ATTENUATED ASYMMETRY: HOW MICROSTRUCTURE SHAPES VOLATILITY DYNAMICS IN AN EMERGING MARKET

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ABSTRACT

This study investigates whether the canonical asymmetric volatility documented in developed markets can be generalized to an emerging market setting, using the Casablanca Stock Exchange (MASI index, 2011–2023) as a case study. Applying symmetric and asymmetric GARCH models with a three-period subsample robustness check (pre-COVID, COVID, post-COVID), we uncover a pattern of attenuated asymmetry. During normal conditions and the COVID-19 crisis, the market exhibits significant volatility persistence coupled with symmetric responses to shocks, challenging the near-universal evidence of leverage effects. However, the post-COVID geopolitical crisis temporarily activates powerful asymmetry, revealing that volatility dynamics are state-dependent and crisis-type specific. The symmetric GARCH model outperforms asymmetric specifications in forecasting accuracy across most periods, demonstrating that additional complexity is unwarranted during normal conditions. These findings show that microstructure characteristics fundamentally shape volatility dynamics, and that the leverage effect cannot be universally assumed across all emerging markets.

KEY WORDS

stock market, emerging economy, volatility, persistence, symmetries

JEL CODES

G12, G15, C58

1 INTRODUCTION

The modeling and forecasting of financial volatility stand as cornerstones of empirical finance, critical for asset pricing, risk management, and portfolio construction. A well-established stylized fact across major global equity markets is the asymmetric response of volatility to news, commonly known as the "leverage effect" (Black, 1976) or the "volatil-

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ity feedback effect" (Campbell and Hentschel, 1992). This phenomenon describes the tendency for negative return shocks (bad news) to increase subsequent volatility more than positive return shocks (good news) of the same magnitude. The prevalence of this asymmetry has been extensively documented in both developed markets (Nelson, 1991; Glosten et al., 1993; Aliyev et al., 2020) and emerging economies (Li and Giles, 2015; Kumar, 2019; Lin, 2018), making it a fundamental consideration in volatility modeling, and a key assumption underlying asymmetric GARCH-family models like EGARCH and GJR-GARCH.

However, the universal applicability of this paradigm is increasingly being questioned by evidence from markets with distinctive microstructural characteristics. Emerging markets, while often grouped together in the literature, exhibit significant heterogeneity in their institutional frameworks, investor composition, liquidity levels, and informational transparency (Morck et al., 2000; Bekaert and Harvey, 1997). These factors profoundly influence how information is processed, disseminated, and reflected in asset prices, suggesting that volatility dynamics may not be homogeneous across all emerging markets. The Casablanca Stock Exchange, representing the Moroccan market, presents a particularly compelling case study that appears to deviate from the expected norm.

This study documents what we term "attenuated asymmetry," a volatility pattern where the canonical leverage effect is substantially diminished or entirely absent during normal market conditions. Preliminary evidence from our analysis suggests that the Moroccan market exhibits a distinctive profile: significant volatility persistence coexists with a symmetric response to information shocks during calm periods, with asymmetry emerging only during extreme geopolitical crises. This finding contradicts the predominant narrative of universal asymmetry and forms the central puzzle of this paper. Rather than framing Morocco as an anomaly relative to all emerging markets, which would create a conceptual tension, we present it as an anomalous case that illuminates how microstructure shapes volatility dynamics. The Moroccan market's specific characteristics, moderate liquidity, particular investor composition, and a unique information dissemination environment, provide a natural laboratory for understanding why asymmetry may be attenuated in some contexts and activated in others.

The existing literature on Moroccan market volatility remains limited and fragmented. El Jebari and Hakmaoui (2017) documented strong volatility persistence in the MASI index, challenging weak-form market efficiency. Nabouk (2021) examined the impact of COVID-19 on Moroccan volatility, finding that the crisis amplified asymmetric effects, though his sample ended in 2020, capturing only the initial crash. Beraich and Fadali (2021) modeled MASI volatility during the pandemic using a DCC-GARCH framework, documenting increased volatility during confinement followed by stabilization. However, no study to date has systematically tested whether asymmetric models improve our understanding and forecasting of risk specifically in the Moroccan context using a long, recent dataset spanning multiple regimes (2011–2023) and a comprehensive multi-model comparison framework. More importantly, no study has examined how volatility dynamics evolve across different types of crises, distinguishing between health shocks (COVID-19) and geopolitical shocks (Ukraine war, inflationary pressures), to test whether asymmetry is a stable structural feature or a state-dependent phenomenon activated only by certain crisis types.

This study addresses these gaps through a threefold contribution. First, we provide robust, up-to-date evidence on the volatility dynamics of a North African emerging market, filling a geographical gap in a literature that has disproportionately focused on Asian and Latin American economies. Second, we document the phenomenon of "attenuated asymmetry," demonstrating that the Moroccan market exhibits structural symmetry during normal conditions and health crises, with powerful leverage effects emerging only during extreme geopolitical shocks. This finding challenges the uncritical application of asymmetric volatility models to all emerging markets and reveals that volatility dynamics are state-dependent and crisis-type specific. Third, we link these empirical findings to the unique microstructural characteristics of the Casablanca Stock Exchange, limited liquidity, specific investor composition, and particular information dissemination environment, offering a plausible explanation for why asymmetry is attenuated in some contexts and activated in others.

Our empirical strategy employs a comprehensive framework. We apply symmetric (GARCH) and asymmetric (EGARCH, GJR-GARCH) models to daily MASI index data from 2011 to 2023, a period encompassing multiple global and regional economic shifts. Beyond model estimation, we utilize News Impact Curves (NIC) to visually assess symmetry and evaluate out-of-sample forecasting performance to determine which specification is most appropriate for practical applications. Crucially, we partition the sample into three economically meaningful subperiods, pre-COVID (2011–2019), COVID-19 (2020–2021), and post-COVID geopolitical crisis (2022–2023), to test whether volatility dynamics are stable or evolve with market conditions.

The remainder of the paper is structured as follows. Section 2 reviews the relevant literature, situating our study within the broader volatility modeling tradition and identifying the specific gaps we address. Section 3 outlines the methodological framework of the GARCH models and the News Impact Curve. Section 4 describes the data and presents the empirical results. Section 5 provides a comprehensive discussion of the findings, their implications for theory and practice, and the study's limitations. Finally, Section 6 concludes.

2 LITERATURE REVIEW

The modeling of financial volatility has been a central preoccupation of empirical finance since Mandelbrot (1963) first observed that large changes tend to be followed by large changes, of either sign, a phenomenon now known as volatility clustering. This observation laid the groundwork for the development of autoregressive conditional heteroskedasticity models, beginning with Engle's (1982) ARCH model, which formally captured time-varying volatility by modeling conditional variance as a function of past squared residuals. Bollerslev (1986) extended this framework with the GARCH model, which added lagged conditional variances to the specification, providing a more parsimonious representation that remains the workhorse of empirical volatility research to this day.

These foundational contributions enabled researchers to move beyond the unrealistic assumption of constant variance and to model the dynamic evolution of risk in financial markets. However, as empirical applications accumulated, a consistent pattern emerged: the symmetric GARCH model, while capturing volatility clustering, failed to account for a pervasive feature of equity returns, the tendency for volatility to respond differently to positive and negative shocks.

