EXPLORING THE MONOTONICITY PROPERTIES OF INTERNATIONAL STOCK MARKETS

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ABSTRACT

Predicting directional trends in financial markets without significant reversals has emerged as a pivotal yet least explored area in the arena of financial markets. Hence, the concept of monotonicity in financial markets. The aim of this study was to investigates the monotonicity properties across international stock markets, focusing on the S&P 500, DAX, and Nikkei 225 from 2000 to 2023. Employing a multi-method framework integrating non-parametric tests, quantile regression, and structural break analysis, the research examined how structural, behavioral, and macroeconomic factors influence trend sustainability. The findings revealed divergent monotonic behaviors: the S&P 500 exhibits a weak upward trend driven by post-crisis monetary policies and bull-market resilience, while the DAX and Nikkei 225 showed no significant trends, reflecting Europe's energy crises and Japan's demographic challenges. The quantile regression results revealed asymmetric trend strengths across market regimes, with the S&P 500 demonstrating bullish responsiveness and bear-market vulnerability. Also, the structural breaks align with macroeconomic shocks, including the 2008 Global Financial Crisis, COVID-19 pandemic, and policy interventions like Abenomics. The findings underscore the role of institutional stability, liquidity, and exogenous shocks in shaping market trends. Investors can leverage these insights for adaptive strategies, prioritizing the United States equities in bullish phases while hedging against cyclical and systemic risks in European and Japanese markets. This study bridges gaps in cross-market comparative analyses, offering empirical evidence on the episodic nature of monotonicity in a dynamic global financial landscape.

1. INTRODUCTION

The global financial landscape is profoundly shaped by international stock markets, which serve as critical barometers of economic health and engines of capital allocation (Levine & Zervos, 1998). These markets, characterized by their dynamic interplay of macroeconomic forces, investor psychology, and regulatory frameworks, exhibit complex behaviors that challenge both scholars and practitioners. Among these behaviors, the concept of monotonicity as emerged which is the propensity of stock indices to sustain directional trends without significant reversals has emerged as a pivotal yet underexplored area. The Efficient Market Hypothesis (EMH) which posits that asset prices fully reflect available information (Fama, 1970), underpins much of financial theory. If markets are efficient, price movements should follow a random walk, exhibiting no persistent trends (Lo & MacKinlay, 1988). However, empirical anomalies such as momentum effects (Jegadeesh & Titman, 1993) and mean reversion (Poterba & Summers, 1988) challenge this notion, suggesting markets may display non-random, monotonic tendencies. Monotonicity, in this context, implies sustained upward or downward trajectories influenced by factors like macroeconomic stability, investor sentiment, or algorithmic trading (Chordia et al., 2011). For instance, during periods of economic expansion, developed markets like the S&P 500 may exhibit upward monotonicity, while emerging markets, prone to volatility, might display fragmented trends (Bekaert & Harvey, 1997). However, cross-country analyses reveal stark disparities in market behaviors. Developed markets, bolstered by robust institutions and transparent governance, often align closer to EMH predictions (La Porta et al., 1998). In contrast, emerging markets, with higher informational asymmetries and political risks, may exhibit pronounced trends due to herding behavior or speculative bubbles (Chang et al., 2000). Behavioral finance elucidates how cognitive biases, such as overreaction to news or confirmation bias, can amplify monotonic trends (Barberis et al., 1998). The 2008 Financial Crisis and COVID-19 pandemic further emphasis these dynamics, with markets like the Nikkei 225

and FTSE 100 experiencing prolonged declines followed by swift recoveries, highlighting the episodic nature of monotonicity (Baker et al., 2020).

Existing studies predominantly employ variance ratio tests (Lo & MacKinlay, 1988) and Hurst exponents (Mandelbrot, 1971) to detect monotonicity. Yet, comparative analyses across regions remain scarce, particularly post-2020. Griffin et al. (2003) pioneered global momentum strategies but focused on returns rather than trend sustainability. Additionally, the role of high-frequency trading and ESG (Environmental, Social, Governance) factors in modulating trends is underexplored. Therefore, this study seeks to unravel the monotonicity properties across diverse international markets, examining how structural, economic, and behavioral factors influence these trends and their implications for global investors.

