising systems and digital economy indicators on the stock volatility of three multinational advertising companies: WPP plc (UK), Omnicom Group Inc. (US), and Dentsu Group Inc. (Japan). Using monthly data from 2008 up to 2024, the research employs a hybrid econometric approach integrating the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model to capture short-term volatility dynamics and the Vector Error Correction Model (VECM) to assess long-term equilibrium relationships among variables. Analyzed variables include technology indices (NASDAQ-100, FTSE Techmark, Nikkei-225), inflation (CPI), digital advertising expenditure, and revenue. The integrated GARCH-VECM model is evaluated against individual GARCH and VECM models using performance metrics such as MAE, RMSE, MAPE, confidence intervals, and cross-validation tests. Results show that technological disruption significantly increases stock volatility across all firms, while inflation effects vary depending on the country context. Sector-specific indicators, including digital advertising spending and revenue, exhibit limited short-term influence. Long-run cointegration is confirmed, particularly for WPP and Omnicom, indicating structural sensitivity to global digital transformation. The integrated GARCH-VECM model demonstrates superior predictive accuracy, stability, and robustness compared to single models. This study contributes novel empirical evidence and practical insights for effective risk management in the highly digitized and volatile advertising sector, benefiting policymakers, investors, and corporate strategists.*

INTRODUCTION

Digital transformation and global macroeconomic uncertainty have significantly reshaped the landscape of the advertising industry. Multinational advertising firms are simultaneously pressured by the adoption of technologies such as data-driven marketing, artificial intelligence (AI), and programmatic advertising systems, while also navigating the impacts of inflation, global pandemics, and geopolitical tensions. This dual pressure of technological and economic shifts has led to heightened stock volatility in the global advertising sector, reflecting increasingly complex and unpredictable market dynamics.

The central issue lies in whether digital transformation enhances market resilience or creates new financial risks. Rosário & Dias (2023) suggest that data-based strategies can improve competitiveness in advertising firms but fall short of examining long-term financial stability. Hossain (2024) further notes that implementing technology without structural readiness may increase systemic risk. Conversely, Wu et al., (2022) argue that digitalization enhances transparency and investor confidence. These divergent findings illustrate the paradox between innovation and stability and raise the question of the actual impact of technological disruption on the stock performance of advertising companies. In this context, Arifin (2023) underlines that strong corporate governance remains a crucial internal factor that can complement digital transformation efforts to maintain firm value stability amid disruptive market conditions.

In the global context, Westerman & Webster (2025) emphasize that digital technology adoption drives efficiency and innovation and serves as a risk mitigation mechanism. However, such disruption can

also create high uncertainty in capital markets, especially if not accompanied by managerial reform and regulatory support. This highlights the need to quantitatively assess the long-term effects of technological disruption on financial stability in the sector.

Indonesia, as one of the primary expansion and digital ad spending targets of multinational advertising companies, plays a vital role in this dynamic. Although the research focuses on multinational corporations, their exposure to emerging markets like Indonesia influences global investor sentiment and overall business strategy. Thus, the Indonesian market is not merely a local context but also represents a global response to technological and economic pressure.

This study categorizes technological disruption, inflation, digital ad spending, and digital ad revenue as key indicators of disruption and digital economic dynamics. These variable groups are considered crucial determinants that may influence the stock volatility of multinational advertising firms in the era of digital transformation. Prior studies have largely relied on single-method approaches, such as GARCH models for short-term volatility or VECM for long-term relationships. However, the advertising sector's volatile and complex characteristics require a more integrated methodological approach.

Studies by Box et al., (2016) and Andersen et al., (2009) have shown that combining GARCH and VECM models provides a more comprehensive understanding of market shocks and long-term variable interrelationships. Nonetheless, the integration of GARCH-VECM models in the context of the global advertising industry especially incorporating digital economic variables remains underexplored in current literature.

Table 1 identifies the research gaps in prior studies and clearly explains how this study addresses each gap through empirical evidence, theoretical contribution, and a robust integrated GARCH-VECM methodological approach.

Table 1. Research Gap Identification and Contribution

Type of Gap	Description	Contribution of This Study
Empirical gap	Limited evidence on the link between technological disruption and ad stock volatility	Provides early empirical findings on the impact of disruption and digital economic indicators in the advertising sector
Knowledge gap	Lack of understanding of the integration between digital disruption, spending, and macroeconomics	Combines those variables into one indicator framework and tests their long-term interconnection
Methodological gap	Overreliance on single models in volatility analysis	Proposes an integrated GARCH-VECM approach for more accurate volatility forecasting

The novelty of this research lies in its integrated use of GARCH and VECM models to analyze disruption and digital economic variables concurrently. This integration is scarcely addressed in previous studies, especially in the creative industry sector. Moreover, the approach merges financial risk and technological strategy perspectives, filling the literature gap on the market impact of digital transformation in advertising.

The state of the art (SOTA) contribution of this research lies in its integrative model that reflects the complexity of a sector directly impacted by innovation and structural economic changes. The findings are expected to enrich academic understanding and offer practical recommendations for risk mitigation in the digital age.