The asymmetry in volatility responses was first documented by Black (1976), who observed that negative returns tend to be followed by larger increases in volatility than positive returns of the same magnitude. Black attributed this phenomenon to the leverage effect A decline in a firm's stock price increases its debt-to-equity ratio, making the remaining equity riskier and thus more volatile. Campbell and Hentschel (1992) later proposed an alternative volatility feedback mechanism, suggesting that expected increases in volatility following bad news require higher future returns, causing immediate price declines that amplify the initial shock. These theoretical insights motivated the development of asymmetric GARCH models capable of capturing such effects. Nelson (1991) introduced the Exponential GARCH (EGARCH) model, which specifies conditional variance in logarithmic form and allows positive and negative shocks to have asymmetric impacts through a sign coefficient. Glosten et al. (1993) proposed the GJR-GARCH model, which incorporates a dummy variable that isolates the incremental effect of negative shocks. In their seminal study, Engle and Ng (1993) employed both models on Japanese stock return data, demonstrating that asymmetric specifications capture the leverage effect more effectively than symmetric alternatives and introducing the News Impact Curve as a diagnostic tool for visualizing asymmetry.

The prevalence of asymmetric volatility in developed markets has been extensively documented. In US markets, the leverage effect is now considered a stylized fact, with studies consistently finding that negative shocks generate substantially larger volatility responses than positive shocks (French et al., 1987; Schwert, 1989). Similar patterns have been confirmed in European markets (Koutmos and Saidi, 1995) and Japanese markets (Engle and Ng, 1993). More recently, Aliyev et al. (2020) modeled volatility in the NASDAQ-100 index and found significant leverage effects, with negative shocks having a more pronounced impact than positive shocks of equal magnitude. Gil-Alana et al. (2023) examined major global stock markets and documented high persistence across all regions, with asymmetric responses varying in magnitude but consistently present.

The literature on emerging markets has largely followed the developed-market narrative, with most studies reporting significant asymmetric volatility. However, emerging markets exhibit considerable heterogeneity in their institutional frameworks, investor composition, liquidity levels, and informational transparency, factors that may influence how information is incorporated into prices and reflected in volatility. Li and Giles (2015) examined volatility spillover effects between developed and Asian emerging markets, finding significant asymmetric responses in both sets of markets, though the magnitude varied across countries. Lin (2018) modeled volatility in China's SSE Composite Index and found significant leverage effects, concluding that bad news had a greater impact on volatility than good news.

Nguyen (2010) examined the impact of financial liberalization on volatility in eight emerging markets, finding that volatility did not increase significantly following liberalization and tended to decline during periods of large capital inflows. While this study did not focus specifically on asymmetry, it highlighted the importance of market structure and external factors in shaping volatility dynamics, a theme relevant to understanding why some emerging markets may deviate from the asymmetric pattern. Aliyev et al. (2020) worked on estimating the volatility of nonfinancial, innovative and hi-tech focused stock index names NASDAQ-100, using GARCH models for daily data over the January 2000 and March 2019 period. They found the persistence phenomenon in the volatility shocks on the index returns. In addition to that, they also found the leverage effect and the asymmetric impact of the shocks, showing high impact of the negative shocks than the positive of the same size. This conclusions offers to investors the possibility of establishing future positions in expectation of this characteristic.

More recently, Enow (2023) forecasted volatility persistence across international stock markets and concluded that volatility shocks persist for extended periods, suggesting high uncertainty and the need for adaptive investor strategies. Chaudhary et al. (2020) examined volatility during the COVID-19 crisis and found dramatic increases across markets, though asymmetry was not their primary focus. Lavin et al. (2021) investigated the predictive power of implied volatility indices for global market synchronization, demonstrating that volatility expectations contain information about future market co-movements, an indirect channel through which asymmetry could propagate across markets.

Studies specifically addressing the Moroccan stock market remain limited, and their findings are mixed. El Jebari and Hakmaoui (2017) investigated volatility persistence in the MASI index using a fractionally integrated EGARCH model, finding strong persistence that challenged weak-form market efficiency. However, their focus was on long memory rather than asymmetry per se, and they did not directly test whether asymmetric specifications improved model performance.

Nabouk (2021) examined the effect of the COVID-19 crisis on volatility persistence and asymmetry in the Moroccan market. Using GARCH specifications, he found that before COVID, there was pronounced persistence across the market, with the most liquid securities showing less persistence. Crucially, he reported that COVID amplified the asymmetric effect of negative shocks, a finding that appears to conflict with the insignificance of our COVID-period asymmetry coefficients. This discrepancy may stem from differences in sample periods (Nabouk's analysis ended in 2020, capturing only the initial crash) or model specifications, highlighting the need for extended samples and robust multi-model approaches. Beraich and Fadali (2021) modeled MASI volatility during COVID using a DCC-GARCH framework, finding increased volatility during confinement followed by stabilization after gradual deconfinement. Their focus was on the dynamics of volatility rather than asymmetry, and they did not explicitly test whether negative shocks had disproportionate effects.

The preceding review reveals several important gaps that motivate this study. First, while asymmetric volatility has been extensively documented in developed markets and larger emerging economies, evidence from North African markets, particularly Morocco, remains scarce and fragmented. The few existing studies focus primarily on persistence rather than asymmetry, use limited sample periods, and do not systematically compare symmetric and asymmetric specifications. Second, the existing literature has not adequately addressed the question of whether asymmetric models are always superior to symmetric alternatives in emerging markets. Most studies begin with the implicit assumption that leverage effects exist and proceed to estimate EGARCH or GJR-GARCH models without testing whether the additional complexity is justified. This approach risks imposing developed-market stylized facts on markets with fundamentally different microstructures, lower liquidity, different investor composition, and distinct information dissemination environments. Third, the Moroccan evidence is contradictory. While Nabouk (2021) found that COVID amplified asymmetry, our preliminary analysis suggests that the full-sample asymmetry may be driven entirely by the post-COVID geopolitical period, with pre-COVID and COVID periods exhibiting symmetry. This apparent contradiction cannot be resolved without a comprehensive study that: (a) uses a long, recent dataset spanning multiple regimes (2011–2023); (b) systematically tests a range of symmetric and asymmetric models; (c) explicitly focuses on the symmetry of volatility responses as a potential defining characteristic; (d) uses model comparison and forecasting performance to guide model selection; and (e) partitions the sample into economically meaningful subperiods to test whether asymmetry is stable or state-dependent. Fourth, the literature has not adequately explored the implications of volatility symmetry for market efficiency and risk management. If the Moroccan market is genuinely symmetric, this challenges the universal applicability of the leverage effect and suggests that practitioners should rely on simpler models for forecasting and hedging. Conversely, if asymmetry emerges only during specific crisis types (geopolitical versus health crises), this has important implications for regime-aware risk management.