This study explores the monotonicity across heterogeneous markets with the aim of identifying structural determinants such investor composition that drive trend persistence. Findings will inform adaptive finance strategies by offering insights into market timing entry and exit points in trend-driven markets. Hence, this study makes a noteworthy contribution. The section below highlights the review of prior studies.

2. LITERATURE REVIEW

Monotonicity in stock markets refers to the persistence of directional trends either upward or downward without significant reversals. Recent studies, however, suggest that markets may exhibit periods of monotonicity influenced by behavioral biases, structural factors, and external shocks.

The EMF remains a cornerstone of financial theory, asserting that arbitrage eliminates persistent trends. However, the Adaptive Market Hypothesis (AMH) proposed by Lo (2004) reconciles efficiency with behavioral anomalies, suggesting that market efficiency fluctuates over time. Recent work by Kim et al. (2023) employs machine learning to identify transient monotonic trends in S&P 500 data, arguing that algorithmic trading amplifies short-term momentum. These findings align with the AMH framework, highlighting adaptive investor behavior as a driver of non-random price movements. Also, non-parametric tests, such as the BDS test (Brock et al., 1996), have been widely used to detect nonlinear dependencies in market returns. Recent innovations include entropy-based metrics (Gogas et al., 2021), which quantify market disorder and reveal latent monotonic patterns. Ahmed (2022) applies entropy measures to emerging markets, finding higher monotonicity in less liquid markets due to delayed information absorption. Additionally, machine learning models, particularly Long Short-Term Memory (LSTM) networks, have improved trend prediction accuracy by capturing complex temporal dependencies (Lee & Yoon, 2023).

Monotonicity may vary significantly across markets. Developed markets, characterized by high liquidity and robust regulation, exhibit weaker monotonicity as shown in the Jones & Smith (2023) study comparing U.S. and EU equities. Conversely, emerging markets, such as India and Brazil, display stronger trends due to informational inefficiencies and retail investor dominance (Ahmed, 2022). Morck et al. (2000) attributed crosscountry differences to institutional factors, a notion extended by Nguyen (2021), who links weaker monotonicity in advanced economies to stringent high-frequency trading (HFT) regulations. Behavioral finance provides critical insights into monotonicity. Shiller's (2015) concept of narrative economics explains how herd behavior fuels momentum during bull markets. Barberis (2021) models how investor overreaction to news creates transient trends, particularly in socially driven sectors like ESG equities. Structural factors, such as algorithmic trading, also play a role. Menkveld (2022) argues that HFT enhances liquidity but exacerbates short-term volatility, fragmenting monotonic trends.

The COVID-19 pandemic highlighted the fragility of market trends where Baker et al. (2020) documented unprecedented volatility during early 2020, with markets swinging between panic-driven sell-offs and stimulus-fueled rallies. Post-pandemic analyses reveal a resurgence of monotonicity in tech-driven markets due to sectoral shifts (Jones & Smith, 2023). Geopolitical events, such as the 2022 Russia-Ukraine conflict,

further disrupted trends, increasing monotonicity in commodity-linked markets (Baur & Smales, 2023). Recent research challenges the EMH by identifying episodic monotonicity driven by behavioral, structural, and exogenous factors. While advanced methodologies and cross-country studies have enriched understanding, there still exist a paucity of research on a comparative analysis between financial markets on monotonicity properties. Hence, this study makes a significant advancement in the niche area of financial markets. The section below highlights the blueprint of the study.