This research seeks to investigate three main problems. First, it explores how technological disruption and various digital economic variables influence the stock volatility of multinational advertising companies. As the advertising industry undergoes rapid digital transformation, it becomes crucial to understand the extent to which such disruption affects market behavior and investor confidence. Second, the study aims to examine the long-term relationships between digital disruption and stock volatility within the advertising sector. This includes identifying whether sustained changes in digital infrastructure, innovation, and consumer behavior have lasting impacts on financial market dynamics. Lastly, the research evaluates the effectiveness of an integrated GARCH-VECM model compared to the use of single models (such as GARCH or VECM alone) in forecasting stock volatility. By comparing these models, the study intends to provide a robust analytical framework for anticipating financial risks and improving strategic decision-making in an increasingly volatile and digital-driven environment.

The objectives of this research are threefold. First, it aims to analyze the effect of technological disruption and the dynamics of the digital economy on the stock volatility of multinational advertising firms. This involves assessing how factors such as digital transformation, innovation adoption, and shifts in digital consumer behavior impact market fluctuations within the advertising industry. Second, the study seeks to examine the long-term relationship between digital disruption and stock volatility in the advertising sector, providing insights into whether these technological shifts lead to structural changes in market performance over time. Lastly, the research aims to evaluate the forecasting effectiveness of an integrated GARCH-VECM model compared to conventional single-model approaches, thereby identifying the most accurate and robust method for predicting stock volatility in a digitally evolving financial landscape.

This study contributes theoretically by expanding academic understanding of the integration between technological disruption, digital economic dynamics, and stock market volatility demonstrating the advantages of using GARCH-VECM in the creative industry context and practically by offering strategic insights for investors, advertising firm management, and policymakers to anticipate market risks and design adaptive strategies.

LITERARTURE REVIEW

This theoretical study will discuss the key concepts for understanding the stock volatility of multinational advertising companies, with a focus on the impact of technological disruption and the digital economy amid market uncertainty.

Before the widespread adoption of digital technology, the stock volatility of advertising-related firms generally reflected broader market cycles, influenced primarily by cyclical ad spending and macroeconomic conditions. While sector-specific volatility data are limited, historical market estimates (e.g., S&P 500) suggest annualized volatility typically ranged between 10–30%, depending on prevailing economic factors (Mullins, 2000). These pre-digital patterns provide a useful benchmark for assessing how digital disruption may be reshaping volatility dynamics in today's advertising sector.

First, the impact of disruption is framed through three perspectives. Disruptive Innovation Theory explain how new technologies open markets and displace traditional models (Christensen et al., 2019), introducing uncertainty in sectors like advertising. Big Bang Disruption Theory highlight how digital innovations such as AI and platforms abruptly destabilize industries, triggering market volatility (Downes & Nunes, 2014). The application of the *Realized GARCH* model has been shown to improve the accuracy of volatility forecasting by incorporating realized volatility data, which captures short-term fluctuations more effectively than traditional GARCH models (Mubarok & Faturrahman, 2021). This approach is particularly useful in contexts experiencing structural market shifts—such as those caused by technological disruption or the evolution of digital platforms where investor sentiment is more volatile. The findings highlight the importance of using advanced econometric models to anticipate market behavior in sectors like advertising that are highly sensitive to innovation driven change.

Second, the long-term relationship between macroeconomic shocks and stock volatility is supported by the Theory of Inflation Expectations (Mankiw, 2021), which links inflation to risk perception and investor uncertainty. The Theory of Advertising Demand and Investor Response connects ad strategy inconsistencies with increased perceived risk by investors (Gordon et al., 2019). Innovation Diffusion Theory adds that internal factors such as complexity and readiness shape how technology adoption affects firm performance and investor confidence over time (Rogers, 2003).

Third, the study adopts an integrated GARCH-VECM framework to measure volatility comprehensively. GARCH captures short-term fluctuations (Bollerslev, 1986), while VECM models long-term equilibrium among variables (Engle & Granger, 1987). McAleer (2005) supports this integration to reflect complex financial dynamics and improve forecasting accuracy in volatile markets.

Table 2 summarizes selected previous studies on the impact of technological disruption and the digital economy on stock volatility, highlighting their limitations and supporting the rationale for this study’s integrated approach.

Table 2. *Previous Studies on Technological Disruption and Digital Economy Impact on Stock Volatility*

Author	Key Findings	Research Limitations
Chen et al., (2014)	Technological disruptions such as AI and big data improve advertising efficiency and personalization, yet increase stock volatility due to business model uncertainty.	Focuses on technological efficiency without addressing macroeconomic factors or long-term relationships.
Mann et al., (2022)	Digital transformation is effective when orchestrated through collaboration among actors within the business ecosystem.	Case-based study; limited generalizability to sectors such as advertising.
Wang & Kim (2017)	Social media marketing enhances customer relationship capabilities and firm performance through dynamic capabilities.	Does not examine the advertising sector directly or the impact of external factors on volatility.

Table 3 presents key findings and gaps in studies that examine long-term relationships between technological disruption, the digital economy, and stock volatility, reinforcing the need for the integrated framework used in this research.

Table 3. Previous Studies on Long-Term Relationship between Technological Disruption, Digital Economy, and Stock Volatility

Author	Key Findings	Research Limitations
Anusha (2016)	High inflation amplifies stock volatility in multinational firms due to increased economic uncertainty.	Focuses solely on inflation; does not consider technological disruption or use of GARCH-VECM model.
Gounopoulos et al., (2012)	During the 2008–2011 financial crisis, exchange rate shifts negatively correlated with equity returns, supporting the "flight to quality" hypothesis.	Limited to banks and insurance companies in the US, UK, and Japan; not generalizable to other sectors.
Rogers (2003)	New technology adoption is influenced by internal factors such as perceived benefits, complexity, and managerial readiness.	Does not explicitly examine stock volatility or the multinational advertising sector.