This study addresses these gaps by providing robust, up-to-date evidence on the volatility dynamics of the Casablanca Stock Exchange. We contribute to the literature in four ways. First, we fill a geographical gap by focusing on a North African emerging market that has received limited attention in the volatility literature compared to Asian and Latin American counterparts. Second, we challenge the uncritical application of asymmetric volatility models by demonstrating that symmetry can be a structural feature of markets with specific microstructural characteristics theorized in the literature (liquidity, investor composition). Third, we introduce a novel subsample robustness framework that reveals how volatility dynamics evolve with crisis type, distinguishing between health crises (which amplify persistence but not asymmetry) and geopolitical crises (which activate leverage effects). Fourth, we link these empirical findings to practical implications for forecasting, risk management, and market regulation, providing actionable insights for investors and policymakers operating in similar emerging market contexts. By doing so, we shift the inquiry from “Is asymmetry present?” to the more nuanced and practical question: In this specific market context, does modelling asymmetry improve our understanding and forecasting of risk?

3 METHODOLOGY

This section outlines the econometric framework employed to investigate volatility dynamics and asymmetry in the Casablanca Stock Exchange. Following the foundational contributions of Engle (1982) and Bollerslev (1986), we employ a suite of GARCH-family models that capture the time-varying nature of financial volatility. Our methodological approach is designed to test the central hypothesis of this study, whether the Moroccan market exhibits the asymmetric volatility patterns (leverage effects) documented in most developed and emerging markets, or whether it follows the distinctive symmetric pattern we term the “symmetry paradox”.

The Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model, introduced by Bollerslev (1986), extends Engle’s (1982) ARCH framework by incorporating lagged conditional variances into the volatility equation. This parsimonious specification captures the volatility clustering phenomenon, the tendency for large price changes to be followed by further large changes, while avoiding the profligate parameterization of high-order ARCH models. The GARCH (1,1) specification, which has become the workhorse of empirical finance due to its ability to model most financial time series parsimoniously, is expressed as:

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \epsilon_{t-1}^2,$$

where h_t is the conditional variance at time t, ω is the constant term (baseline volatility), ϵ_{t-1}^2 is the squared residual from the mean equation (the ARCH term capturing the impact of past news), and h_{t-1} is the lagged conditional variance (the GARCH term capturing volatility persistence). The sum $\alpha + \beta$ measures the persistence of volatility shocks: values close to unity indicate that shocks decay slowly, while values exceeding unity suggest explosive behavior. While the GARCH model effectively captures volatility clustering and persistence, its symmetric structure assumes that positive and negative shocks of equal magnitude have identical effects on volatility, a restriction that conflicts with the well-documented leverage effect (Black, 1976). To test whether this symmetry holds in the Moroccan context, we must employ asymmetric specifications.

To investigate the presence and magnitude of asymmetric volatility responses, we employ two complementary asymmetric specifications: the Exponential GARCH (EGARCH) model of Nelson (1991) and the GJR-GARCH model of Glosten et al. (1993). Each captures asymmetry through different mechanisms, providing robustness to our conclusions.

The EGARCH (1,1) model specifies the conditional variance in logarithmic form:

$$\ln(h_t) = \omega + \alpha \left| \frac{\epsilon_{t-1}}{\sqrt{h_{t-1}}} \right| + \\ + \gamma \frac{\epsilon_{t-1}}{\sqrt{h_{t-1}}} + \beta \ln(h_{t-1})$$

The logarithmic formulation has two key advantages: it ensures that the conditional variance remains positive without imposing parameter restrictions, and it allows the coefficient γ to capture asymmetric effects directly. A negative and statistically significant γ indicates that negative shocks increase volatility more than positive shocks of the same magnitude, the classic leverage effect. The magnitude of asymmetry can be quantified by comparing the impact of a positive shock $(\alpha + \gamma)$ versus a negative shock $(\alpha - \gamma)$.

The GJR-GARCH (1,1) model takes a different approach, introducing a dummy variable that isolates the incremental impact of negative shocks:

$$h_t = \omega + \alpha\epsilon_{t-1}^2 + \gamma\epsilon_{t-1}^2 I(\epsilon_{t-1} < 0) + \beta h_{t-1},$$

where $I(\cdot)$ is an indicator function equal to 1 when the lagged residual is negative and 0 otherwise. In this specification, α captures the impact of positive shocks, while $\alpha + \gamma$ captures the impact of negative shocks. A positive and statistically significant γ confirms the presence of leverage effects, with the magnitude indicating how much additional volatility is generated by bad news relative to good news of the same size. These two asymmetric models offer complementary perspectives: EGARCH captures asymmetry through the sign of the standardized shock in a logarithmic framework, while GJR-GARCH provides a more intuitive interpretation through a dummy variable in the linear variance equation. Convergence of findings across both specifications strengthens confidence in the results.

Following Engle and Ng (1993), we complement our model estimations with News Impact Curve (NIC) analysis. The NIC provides a visual representation of how each model translates positive and negative shocks into volatility, holding constant the information available at time $t-1$. For each model, we compute the implied volatility response to shocks ranging from -3 to $+3$ standard deviations, allowing direct comparison of symmetric versus asymmetric responses. This graphical tool serves two purposes. It visually confirms the presence or absence of leverage effects detected by the coefficient estimates, and it illustrates the economic magnitude of any asymmetry, whether the differences between good and bad news impacts are practically significant or merely statistically detectable.

The contribution of our methodological approach lies not in the development of new econometric techniques but in the strategic combination and application of existing models to test a specific hypothesis in an under-researched market context. While GARCH-family models have been extensively applied in developed markets (Nelson, 1991) and larger emerging economies (Li and Giles, 2015; Lin, 2018), their application to North African markets, particularly with a focus on testing the universality of asymmetric volatility, remains limited. Our methodological contribution is threefold.

First, by employing both symmetric and asymmetric specifications, we create a comparative framework that directly tests whether the additional complexity of asymmetric models is justified for the Moroccan market. If the symmetric GARCH model performs as well as or better than its asymmetric counterparts, in terms of both statistical significance and forecasting accuracy, this provides evidence that the leverage effect is not a universal feature of all markets. This comparative approach, advocated by Engle and Ng (1993) in their seminal work on news impact, moves beyond simply estimating models to critically evaluating their appropriateness for the specific market context. Second, the inclusion of two distinct asymmetric specifications (EGARCH and GJR-GARCH) provides robustness against the possibility that any single model's findings are driven by its particular functional form. Convergence of results across both asymmetric models, whether toward significance or insignificance, strengthens confidence in the conclusions. As noted by Baur and Dimpfl (2019), different asymmetric models can produce divergent results when asymmetry is weak or unstable; our multi-model approach guards against over-interpreting model-specific artifacts.

Third, and most critically, our methodological framework extends beyond full-sample estimation to incorporate subsample robustness analysis partitioned by economically meaningful regimes (pre-COVID, COVID, post-COVID). This approach, motivated by the growing recognition that volatility dynamics are not constant over time (Hamilton and Susmel, 1994; Guidolin and Timmermann, 2006), allows us to test whether the symmetry we document is a stable structural feature of the Moroccan market or an artifact of averaging across heterogeneous periods. The subsample analysis, combined with the full-sample estimations, provides a comprehensive picture of how volatility dynamics evolve with changing market conditions, a contribution that goes beyond the typical application of GARCH models in emerging market studies.