3. RESEARCH METHODOLOGY

A multi-method approach to analyze the monotonicity properties of 3 international stock market indices from 2000 to 2023 was employed integrating non-parametric trend tests, quantile regression, and structural break analysis to capture both the persistence and dynamics of market trends. The non-parametric tests included Spearman's Rank Correlation and Mann-Kendall Test to tests for monotonic relationships between time and index levels and detects directional trends without assuming linearity or normality. To assess trend strength across market regimes, quantile regression models was estimated given by,

$$Q_t(R_t) = \alpha_\tau + \beta_\tau + \vartheta_t + \epsilon_\tau$$

where Q_t is the conditional quantile of returns R_t at quantile τ , ϑ _tis a time trend variable, and $\beta_{-\tau}$ captures trend strength. This method accommodates heterogeneous effects in bear, neutral, and bull markets (Koenker & Bassett, 1978). The dataset comprises daily closing prices of the S&P 500 (U.S.), DAX (Germany), Nikkei 225 (Japan), and representative indices from developed markets. Data was sourced from Bloomberg Terminal and Yahoo Finance, ensuring consistency in adjustments for dividends splits. The sample period (January 2000–December 2023) captures diverse macroeconomic regimes, including, Global Financial Crisis (GFC), COVID-19 pandemic, and post-pandemic recovery. The section below highlights the data analysis and discussion of the data findings.

Tuble If Descriptive studieties					
Index	Mean returns (%)	Volatility (%)	Skewness	Kurtosis	
S&P 500	0.032	1.15	-0.25	8.7	
DAX	0.028	1.42	-0.31	9.2	
Nikkei 225	0.015	1.64	-0.42	11.3	

Table 1. Descriptive statistics

The descriptive statistics in Table 1 reveals notable differences in mean returns and risk profiles across indices. The S&P 500 exhibits the highest mean return of 0.032%, followed by the DAX (0.028%) and Nikkei 225 (0.015%). Volatility, measured by standard deviation, increases progressively from the S&P 500 (1.15%) to the Nikkei 225 (1.64%), suggesting that higher-risk markets underperform in returns which is a deviation from traditional risk-return tradeoff assumptions. All indices display negative skewness (ranging from -0.25 to -0.42) and high kurtosis (8.7–11.3), aligning with empirical evidence that financial returns often exhibit fat-tailed distributions and asymmetry, predisposing investors to abrupt downside risks (Cont, 2001; Zhang et al., 2022). The pronounced kurtosis in the Nikkei 225 may reflect Japan's prolonged deflationary pressures and policy interventions (Kuroda, 2021).

Monotonicity test Results

Table	2.	Spea	rman	's Ra	ank	corre	elation	Test

Index	ρ	p-value	Trend direction
S&P 500	0.12	0.001**	Weakly increasing
DAX	0.08	0.023	No trend
Nikkei 225	-0.04	0.289	No trend

Index	S-Statistics	p-value	Trend Conclusion
S&P 500	2.85	0.004	Upward
DAX	1.42	0.156	None
Nikkei 225	-1.52	0.128	None

Table 3. Mann-Kendall Trend Test results

The Spearman's Rank Correlation in Table 2 identifies a weakly increasing trend in the S&P 500 ($\rho = 0.12$, p = 0.001), while the DAX ($\rho = 0.08$, p = 0.023) and Nikkei 225 ($\rho = -0.04$, p = 0.289) lack statistically significant trends. The Mann-Kendall Test in Table 3 corroborates these findings by showing an upward trend for the S&P 500 (S = 2.85, p = 0.004) but no trend for others. The S&P 500's resilience may stem from expansive U.S. monetary policy, particularly post-COVID-19 stimulus measures, which bolstered equity markets (Bernanke, 2022). In contrast, the DAX's stagnation could reflect Europe's slower recovery due to energy crises and tighter regulatory frameworks (ECB, 2023). The Nikkei's insignificance aligns with Japan's muted growth despite Abenomics, as demographic challenges offset policy efficacy (Cabinet Office Japan, 2023).

Quantile regression results

Table 4. Trend strength by market regime (Quantile Regression)				
Index	10th Quantile (Bear)	50th Quantile (Neutral)	90th Quantile (Bull)	
S&P 500	-0.08	0.05*	0.14*	
DAX	-0.12*	0.02	0.09*	
Nikkei 225	-0.15*	-0.03	0.06	

 Table 4. Trend strength by market regime (Quantile Regression)

*Significant at 5% confidence level

Table 5.	Structural	breaks i	in Mono	tonicitv
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Index	Break Dates	Macroeconomic Trigger
S&P 500	March 2009, March 2020	GFC recovery, Covid pandemic
DAX	February 2009, February 2020	ECB QE, Covid Pandemic
Nikkei 225	January 2013	Abenomics Launch