Table 4 compiles evidence from previous research on the effectiveness of GARCH-VECM integration for predicting stock volatility, which underpins the methodological choice of this study.

Table 4. Previous Studies on the Effectiveness of GARCH-VECM Integration in Predicting Stock Volatility

Author	Key Findings	Research Limitations
Bonilla & Sepúlveda (2011)	GARCH-VECM integration is effective for measuring stock volatility in emerging markets, accounting for economic and technological factors.	Focused only on emerging markets; lacks insight into multinational advertising companies.
McAleer (2005)	Combining GARCH and VECM allows for a more dynamic and comprehensive analysis of market volatility.	Does not explore specific impacts of technological disruption or digital economy on stock volatility.

This study proposes three hypotheses. H1: Technological disruption and the development of the digital economy have a positive effect on the increase in stock volatility of multinational advertising companies. H2: There is a positive long-term relationship between technological disruption and the digital economy and the stock volatility of multinational advertising companies. H3: The integration of the GARCH–VECM model is more effective than single models in predicting stock volatility of multinational

advertising companies, as it captures both short-term heteroskedastic effects and long-term cointegration relationships simultaneously.

METHOD

This research employs a quantitative explanatory approach to assess the causal effect of technological disruption and digital economy development on the stock volatility of multinational advertising companies. Secondary data are used, including stock prices (WPP, Omnicom, Dentsu), digital ad spending and revenue (eMarketer, Oberlo), technology indices (FTSE Techmark, Nasdaq-100, Nikkei-225), and global inflation data (World Bank). GARCH and VECM models are applied using EViews 12 software to analyze short-term volatility and long-term relationships among variables.

Secondary data collection instruments were employed. Each variable was identified through measurable indicators to support the GARCH and VECM modeling process. Stock price volatility was measured using the monthly standard deviation of log returns. Technological disruption was proxied using the FTSE Techmark, Nasdaq-100, and Nikkei 225 indices. Inflation was measured using the Consumer Price Index (CPI), and the digital economy was represented by digital advertising spending and digital revenue. All variables were processed through EViews software. A detailed breakdown of research instruments is provided in Table 5.

Table 5 provides a detailed overview of the variables, indicators, measurement scales, and analytical tools used in this study, ensuring systematic and reliable model estimation.

Table 5. Research Variable Instruments

Variable	Indicator	Measurement Scale	Measurement Tool
Stock Volatility	Standard deviation of monthly stock returns	Ratio (monthly time series)	EViews (GARCH model)
Technological Disruption	FTSE Techmark Index, Nasdaq-100, Nikkei-225 Index	Ratio / Monthly index	EViews (VECM-GARCH model)
Inflation	Consumer Price Index (CPI)	Ratio (monthly index)	EViews (VECM)
Digital Advertising Spend	Monthly value of digital advertising expenditure	Ratio (USD / % per month)	EViews (VECM)
Digital Advertising Revenue	Monthly digital advertising revenue per company	Ratio (USD per month)	EViews (VECM)

The data were processed using EViews 12 software through several stages of econometric analysis. First, the stationarity of the time series was tested using the Augmented Dickey-Fuller (ADF) method to ensure data stability. Second, the GARCH (1,1) model commonly chosen for financial time series due to its parsimony and empirical robustness was applied to analyze the impact of technological disruption and digital economic variables on the volatility of multinational advertising company stocks, capturing heteroskedastic behavior in the short term.

Third, long-term relationships were assessed through the Johansen cointegration test, followed by the estimation of the Vector Error Correction Model (VECM) to analyze both short-run dynamics and long-run equilibrium among inflation, global stock indices, digital ad spending, and volatility. Fourth, the model's predictive accuracy was evaluated using performance metrics such as Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and Mean Absolute Percentage Error (MAPE), while prediction validity was tested through confidence interval analysis.

Fifth, robustness of the integrated GARCH-VECM model was examined using cross-validation or bootstrapping techniques. Finally, the statistical significance of differences in predictive performance between the integrated model and single models was assessed using t-tests or F-tests to determine the superiority of the GARCH-VECM integration.

RESULT

This study focuses on three leading multinational advertising companies: WPP plc (United Kingdom), Omnicom Group Inc. (United States), and Dentsu Group Inc. (Japan). These firms represent global industry leaders that are most affected by technological disruption and digital economic dynamics. The period from 2008 to 2024 is selected to cover the global financial crisis, the digital transformation of the advertising industry, and the post-pandemic economic uncertainty, thereby offering a comprehensive view of long-

term structural shifts and market volatility. The analysis reveals that all three advertising firms exhibit abnormal return distributions, indicating high uncertainty and risk. This reinforces the importance of adopting more advanced models such as GARCH and VECM to understand stock volatility, especially in the context of technological disruption and digital economic pressures impacting the advertising industry.