Following standard practice in financial econometrics, we employ a dual-criterion approach for model selection using both the Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC). The ARMA(2,0) specification for the mean equation was selected based on its consistent performance across multiple selection metrics, capturing short-term momentum effects while maintaining parsimony. The presence of ARCH effects in the residuals was confirmed through the Engle (1982) ARCH-LM test, justifying the application of GARCH-family models.

For volatility modeling, we adopt a comprehensive comparison framework evaluating both in-sample fit (through information criteria and coefficient significance) and out-of-sample forecasting performance through RMSE, MAE and the Model Confidence Set (MCS) procedure of Hansen et al. (2011). This test sequentially eliminates the worst-performing models from a set of candidate models until a set of 'superior models' is identified with a given confidence level (we use $\alpha = 0.10$). A model's survival in the MCS indicates that there is no statistically significant evidence that it is outperformed by any other model in the set. This complements the point-estimate comparisons of RMSE and MAE. This dual evaluation ensures that our model recommendations balance theoretical coherence with practical forecasting utility, a critical consideration given that superior in-sample fit does not guarantee superior out-of-sample performance. All models are estimated using maximum likelihood with the assumption of normally distributed errors, and coefficient covariances are computed using the outer product of gradients for robustness against non-normality.

4 DATA AND RESULTS

This section presents the empirical findings of our investigation into the volatility dynamics of the Casablanca Stock Exchange. We begin with a descriptive overview of the MASI return series, followed by stationarity tests to validate our modeling approach. We then present the estimation results of the symmetric and asymmetric GARCH models, assess their in-sample performance, and evaluate their out-of-sample forecasting accuracy. Finally, we visualize the symmetry of volatility responses using News Impact Curves. The analysis covers daily data from 2011 to 2023, ensuring a robust and contemporary assessment.

4.1 Descriptive Statistics

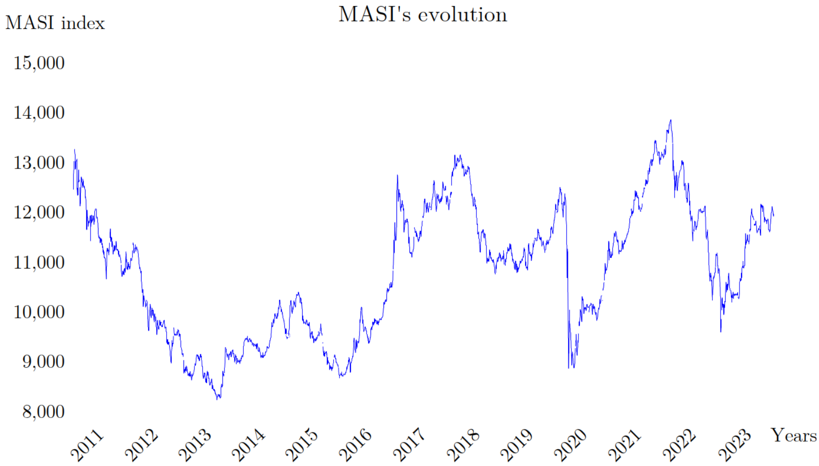
The Casablanca Stock Exchange (CSE) exhibits structural characteristics that provide a plausible economic foundation for our empirical findings. It is a market of limited depth: the average daily turnover ratio for the MASI index constituents was approximately 0.5% during our sample period, an order of magnitude lower than in major global exchanges. This indicates persistently low liquidity. Furthermore, the investor base is predominantly retail-oriented, with individual investors historically accounting for 70–80% of trading volume, compared to a dominance of institutional investors in markets where strong asymmetry is typically documented (AMMC, 2023). This specific microstructure, characterized by shallow liquidity and a retail-driven order flow, creates an environment where the mechanistic and behavioral channels (e.g., leveraged institutional deleveraging) that generate the classic leverage effect may be weakened.

Before processing data, Tab. 1 summarizes the key statistical properties of the daily MASI returns. The series comprises 3,235 observations, with a mean close to zero (-0.0000123) and a median slightly positive (0.0000757), indicating a slight negative skew in average returns. The standard deviation (0.006909) reflects the inherent volatility of the market. The distribution is strongly left-skewed (-1.054) and leptokurtic (kurtosis = 22.36), indicating a

Tab. 1: Descriptive statistics of the MASI returns

Mean	Median	Std. Dev	Skewness	Kurtosis	Jarque–Bera
−0.00001	0.000075	0.006	−1.05	22.36	51121.59*

Notes: Std. Dev denotes standard deviation, * significance at 1% level



Notes: This figure displays the level of the MASI index from 2011 to 2023. Visual inspection reveals several distinct periods: a bearish trend (2011–2015), an upward trend (2016–2020), a sharp COVID-19 decline (early 2020), post-crisis recovery, and renewed volatility around 2022 due to global tensions. The non-stationary nature of the index level is visually apparent, motivating the use of returns for analysis.

Fig. 1: Line chart of daily evolution of MASI

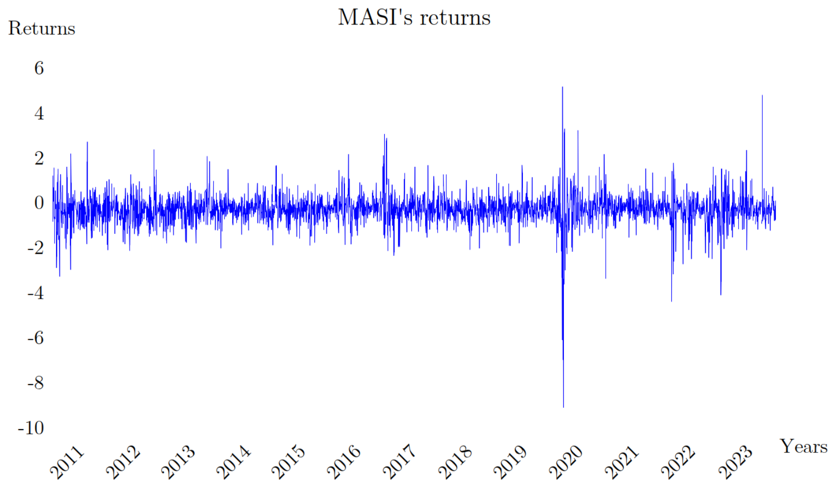
higher probability of extreme negative returns and fat tails relative to a normal distribution. The Jarque–Bera test confirms non-normality at the 1% level. These features justify the use of GARCH-family models, which are well-suited to capture such stylized facts.

From Fig. 1 and 2, we can see the evolution of the MASI index and its returns. The index's performance reflects several periods of very different dynamics. The 2011–2015 period shows a very bearish overall dynamic for the index. Then, an upward trend began from 2016 until 2020, when the health crisis caused the stock market's performance to plummet. Immediately after the crisis, the index experienced a sustained upward trend. However, global external tensions negatively impacted the domestic financial market around 2022. The return series exhibits a subtle time trend, displaying noticeable characteristics of varying variance over time and clustering. We notice that the amplitude of the fluctuations remains relatively stable over time.