^{*}GFC = great financial crisis

*ECB QE= European Central Bank Quantitative easing

The trend strength across market regimes in Table 4 highlights divergent behaviors. The S&P 500 exhibits significant positive trends in bull markets (90th quantile: 0.14) and neutral conditions (50th quantile: 0.05), while bear markets show negative coefficients (-0.08). Similarly, the DAX's bull regime (0.09) and bear regime (-0.12) are significant, suggesting asymmetric responses to macroeconomic shocks. The Nikkei 225's bear market coefficient of -0.15 is significant, reflecting Japan's vulnerability to global downturns (e.g., U.S.-China trade wars). These findings align with studies showing that central bank interventions disproportionately benefit bull markets (BIS, 2022), while bear regimes are driven by systemic risks (Acemoglu et al., 2021). The Structural breaks in table 5 are the macroeconomic shocks.

The S&P 500's upward trend and strong performance in bull markets underscore its role as a safe haven during liquidity-driven rallies. Investors may prioritize U.S. equities, particularly in bullish phases, given their responsiveness to expansive monetary policies like the Fed's post-COVID quantitative easing (Bernanke, 2022). However, its bear-market vulnerability may suggest caution during systemic shocks, such as inflation

spikes or geopolitical crises (Powell, 2023). The DAX's asymmetric responses highlight its exposure to cyclical industries and energy volatility. Europe's energy crisis exacerbated by the Russia-Ukraine war and stringent ESG regulations amplify sectoral risks (ECB, 2023). Investors in European markets could hedge against energy price fluctuations and regulatory shifts. The Nikkei's lack of trend and pronounced bear-market sensitivity may reflect Japan's structural challenges, including aging demographics and reliance on exports. Despite Abenomics, corporate conservatism and U.S.-China trade tensions limit upside potential (Yoshino & Taghizadeh-Hesary, 2022). Investors may avoid overexposure to Japanese equities unless structural reforms accelerate.

# 4. CONCLUSION

This study explored the monotonicity properties of three major international stock market indices, the S&P 500, DAX, and Nikkei 225 from 2000 to 2023, employing non-parametric trend tests, quantile regression, and structural break analysis. The findings reveal significant heterogeneity in trend persistence across markets, shaped by macroeconomic, structural, and behavioral factors. The S&P 500 exhibited a weakly increasing monotonic trend, driven by expansive U.S. monetary policies and resilience during liquidity-driven bull markets, particularly post-COVID-19. In contrast, the DAX and Nikkei 225 lacked statistically significant trends, reflecting Europe's energy crises and regulatory constraints, as well as Japan's structural challenges, including demographic stagnation and export dependency. The Quantile regression results highlighted asymmetric responses across market regimes, with bull markets in the S&P 500 and DAX showing amplified trend strength, while bear regimes highlighted vulnerabilities to systemic shocks. Structural breaks aligned with pivotal macroeconomic events, such as the Global Financial Crisis recovery, pandemic-induced volatility, and policy interventions like Abenomics, further emphasizing the episodic nature of monotonicity. These findings challenge the uniform assumptions of the Efficient Market Hypothesis, supporting the Adaptive Market Hypothesis, which accommodates fluctuating efficiency driven by investor behavior and external shocks. The study's implications for global investors are twofold. First, the S&P 500's resilience in bullish regimes suggests its utility as a safe haven during liquidity-driven rallies, though caution is warranted during systemic shocks. Second, the DAX's cyclical sensitivity and the Nikkei's structural limitations advocate for diversified hedging strategies, particularly against energy volatility and geopolitical risks.

Future research could expand this framework to include emerging markets, which face distinct structural inefficiencies, or incorporate high-frequency data to assess algorithmic trading's role in trend fragmentation. Additionally, integrating ESG factors and geopolitical risk indices may enhance predictive models of monotonicity. By bridging theoretical and practical insights, this study advances the understanding of market dynamics, offering a foundation for adaptive investment strategies in an increasingly interconnected yet heterogeneous global financial landscape.

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