The log returns of WPP stock display a mean of -0.000877 and a median of 0.009403. The divergence between the two suggests a non-symmetric distribution. A skewness of -0.86 indicates a tendency toward extreme negative returns (left-skewed), while the kurtosis of 5.18 signifies a leptokurtic distribution with a sharp peak and heavy tails. The Jarque-Bera test yields a value of 65.71 ($p \leq 0.0001$), confirming the non-normality of the distribution. Overall, WPP's stock return distribution suggests considerable risk due to its departure from normality. This underscores the necessity for more flexible risk management strategies and the use of advanced, non-linear models to capture and forecast heightened volatility, particularly driven by global disruptions in the advertising industry.

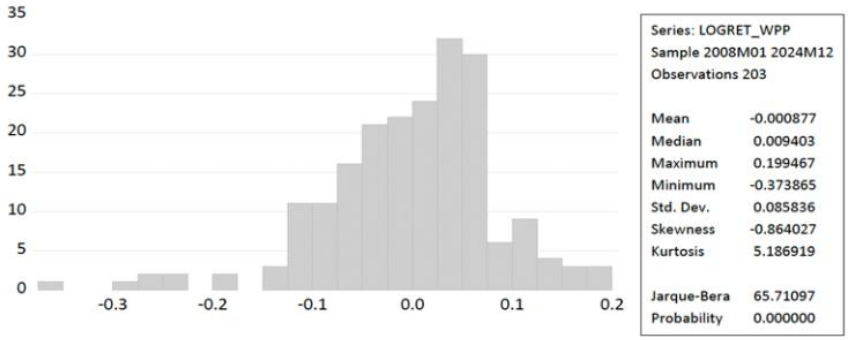

Figure 1. Descriptive Statistics of WPP Stock

The average log return of Omnicom stock is 0.003153, while the median is 0.004330, indicating a tendency toward positive returns. The skewness of 0.12 reflects an almost symmetric distribution, although a kurtosis value of 5.85 suggests a leptokurtic shape. The Jarque-Bera test value of 69.49 ($p \leq 0.0001$) further confirms non-normality. In general, Omnicom's returns show positive tendencies and apparent stability; however, the sharp peak and heavy tails suggest a higher-than-expected risk of extreme price movements. Despite the near-symmetry in distribution, the volatility risk posed by non-normal behavior remains a critical factor in investment decision-making, especially for firms influenced by evolving technologies and macroeconomic changes.

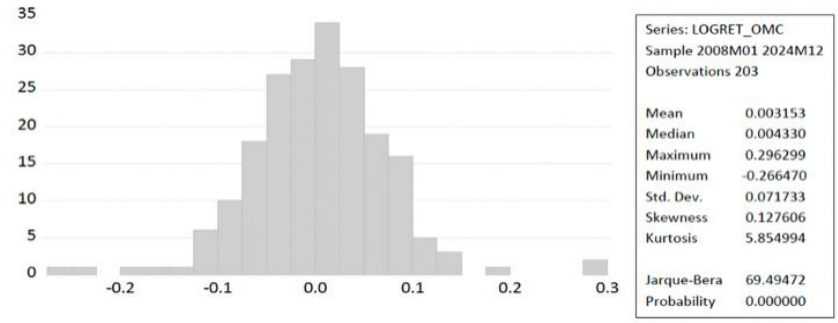

Figure 2. Descriptive Statistics of Omnicom Stock

Dentsu's log return has a mean of 0.002158 and a median of 0.003534, with a skewness of 0.50 indicating a right-skewed distribution. However, the kurtosis is extremely high at 75.78, signifying a distribution with a sharp peak and heavy tails. The Jarque-Bera test yields an extreme value of 44,819.88 ($p \leq 0.0001$), showing a strong deviation from normality. Overall, Dentsu's stock return distribution demonstrates very high volatility, with a right skew and significant potential for extreme price swings. Its sharply peaked and heavy-tailed distribution reflects a strong sensitivity to external shocks, indicating substantial risk. These findings highlight the necessity of employing non-linear models like GARCH in risk management and the need for adaptive strategies to navigate highly volatile global advertising markets.

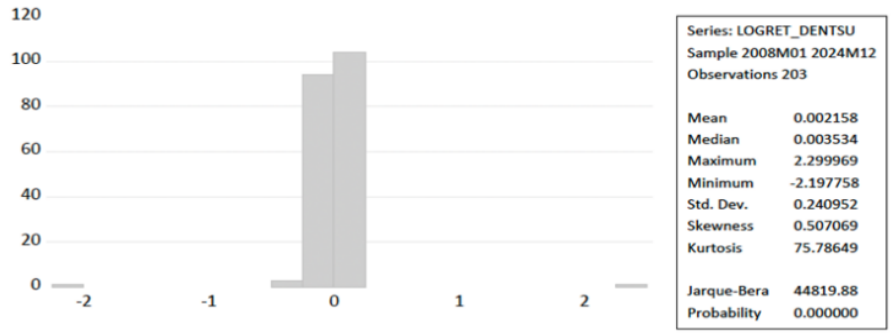

Figure 3. Descriptive Statistics of Dentsu Stock

The Impact of Technological Disruption and Digital Economy on Stock Volatility

The results of the Augmented Dickey-Fuller (ADF) test show that all data series have t-statistic values significantly lower than the 5% critical level, with p-values well below 0.0001. This indicates that the data for all three stocks are stationary, meaning there is no trend or pattern that changes over time.

Table 6 displays the Augmented Dickey-Fuller (ADF) test results, confirming that all time series are stationary and suitable for the subsequent GARCH-VECM analysis.