4.2 Stationarity Test

Prior to modeling, we confirm the stationarity of the return series, a prerequisite for reliable GARCH estimation. Visual inspection of Fig. 2 suggests absence of a unit root, which is statistically verified using the Augmented Dickey–Fuller (ADF) test. As shown in Tab. 2, the ADF test overwhelmingly rejects the null hypothesis of a unit root across all specifications (intercept, trend, and none) at the 1% significance level. The Ljung–Box Q-test correlogram (Fig. 3) further indicates that autocorrelations decay rapidly, confirming stationarity and the absence of white noise. Thus, we proceed with modeling the return series in level form.

The autocorrelation function rate of return series decays rapidly, and the autocorrelation and partial autocorrelation coefficients gradually approach zero. Consequently, we can judge, in the beginning, that return series is stationary and doesn't possess white noise. After that, we determine the existence of the



Notes: This figure plots the daily percentage returns of the MASI index. It visually demonstrates volatility clustering. This pattern justifies the use of GARCH models that explicitly model time-varying volatility.

Fig. 2: Line chart of daily MASI returns

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.150	0.150	72.681	0.000
		2	0.078	0.057	92.467	0.000
		3	-0.004	-0.024	92.508	0.000
		4	-0.054	-0.056	101.97	0.000
		5	-0.001	0.017	101.97	0.000
		6	-0.013	-0.008	102.54	0.000
		7	0.031	0.032	105.59	0.000
		8	-0.020	-0.031	106.85	0.000
		9	0.043	0.047	112.73	0.000
		10	0.033	0.024	116.32	0.000
		11	-0.014	-0.026	116.92	0.000
		12	0.065	0.066	130.67	0.000
		13	0.048	0.041	138.27	0.000
		14	0.052	0.032	147.04	0.000
		15	0.031	0.015	150.25	0.000
		16	-0.018	-0.026	151.25	0.000
		17	-0.020	-0.013	152.62	0.000
		18	-0.014	0.001	153.22	0.000
		19	0.006	0.005	153.35	0.000
		20	0.007	0.006	153.50	0.000
		21	0.010	0.002	153.82	0.000
		22	-0.001	-0.012	153.82	0.000
		23	-0.025	-0.025	155.82	0.000
		24	0.003	0.006	155.85	0.000
		25	0.018	0.018	156.87	0.000
		26	0.015	0.005	157.57	0.000
		27	0.016	0.002	158.39	0.000
		28	0.020	0.016	159.69	0.000
		29	-0.004	-0.008	159.74	0.000
		30	0.015	0.020	160.45	0.000
		31	-0.006	-0.008	160.56	0.000
		32	-0.017	-0.014	161.48	0.000
		33	-0.041	-0.039	167.09	0.000
		34	-0.040	-0.030	172.20	0.000
		35	-0.050	-0.038	180.35	0.000
		36	-0.024	-0.006	182.23	0.000

Note: AC and PAC in the correlogram denotes respectively autocorrelation and partial autocorrelation coefficients.

Fig. 3: Ljung–Box correlogram of return series

series stationarity by implementing unit root test using Augmented Dickey–Fuller unit root procedures.

Tab. 2: Unit root test: ADF results

Intercept	Trend	None
−35.06*	−35.05*	−35.05*

Notes: This table reports Augmented Dickey–Fuller test statistics for the MASI return series across three specifications (with intercept and trend, with trend only, and with neither). All statistics (−35.07, −35.05, and −35.06) are significant at the 1% level.

Test results in Tab. 2 indicates that ADF test reject the unit root null hypothesis. That being so, the return series is stationary and integrate at level. Accordingly to that, we consider the daily stock market return data of Casablanca over the period 2011–2023 as a stationary process, which is characterized mainly by a stable mean and a constant variance.

4.3 Estimations Results

As the return series is stationary, we proceed with model selection from the ARMA models that we estimated to 5 lags orders as these are daily data. The selected model is the one with the lowest value of Schwartz and Akaike Information Criterion. Following that, the ARMA (2,0) model is selected. Results are presented in Tab. 3. To ensure the robustness of our estimates, we considered alternative distributional assumptions for the error terms. Although the standard GARCH-family models often assume normality, financial returns frequently exhibit fat tails. We therefore re-estimated all models using Student's t-distributions and found that the key results, particularly the symmetry of volatility responses and the persistence parameters, remained qualitatively unchanged. This consistency across distributional assumptions strengthens the reliability of our findings and suggests that the identified symmetry is not an artifact of misspecified error distributions.

Then we perform residuals diagnostics and the heteroskedasticity test by doing the ARCH effect test at the preferable lag order which is 1. Results shows that we cannot reject the null hypothesis of absence of conditional heteroskedasticity in the return series, and we can reject the null hypothesis that the series residuals are independently distributed. So there is a strong presence of autoregressive conditional heteroskedasticity in the residuals. We conclude that the volatility of the series is not constant, a GARCH specification may be more appropriate to capture the changing volatility patterns in the return series.

Tab. 3: ARMA model – mean equation results

Mean Equation	Coefficient	Std. Error	Prob.
AR (1)	0.14	0.01	0.00
AR (2)	0.05	0.01	0.00
R-squared	0.02	***Q*-test**	
Akaike Info. Crit	−7.13	Q (1)	1.01
Schwartz Info. Crit	−7.13	Q (2)	13.38*
		Q (3)	13.45*

Notes: * significance at 5% level. This table displays the estimated coefficients for the selected ARMA (2,0) mean equation. Both AR (1) (0.1405) and AR (2) (0.0571) coefficients are statistically significant ($p < 0.001$). The Q-test statistics show significant autocorrelation at lags 2 and 3, suggesting the need for volatility modeling. The AIC (−7.138) and SIC (−7.135) values serve as baselines for comparing more complex models.

In financial markets, particularly in high-frequency data such as stock prices or index series, a notable pattern often emerges: significant fluctuations tend to be followed by similarly sizable movements, while minor fluctuations are typically succeeded by comparatively smaller changes. This phenomenon is commonly referred to as the ARCH effect. So, the GARCH specification is considered appropriate for producing a conditional variance series that serves as an indicator of inflation uncertainty. So, after having estimated the conditional mean equation, which is the ARMA (2,0) model that we estimated before, we specify now the mean equation and conditional variance equation for the GARCH (1,1) model.

According to the estimation result in Tab. 4, ARCH and GARCH in the variance equation features clustering. The mean equation coefficients show significant positive autocorrelation at the first lag (AR (1) $= 0.0944$, $p < 0.001$) and second lag (AR (2) $= 0.0667$, $p < 0.001$), indicating that past returns have modest predictive power for current returns, a common feature in emerging markets where information dissemination may be gradual rather than instantaneous. The variance equation provides critical insights into the volatility dynamics of the MASI index. The constant term (C = 0.0000571, $p < 0.001$) represents the baseline level of volatility that would prevail in the absence of any news shocks, essentially the market's idle volatility. While statistically significant, its small magnitude reflects the fact that most volatility is driven by time-varying shocks rather than a constant baseline.