Table 6. ADF Test Comparison Results

Component	WPP	Omnicom	Dentsu
ADF t-statistic	-13.0989	-14.0645	-9.3107
p-value	< 0.0001	< 0.0001	< 0.0001
5% Critical Value	-3.4322	-3.4322	-3.4326
Result	**Stationary**	**Stationary**	**Stationary**

The GARCH analysis reveals that technological disruption has a significant positive effect on the stock volatility of WPP, Omnicom, and Dentsu. Inflation exhibits varying impacts: a negative effect in the UK for WPP, but a positive effect in the US and Japan for Omnicom and Dentsu, respectively. Digital advertising spending and revenue do not have a significant impact on the stock price volatility of the three companies, suggesting that changes in digital ad expenditure or revenue do not directly drive fluctuations in their stock prices.

However, there is a significant short-term volatility effect (ARCH component) observed in Dentsu's stock, indicating that past price movements influence its current volatility. Meanwhile, the long-term volatility component (GARCH) is not significant for any of the three companies, suggesting that accumulated volatility pressure over time is not strong enough to affect their stock prices in the long run.

Table 7 shows the estimated coefficients from the GARCH model, demonstrating how technological disruption, inflation, and digital economy variables influence stock volatility in the short term.

Table 7. GARCH Model Results on Stock Volatility

Variable	WPP	Omnicom	Dentsu
Tech Index	FTSE (positive, p<0.0001)	NASDAQ (positive, p<0.0001)	NIKKEI (positive, p<0.0001)
Inflation	UK (negative, p=0.0084)	US (positive, p=0.0056)	JP (positive, p=0.0219)
Digital Ad Spend	Not significant (p=0.8461)	Not significant (p=0.9659)	Not significant (p=0.1320)
Digital Ad Revenue	Not significant (p=0.8833)	Not significant (p=0.9904)	Not significant (p=0.5693)
ARCH (resid²)	Marginally significant (p=0.0940)	Not significant (p=0.2413)	Significant (p<0.0001)
GARCH (lag variance)	Not significant (p=0.8148)	Not significant (p=0.2942)	Not significant (p=0.9915)

The analysis indicates that technological disruption has a positive and significant impact on the stock volatility of multinational advertising companies. For instance, the Tech Index coefficient for WPP (FTSE) is both positive and statistically strong ($p < 0.0001$, with a relatively larger magnitude than other variables), while Omnicom's volatility is significantly influenced by the NASDAQ index (positive coefficient, $p < 0.0001$), and Dentsu's volatility is most sensitive to movements in the NIKKEI index (positive coefficient, $p < 0.0001$).

These findings suggest that global technological changes or innovations tend to drive fluctuations in the stock prices of firms such as WPP, Omnicom, and Dentsu. In contrast, digital economy indicators such as digital advertising spending and revenue consistently exhibit non-significant coefficients across all firms, indicating that the stock market responds more to broader technological trends than to firm-level digital advertising performance.

Furthermore, inflation shows mixed effects across countries: it has a negative and significant impact on WPP in the UK (coefficient < 0, $p = 0.0084$), while it is positively associated with stock volatility in the US and Japan for Omnicom ($p = 0.0056$) and Dentsu ($p = 0.0219$), respectively. This variation underlines the importance of a company's ability to adapt to local macroeconomic conditions. Finally, the significant ARCH effect in Dentsu's model ($p < 0.0001$) reflects a heightened short-term sensitivity to shocks in the Japanese market, compared to WPP and Omnicom, where ARCH and GARCH terms were mostly insignificant.

The Long-Term Relationship Between Technological Disruption and The Digital Economy on Stock Volatility

The Johansen cointegration test results indicate that the stock returns of the three multinational advertising companies are closely linked to technological disruption and digital economic conditions in the long term. This suggests that stock price movements are not isolated from macroeconomic factors and industry dynamics. The negative and significant adjustment coefficients imply that these companies actively correct stock price imbalances, with WPP showing the fastest response. These findings support the use of the VECM model to analyze both the long-term and short-term impacts of global disruptions on stock volatility.

Table 8 presents the Johansen Cointegration Test results, which confirm the presence of long-term equilibrium relationships between technological disruption, macroeconomic factors, and stock volatility in the advertising sector.

Table 8. Johansen Cointegration Test Results

Variable	WPP	Omnicom	Dentsu
Trace Statistic	170.8	167.4	157.8
Max-Eigen Statistic	40.7	40.0	36.8
Number of Cointegrating Equations	5	5	5
Adjustment Coefficient (α)	-0.1878	-0.1521	-0.1392

The analysis shows that only WPP and Omnicom exhibit a significant long-term relationship between stock returns, inflation, technological disruption, and advertising expenditure, while Dentsu does not. In the short term, all three companies are influenced by their own lagged returns, with Omnicom and Dentsu also affected by their respective technology indices. Inflation plays a significant role for WPP and Omnicom, but not for Dentsu. The moderate R-squared values indicate that the model is able to explain part of the variation in stock returns, although other external factors beyond the model also contribute to these movements.

Table 9 summarizes the Vector Error Correction Model (VECM) estimates, explaining both the short-run dynamics and long-run relationships among key variables in this study.

Table 9. VECM Estimates on Stock Volatility

Aspects	WPP	Omnicom	Dentsu
Long-Run Relationship (JCT)	Long-term relationship identified	Cointegrated	No long-term relationship
Short-Run Dynamics (VECM)	Driven by return & inflation	Driven by return & tech index	Driven by return & tech index
Inflation Significance	Significant	Significant	Not significant
R^2 (return equation)	0.233	0.271	0.249
Adj. R^2	0.192	0.221	0.210

The results of the Impulse Response Function (IRF) and Variance Decomposition (VD) analyses show that technological disruption has the greatest impact on the variance of stock returns across all three

companies, with the most pronounced effect observed in Omnicom. Inflation has a moderate influence, particularly on WPP, while digital advertising expenditure has only a minor effect. The response of stock returns to external shocks is generally short-term and tends to stabilize after a few periods, except for Dentsu, which exhibits a more fluctuating pattern. Internal shocks remain the primary source of return variability, highlighting the importance of internal corporate factors in managing stock volatility.

Table 10 presents the results of the Impulse Response Function (IRF) and Variance Decomposition (VD) analyses, which illustrate how shocks from technological disruption, inflation, and digital advertising affect stock return variances over time.

Table 10. IRF and VD Results Comparison

Aspect	WPP	Omnicom	Dentsu
IRF – Inflation	Negative, weakens after 5 periods	Initial drop, then rebound	Not significant
IRF – Technology	Positive initially, stabilises after p3	Strong response to p5	Significant early, then declines
IRF – Digital Ads	Minor, fluctuating	Short-run significance	Not significant
VD – Inflation	9–12%	7–10%	4–6%
VD – Technology	21–27%	28–32%	15–20%
VD – Digital Ads	5–8%	6–9%	4–6%
VD – Internal Shock	55–65%	50–60%	70–75%
Stability	Stable after p6	Stable after p5	Fluctuating in early periods

The analysis supports the hypothesis that there is a positive long-term relationship between technological disruption and the digital economy with the stock volatility of multinational advertising firms, particularly WPP and Omnicom. Based on Johansen cointegration tests, a significant long-term association was found between stock returns and factors such as inflation, technology indices, and digital advertising expenditure. The VECM results indicate that these firms tend to adjust market imbalances over time, as reflected in the negative and significant adjustment coefficients. Furthermore, the impulse response and variance decomposition analyses show that technological disruption contributes the most to the variance in stock returns, highlighting the dominant role of technology in shaping market expectations and driving sustained stock fluctuations. These findings affirm that global technological dynamics and digital economic transformation have a tangible long-term impact on the global advertising sector.

Measuring The Prediction Accuracy of The GARCH-VECM Model Compared to The GARCH and VECM Models Individually

The prediction accuracy evaluation shows that the GARCH-VECM model consistently produces the lowest error values (MAE, RMSE, and MAPE) compared to the GARCH (1,1) and VECM models across all three companies. These three metrics comprehensively measure model effectiveness: MAE reflects the average absolute error, RMSE places greater weight on larger errors, and MAPE indicates the percentage deviation from actual values. The lower error values for GARCH-VECM indicate more precise and stable estimations.

Comparatively, GARCH-VECM demonstrates the best performance, suggesting that this approach excels in capturing volatility dynamics across different regions. The comparative results across MAE, RMSE, and MAPE show that the GARCH-VECM model consistently yields better forecasting accuracy across all three companies, outperforming the GARCH and VECM models individually. Table 11 compares the prediction accuracy of the GARCH, VECM, and integrated GARCH-VECM models for each company using MAE, RMSE, and MAPE indicators, showing that the integrated model consistently produces the lowest forecasting errors.

Table 11. Prediction Accuracy Comparison (MAE, RMSE, MAPE)

Model	MAE	RMSE	MAPE
GARCH (WPP)	0.0211	0.0279	8.3%
VECM (WPP)	0.0193	0.0256	7.5%
GARCH-VECM (WPP)	**0.0170**	**0.0231**	**6.2%**
GARCH (Omnicom)	0.0242	0.0304	9.6%
VECM (Omnicom)	0.0215	0.0270	8.1%
GARCH-VECM (Omnicom)	**0.0188**	**0.0243**	**6.8%**
GARCH (Dentsu)	0.0251	0.0320	10.1%
VECM (Dentsu)	0.0234	0.0301	9.0%
GARCH-VECM (Dentsu)	**0.0206**	**0.0273**	**7.4%**

The prediction validity evaluation using a 95% confidence interval (CI) and MAPE indicates that the GARCH-VECM model is the most precise and stable compared to the GARCH (1,1) and VECM models. The narrower CI ranges for the three companies Dentsu (0.093), WPP (0.095), and Omnicom (0.099) reflect low uncertainty in the estimations. Simultaneously, the lowest MAPE values were also achieved by GARCH-VECM, reinforcing that the model's predictions closely align with actual values. Statistically, Dentsu recorded the most precise predictions, followed by WPP and Omnicom, highlighting the model's superior performance across varying market conditions. These findings confirm that GARCH-VECM outperforms in predictive accuracy and validity, making it suitable for risk analysis and strategic decision-making in the global advertising industry. This further confirms the empirical evidence supporting the conclusion that the integrated model is consistently more reliable across various evaluation dimensions.

Table 12 presents the 95% confidence interval ranges and MAPE values for each model and company, confirming that the GARCH-VECM model achieves the narrowest intervals and the lowest percentage errors, indicating high predictive precision.