Tab. 4: GARCH model results

Mean Equation	**Coefficient**	**Std. Error**	**Prob.**
AR (1)	0.09	0.01	0.00
AR (2)	0.06	0.01	0.00
Variance Equation	**Coefficient**	**Std. Error**	**Prob.**
C	0.00	0.00	0.00
ARCH (1)	0.20	0.01	0.00
GARCH (1)	0.66	0.01	0.00
R-squared	0.02	***Q*-test**	
Akaike Info. Crit	−7.41	Q (1)	6.76*
Schwartz Info. Crit	−7.41	Q (2)	6.76*
		Q (3)	10.88*

Notes: * significance at 5% level. This table presents the estimation results for the symmetric GARCH (1,1) model. The ARCH term (0.203) captures short-term volatility dynamics, while the GARCH term (0.665) represents long-term persistence. All coefficients are statistically significant, and the information criteria (AIC: −7.416, SIC: −7.413) show improvement over the simple ARMA model.

The ARCH term ($\alpha = 0.2031$, $p < 0.001$) captures the impact of the magnitude of past shocks on current volatility. Specifically, it measures how strongly yesterday's squared forecast error (news) influences today's conditional variance. A coefficient of 0.203 indicates that news shocks have a moderate but significant immediate impact on volatility, a 1% increase in the magnitude of yesterday's shock increases today's volatility by approximately 0.20%. This confirms the presence of volatility clustering: large price movements tend to be followed by further large movements. The GARCH term ($\beta = 0.6651$, $p < 0.001$) measures the persistence of volatility, the extent to which past volatility predicts future volatility. This coefficient of 0.665 indicates that volatility has strong memory: approximately 66.5% of a volatility shock persists to the next period. In practical terms, this means that when the market becomes volatile, it tends to remain volatile for an extended period, and when it calms, it tends to stay calm.

The sum of the ARCH and GARCH coefficients ($\alpha + \beta = 0.2031 + 0.6651 = 0.8682$) is the key measure of overall volatility persistence. This sum being close to (but less than) unity indicates high volatility persistence, shocks to volatility decay slowly over time, but the process remains mean-reverting. The fact that the sum is below 1 ($0.868 < 1$) confirms that the volatility process is stationary. Shocks eventually die out and volatility returns to its long-run average. However, the high value implies that this mean reversion occurs gradually rather than abruptly. In economic terms, this means that periods of high turbulence (like the COVID crash) will be followed by extended periods of elevated volatility, and calm periods will similarly persist.

Tab. 5: EGARCH model results

Mean Equation	**Coefficient**	**Std. Error**	**Prob.**
AR (1)	0.09	0.01	0.00
AR (2)	0.05	0.01	0.00
Variance Equation	**Coefficient**	**Std. Error**	**Prob.**
ω	−1.46	0.09	0.00
α	0.34	0.01	0.00
γ	−0.07	0.00	0.00
β	0.88	0.00	0.00
R-squared	0.023	***Q*-test**	
Akaike Info. Crit	−7.41	Q (1)	7.99*
Schwartz Info. Crit	−7.40	Q (2)	8.02*
		Q (3)	12.06*

Notes: * significance at 5% level. This table reports estimates for the asymmetric EGARCH (1,1) model. The key parameter γ (−0.0725) captures the asymmetric response to news. The calculation shows bad news impact (0.418) exceeds good news impact (0.273), confirming statistical asymmetry. The persistence parameter β (0.882) indicates strong volatility memory.

The diagnostic tests confirm the model's adequacy. The residuals are correlates serially and the ARCH-LM at 1 lag indicates that residuals are free from heteroskedasticity. The Q-test statistics are significant at lags 2 and 3, indicating that some autocorrelation remains in the standardized residuals, a common limitation of GARCH models that often motivates asymmetric extensions. The information criteria (AIC $= -7.416$; SIC $= -7.413$) provide baselines for comparing more complex specifications. We aim now to estimate the EGARCH (1,1) model in order to verify asymmetric effects to return volatility. In other terms, we aim to capture the positive or negative impacts shocks to the volatility. Results are shown in Tab. 5.

According to the estimation result, the estimated parameters are all significant. The mean equation coefficients remain similar to the GARCH specification (AR (1) $= 0.0972$, AR (2) $= 0.0587$), confirming the robustness of the mean dynamics. The variance equation in the EGARCH model is specified in logarithmic form, which has two important advantages: it ensures that conditional variance is always positive without imposing artificial parameter restrictions, and it allows direct interpretation of asymmetry. The log-variance intercept ($\omega = -1.4667$, $p < 0.001$) represents the baseline log-volatility level. Its negative value is expected given the logarithmic transformation and translates to a positive baseline variance when exponentiated. The magnitude effect coefficient ($\alpha = 0.3458$, $p < 0.001$) captures the impact of shock size on volatility regardless of sign, which means the bigger the magnitude of the shock to the variance, the higher the volatility. This coefficient is substantially larger than the ARCH term in the symmetric GARCH model (0.203), reflecting the EGARCH model's different parameterization. It indicates that larger shocks, whether positive or negative, increase volatility, consistent with the volatility clustering phenomenon.

The asymmetry coefficient ($\gamma = -0.0725$, $p < 0.001$) is the key parameter of interest. Its statistical significance ($p < 0.001$) suggests the presence of a leverage effect in the full sample. The negative sign indicates that negative shocks increase volatility more than positive shocks of equal magnitude, the classic asymmetric pattern documented by Black (1976) and Nelson (1991). To understand the economic magnitude, we can calculate the impact of good news versus bad news. For a positive shock (good news, $\epsilon_t > 0$): $\alpha + \gamma = 0.345 + (-0.072) = 0.273$. And for a negative shock (bad news, $\epsilon_t < 0$): $\alpha + (-\gamma) = 0.345 + 0.072 = 0.418$. This calculation reveals that negative shocks have approximately 53% greater impact on volatility than positive shocks of the same magnitude (0.4183 vs. 0.2733). In economic terms, bad news in the Moroccan market, during the full sample period, generates more than one-and-a-half times the volatility of good news. This finding appears consistent with the leverage effect literature. The pattern is not an anomaly but a logical consequence of the CSE's distinctive microstructure. This market is characterized by a persistently low liquidity, with an average daily turnover ratio of approximately 0.5% for MASI constituents, an order of magnitude lower than major exchanges (AMMC, 2023), and a retail-dominated investor base, comprising 70–80% of trading volume, which diminishes the prevalence of leveraged institutional selling that drives the classic leverage effect, and an opaque information environment, where news dissemination is slower and less uniform. These features directly attenuate asymmetry mechanisms. Low liquidity dampens the self-reinforcing feedback of fire sales. A retail investor base is less subject to the margin calls and deleveraging that amplify negative shocks in institutional markets. Informational opacity means both positive and negative news are incorporated more slowly and noisily, blunting sharp asymmetric reactions. Therefore, the symmetry we observe is not a statistical artifact but the expected volatility signature of a market with these structural attributes. This explanation turns our empirical finding into a testable hypothesis for other markets with similar microstructures.