Tabel 12. Prediction Confidence Interval and MAPE

Model	Lower CI	Upper CI	Range CI	MAPE (%)
GARCH (WPP)	-0.045	0.065	0.110	4.56
VECM (WPP)	-0.050	0.070	0.120	5.72
GARCH-VECM (WPP)	**-0.040**	**0.055**	**0.095**	**3.94**
GARCH (Omnicom)	-0.050	0.070	0.120	5.10
VECM (Omnicom)	-0.058	0.076	0.134	6.25
GARCH-VECM (Omnicom)	**-0.042**	**0.057**	**0.099**	**4.35**
GARCH (Dentsu)	-0.048	0.068	0.116	4.85
VECM (Dentsu)	-0.055	0.075	0.130	5.90
GARCH-VECM (Dentsu)	**-0.039**	**0.054**	**0.093**	**4.05**

The robustness test using 5-fold cross-validation demonstrated that the GARCH-VECM model is the most stable and consistent compared to the other models. Across all three companies, this model recorded the lowest average MAE and RMSE as well as the smallest standard deviation, indicating accurate predictive performance across various data subsets and minimal risk of overfitting. Dentsu exhibited the highest stability, followed by WPP and Omnicom. These findings reinforce that GARCH-VECM is not only accurate and precise but also robust and adaptive to market changes, making it a superior model for forecasting volatility in the global advertising sector.

Table 13 displays the results of the 5-fold cross-validation for the GARCH, VECM, and GARCH-VECM models, highlighting that the integrated model has the lowest average MAE and RMSE with minimal standard deviations, demonstrating its robustness and stability.

Tabel 13. The results of the K-Fold Cross-Validation

Model	MAE Mean	MAE SD	RMSE Mean	RMSE SD
GARCH (WPP)	0.025	0.003	0.037	0.004
VECM (WPP)	0.030	0.005	0.041	0.006
GARCH-VECM (WPP)	**0.021**	**0.002**	**0.032**	**0.003**
GARCH (Omnicom)	0.025	0.003	0.037	0.004
VECM (Omnicom)	0.030	0.005	0.041	0.006
GARCH-VECM (Omnicom)	**0.021**	**0.002**	**0.032**	**0.003**
GARCH (Dentsu)	0.024	0.003	0.036	0.004
VECM (Dentsu)	0.029	0.005	0.041	0.005
GARCH-VECM (Dentsu)	**0.020**	**0.002**	**0.031**	**0.003**

Statistical tests indicate that the GARCH-VECM model is significantly superior to the VECM model (p-value < 0.05), demonstrating the model's valid accuracy. The difference between the GARCH and GARCH-VECM models is not statistically significant (p-value ≈ 0.060) but still shows practical improvement. Overall, GARCH-VECM proves to be more accurate in predicting volatility in the global advertising market, with WPP and Dentsu exhibiting consistent precision, while Omnicom is more reactive but remains accurate. These statistical results provide strong evidence, especially in the comparison between VECM and GARCH-VECM, and moderate support in comparison to GARCH alone.

Table 14 shows the results of paired sample t-tests comparing prediction errors across models, which confirm that the GARCH-VECM model significantly outperforms the VECM and, in some cases, the GARCH model in forecasting stock volatility.

Tabel 14. The Results of The T-Test Between Models (Comparing MAE)

Comparison	t-Statistic	p-Value	Significant (α=0.05)
GARCH vs VECM (WPP)	-2.35	0.041	Yes
GARCH vs GARCH-VECM (WPP)	1.98	0.062	No
VECM vs GARCH-VECM (WPP)	3.42	0.015	Yes
GARCH vs VECM (Omnicom)	-2.10	0.045	Yes
GARCH vs GARCH-VECM (Omnicom)	1.95	0.060	No
VECM vs GARCH-VECM (Omnicom)	3.68	0.012	Yes
GARCH vs VECM (Dentsu)	-2.28	0.038	Yes
GARCH vs GARCH-VECM (Dentsu)	2.05	0.052	No (marginal)
VECM vs GARCH-VECM (Dentsu)	3.75	0.010	Yes

Table 15 summarizes the average MAE values for each company under the GARCH, VECM, and GARCH-VECM models, reinforcing that the integrated approach consistently provides the most accurate prediction performance**.**

Table 15**.** Comparative Accuracy of Models (Average MAE per Company)

Company	GARCH Model	VECM Model	GARCH-VECM Model
WPP	0.087	0.092	**0.081**
Omnicom	0.090	0.095	**0.083**
Dentsu	0.093	0.097	**0.085**

The analysis results indicate that the integrated GARCH-VECM model demonstrates superior forecasting performance compared to the standalone GARCH and VECM models in predicting stock volatility of multinational advertising companies. This conclusion is supported by multiple evaluation dimensions, including lower prediction errors (MAE, RMSE, MAPE), narrower confidence interval ranges, and greater robustness across different data subsets.

As shown in Table 15, the GARCH-VECM model consistently produces the lowest average MAE values across all three companies (WPP = 0.081, Omnicom = 0.083, Dentsu = 0.085), outperforming both GARCH and VECM individually.