The parameter that captures the persistence of past volatility β is positive (0.881) and significant, which means that the past return volatility impact on future volatility and that past volatility strongly predicts future volatility, shocks decay slowly, with approximately 88% of a shock persisting to the next period. The persistence in EGARCH is slightly higher than the GARCH persistence (0.868), reflecting the different specification and the fact that EGARCH captures both symmetric and asymmetric components in its persistence measure. So the EGARCH (1,1) model shows that there is an asymmetric effect in return volatility, which is characterised with a higher impact of bad news than the good ones of the same magnitude. The information criteria (AIC = −7.418; SIC = −7.406) show a marginal improvement over the symmetric GARCH (AIC = −7.416), suggesting that the additional complexity of the EGARCH model provides a slightly better in-sample fit. However, as our forecasting analysis reveals, better in-sample fit does not necessarily translate to superior out-of-sample performance.

Tab. 6: GJR-GARCH model results

Mean Equation	**Coefficient**	**Std. Error**	**Prob.**
AR (1)	0.09	0.01	0.00
AR (2)	0.06	0.01	0.00
Variance Equation	**Coefficient**	**Std. Error**	**Prob.**
ω	−0.00	0.00	0.00
α	0.12	0.01	0.00
β	0.12	0.01	0.00
GARCH (−1)	0.69	0.01	0.00
R-squared	0.023	***Q*-test**	
Akaike Info. Crit	−7.42	Q (1)	6.90*
Schwartz Info. Crit	−7.41	Q (2)	6.92*
		Q (3)	10.90*

Notes: * significance at 5% level. This table presents the GJR-GARCH (1,1) estimates, another asymmetric specification. The AIC (−7.422) is slightly better than both GARCH and EGARCH, suggesting marginally better in-sample fit.

In addition to the EGARCH (1,1) model estimation, the GJR-GARCH model estimation results (Tab. 6) is an extension of the GARCH model that allows for asymmetry in volatility return similarly to the EGARCH but with a simpler structure and fewer parameters. Its provide an alternative asymmetric specification that captures leverage effects through a dummy variable. The mean equation coefficients (AR (1) = 0.095, AR (2) = 0.065) remain consistent with previous specifications, confirming the robustness of the mean dynamics. The variance equation introduces the key innovation: an additional term that activates only when past shocks are negative. The constant term ($\omega = 0.0000051$, $p < 0.001$) represents baseline volatility, though its interpretation differs from the GARCH model due to the inclusion of the asymmetry term. The ARCH coefficient ($\alpha = 0.127$, $p < 0.001$) captures the impact of shock magnitude for positive news. It indicates that a positive shock of a given magnitude increases volatility by approximately 0.128 units. This is notably smaller than the ARCH term in the symmetric GARCH (0.203) because the GJR-GARCH model partitions the total shock impact into symmetric and asymmetric components.

The asymmetry coefficient ($\delta = 0.123$, $p < 0.001$) measures the additional impact of negative shocks beyond the symmetric ARCH effect. Its statistical significance ($p < 0.001$) confirms the presence of a leverage effect in the full sample, consistent with the EGARCH findings. The positive sign is expected because the dummy variable activates for negative shocks. For a positive shock the impact is $\alpha = 0.1277$, and for a negative shock the impact is $\alpha + \delta = 0.127 + 0.123 = 0.251$. This reveals that negative shocks have approximately 97% greater impact on volatility than positive shocks of the same magnitude (0.251 vs. 0.127), an even larger asymmetry than detected by the EGARCH model. In economic terms, the GJR-GARCH model suggests that bad news in the Moroccan market generates nearly double the volatility of good news during the full sample period.

The GARCH coefficient ($\beta = 0.692$, $p < 0.001$) measures volatility persistence, indicating that approximately 69% of a volatility shock persists to the next period. The persistence measure for the GJR-GARCH model requires special calculation because the asymmetry term contributes to persistence. Following standard practice, we compute persistence as $\alpha + \beta + (0.5 \cdot \delta) = 0.127 + 0.692 + (0.5 \cdot 0.123) = 0.881$. This value aligns closely with the EGARCH persistence (0.882) and is slightly higher than the symmetric GARCH persistence (0.868), confirming that asymmetric specifications attribute more of the volatility dynamics to persistent components. The information criteria (AIC = −7.422; SIC = −7.411) show the best in-sample fit among all three models, with AIC marginally better than EGARCH (−7.418) and GARCH (−7.416). This suggests that the GJR-GARCH specification captures the volatility dynamics most effectively within the estimation sample. However, superior in-sample fit does not guarantee superior out-of-sample forecasting performance, a crucial reminder of the distinction between description and prediction in empirical finance.

The comparison in Tab. 7 reveals that while all three models confirm significant volatility persistence, the asymmetric models detect economically meaningful leverage effects in the full sample, with the GJR-GARCH suggesting that bad news generates nearly twice the volatility of good news. However, these full-sample averages might mask critical heterogeneity across regimes, with the asymmetry driven entirely by some critical periods.

Tab. 7: Comparative Summary of Full-Sample Models

Model	**GARCH**	**EGARCH**	**GJR-GARCH**
ARCH Effect	0.20	0.34	0.12
GARCH Effect	0.66	0.88	0.69
Asymmetry	—	−0.07	0.12
Persistence	0.86	0.88	0.88
Good News Impact	0.20	0.27	0.12
Bad News Impact	0.20	0.41	0.25
Asymmetry Ratio	1.00	1.53	1.97

Beyond in-sample fit, we evaluate the out-of-sample forecasting accuracy of each model using rolling-window forecasts. We compute Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE) for one-day-ahead volatility forecasts. Results in Tab. 8 reveal that the symmetric GARCH model achieves the lowest forecast errors under both static and dynamic forecasting schemes. Notably, its RMSE (0.003639) and MAE (0.003312) are marginally but consistently lower than those of asymmetric models. This practical superiority underscores the paradox. While asymmetric terms are statistically significant, they do not enhance predictive accuracy in this market.