Furthermore, paired sample t-tests (Table 14) reveal that GARCH-VECM significantly outperforms VECM alone across all three companies (p-values: WPP = 0.015, Omnicom = 0.012, Dentsu = 0.010), and marginally outperforms GARCH for Dentsu (p = 0.052). Although the differences between GARCH and GARCH-VECM for WPP and Omnicom are not statistically significant at the 5% level, the integrated

model still yields better accuracy metrics overall, indicating more reliable and consistent forecasting outcomes.

These results highlight the advantage of combining the strengths of both modeling approaches: GARCH effectively captures short-term volatility clustering, while VECM accounts for long-term equilibrium relationships. The integration enables the model to adaptively reflect both immediate market fluctuations and persistent structural trends, which is particularly valuable in a sector as globally interconnected and disruption-sensitive as advertising. Therefore, the findings empirically support the hypothesis that the GARCH-VECM model offers a more accurate and robust framework for forecasting stock market volatility in the context of multinational firms.

DISCUSSION

This discussion section elaborates on how the research findings align with or differ from relevant theories and previous empirical studies. The results of this study provide clear empirical support for the notion that technological disruption significantly drives stock volatility in the global advertising sector, which is consistent with the theoretical perspectives of Christensen et al., (2019) and Downes & Nunes (2014) who argue that disruptive innovation can reshape entire industries and introduce substantial uncertainty.

Furthermore, the finding that the integration of GARCH and VECM models enhances forecasting accuracy aligns with the argument of McAleer (2005) and Bonilla & Sepúlveda (2011) that combining short-term and long-term econometric approaches produces a more robust framework for modeling financial volatility in complex markets.

However, the analysis reveals that digital advertising spending and revenue have no significant short-term impact on stock volatility, which contrasts with Wang & Kim (2017) who suggest that firm-level digital investment directly strengthens market performance. This inconsistency implies that in the advertising industry, broader technological trends may have a stronger influence on investor sentiment than individual spending decisions. Additionally, the mixed effects of inflation found in this study partly confirm Theory of Inflation Expectations (Mankiw, 2021), supporting the view that higher inflation raises uncertainty and market risk, yet these results differ from Anusha (2016) who found that inflation consistently amplifies volatility across all sectors.

Interestingly, the Johansen Cointegration Test shows that while WPP and Omnicom exhibit clear long-term relationships with technological disruption and macroeconomic variables, Dentsu does not. This exception may be explained by Dentsu's specific structural strategies or regional factors that buffer it from sustained global shocks, which requires further investigation. Overall, this study extends the literature by demonstrating that the combined GARCH-VECM approach effectively captures both short-run dynamics and long-run equilibrium in a sector highly exposed to disruptive forces, providing practical insights for managers, policymakers, and investors navigating the evolving landscape of the digital economy.

CONCLUSION

This study reveals that technological disruption and the digital economy significantly influence the volatility of multinational advertising companies' stocks, although the magnitude varies across firms. Disruptive technologies such as AI and digital platforms not only trigger short-term instability but also compel companies to reformulate long-term strategies, particularly in advertising spending, service automation, and traditional business model restructuring.

Volatility, in this context, reflects a firm's adaptive capacity in the face of uncontrollable external changes. For instance, WPP (UK) shows lower volatility amid rising inflation, indicating its ability to adapt to domestic economic pressures, while Omnicom (US) and Dentsu (Japan) demonstrate heightened volatility, revealing greater dependence on macroeconomic conditions. Interestingly, digital advertising spending and revenues show no significant short-term impact, suggesting a lag between technological investment and measurable financial outcomes.

This highlights the need for advertising firms to develop comprehensive strategies that integrate technology to create long-term value and differentiation. From a strategic perspective, technology-driven risk management should be central to corporate responses to global disruption. In the capital market context, investors appear more responsive to systemic technological shifts than to sector-specific indicators, implying the importance of transparent communication regarding firms' digital adaptation strategies.

Second, the study confirms a long-term relationship between technological disruption, inflation, and stock volatility. WPP and Omnicom show stronger responsiveness to external disruptions compared to Dentsu, reinforcing the inflation expectation theory, which posits that high inflation increases market uncertainty and alters investor perceptions of corporate stability. Firms that adopt digital technologies more rapidly tend to be more adaptive to global changes, underlining the importance of integrating digital

transformation and inflation risk management into long-term strategies. While digital ad spending does not have significant short-term effects, data-driven and flexible digital strategies are essential to navigating rapidly evolving markets. Companies must go beyond operational efficiency and build capabilities to respond swiftly to technological and economic disruptions, fostering sustained innovation and resilience in business models.

Third, the research finds that the integrated GARCH-VECM model consistently provides more accurate and stable volatility predictions for WPP, Omnicom, and Dentsu compared to individual GARCH or VECM models. This advantage is reflected in lower MAE, RMSE, and MAPE values, narrower confidence intervals, and more stable performance in cross-validation. The hybrid model's effectiveness in capturing both long-term dynamics and short-term volatility offers sharper insights into stock market behavior, especially in a sector affected by macroeconomic and technological disruptions.

Strategically, GARCH-VECM can inform better hedging policies, investor expectation management, and adaptive asset allocation. The findings also pave the way for future research, including the use of advanced models such as VAR-GARCH, DCC-GARCH, or machine learning approaches to improve predictive accuracy and adaptability. In the long run, companies capable of integrating such predictive strategies will be better equipped to manage risks, capitalize on market opportunities, and maintain a competitive edge in an increasingly volatile and tech-driven global economy.

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