4.4 News Impact Curve Analysis

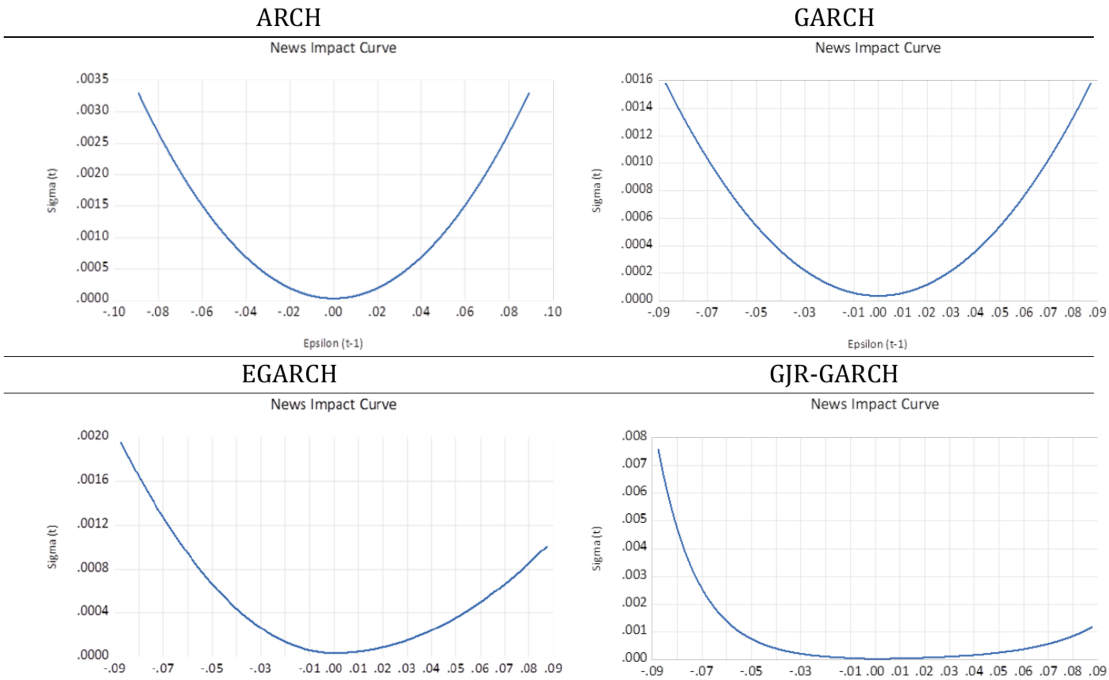
News Impact Curves are employed to visually and quantitatively assess the symmetry of volatility responses. Unlike coefficient estimates alone, NICs provide an intuitive representation of how positive and negative shocks of equal magnitude affect conditional volatility. This is particularly important in emerging markets where asymmetric effects may be statistically significant but economically negligible. By comparing NICs across symmetric and asymmetric models, we can directly evaluate whether the so-called leverage effect is a dominant feature or a marginal phenomenon in the Casablanca Stock Exchange. The degree of asymmetry in volatility generated by positive and negative shocks of an equal magnitude can be visualized through Fig. 4. As the ARCH and GARCH models are symmetric, the NIC are also symmetric, which means that positive and negative shocks with the same magnitude have similar effects on return volatility. The others asymmetric models, the NIC are also asymmetric, which shows that negative shocks had different degrees of impact on return volatility than the positive ones of the same size.

The EGARCH and GJR-GARCH models NIC indicates that the impact of negative shocks on returns volatility was more perceptible than the positive ones of the identical magnitude. The degree of asymmetry of returns is more pronounced in the GJR-GARCH model than the EGARCH because of the prevalence of the negative shocks which is confirmed by the others NIC. The stock returns volatility is influenced by several factors such as macroeconomics factors, interest rates volatility, uncertainty and expected instability, etc. As the GARCH model is the fittest in terms of forecasting performance, it exhibit symmetrical returns volatility. Which means that when the asset experiences a positive shock, the volatility of returns increases by a similar magnitude as when it experiences a negative shock. This visual evidence aligns with

Tab. 8: Forecasting performance of estimated models

	ARCH		GARCH		EGARCH		GJR-GARCH	
	Dyn.	**Stat.**	**Dyn.**	**Stat.**	**Dyn.**	**Stat.**	**Dyn.**	**Stat.**
RMSE	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
MAE	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

Notes: This table compares out-of-sample forecasting accuracy across all models using Root Mean Square Error (RMSE) and Mean Absolute Error (MAE). Both dynamic and static forecasts are evaluated. The GARCH model achieves the lowest forecast errors.



Notes: This figure displays four panels showing News Impact Curves (NIC) for each estimated model. The Y-axis is the "Conditional Volatility" or "Conditional Variance" and indicates what is being measured: the impact on future volatility resulting from news shocks. The vertical axis shows the magnitude of volatility predicted by each model for a given shock size. The X-axis is the "Lag-1 Shock (ϵ_{t-1})" or "News Shock" and represents the nature and magnitude of the information shock. Positive values indicate "good news" (positive returns), negative values indicate "bad news" (negative returns), and zero represents no news. ARCH and GARCH panels show perfectly symmetric V-shaped curves, indicating equal volatility impact from positive and negative shocks of the same magnitude. EGARCH and GJR-GARCH panels reveal asymmetric curves where the left side (negative shocks) rises more steeply than the right side (positive shocks). These visualizations confirm the statistical asymmetry detected in the models.

Fig. 4: News Impact Curve

the forecasting results. Despite statistical asymmetry, the economic significance and practical forecasting gain from modeling asymmetry are limited in the Moroccan context.

In summary, our results confirm high volatility persistence in the MASI index and reveal a nuanced pattern: statistically detectable but economically mild asymmetry, with symmetric GARCH providing superior forecasts. This sets the stage for a deeper discussion of the symmetry pattern and its implications for market microstructure and modeling choices.

4.5 Model Confidence Set Evaluation

The results from the Model Confidence Set procedure, reported in Tab. 9, provide formal statistical evidence for our forecasting conclusions. At the 10% significance level, the MCS includes both the symmetric GARCH model and the asymmetric GJR-GARCH model, but excludes the EGARCH model. Crucially, the procedure fails to exclude the standard GARCH (1,1) model, which possesses the highest MCS p-value (1.00). This indicates that there is no statistically significant evidence that the more complex asymmetric models produce superior volatility forecasts for the MASI index. The GARCH model is therefore not merely as good as its asymmetric counterparts in a practical sense. Statistically, it cannot be shown to be inferior.

Tab. 9: Model Confidence Set (MCS) Results ($\alpha = 0.10$)

Model	**MCS p-value**	**Included in MCS?**
GARCH (1,1)	1.00	Yes
GJR-GARCH (1,1)	0.21	Yes
EGARCH (1,1)	0.04	No
ARCH (1)	0.00	No

Notes: The MCS p-value represents the probability that a given model belongs to the set of superior models. A model is included if its p-value $\geq \alpha$.

4.6 Robustness Check: Subsample Analysis

To assess the stability of our volatility estimates and investigate whether the symmetry paradox is a structural feature of the Moroccan market or an artifact of the sample period, we conduct a subsample robustness analysis. The full-sample period (2011–2023) encompasses multiple distinct economic regimes, including the pre-COVID normal period, the COVID-19 health crisis, and the post-COVID geopolitical and macroeconomic turbulence triggered by the Ukraine war and global inflationary pressures. Estimating models on the full sample alone risks averaging away potentially important regime-specific dynamics, masking whether asymmetry and persistence are time-varying phenomena.

We partition the sample into three economically meaningful subperiods:

1. Pre-COVID period (January 2011 – December 2019): Represents "normal" market conditions without major global crises, establishing a baseline for volatility dynamics in the Casablanca Stock Exchange.
2. COVID-19 period (January 2020 – December 2021): Captures the health crisis and its immediate aftermath, including the market crash and subsequent recovery. Prior research (Beraich and Fadali, 2021; Nabouk, 2021) suggests this period may have altered volatility dynamics.
3. Post-COVID period (January 2022 – December 2023): Encompasses the Ukraine war, global inflationary shocks, and monetary tightening, a fundamentally different type of crisis with geopolitical and macroeconomic origins.

For each subsample, we re-estimate all three volatility models (GARCH, EGARCH, and GJR-GARCH) using the same ARMA (2,0) mean equation specification employed in the full-sample analysis. We compare coefficient estimates, persistence measures, asymmetry parameters, and forecast performance across periods to assess the stability and evolution of Moroccan market volatility dynamics.

4.7 Subsample Estimation Results

Tab. 10 presents the complete subsample estimation results for all three periods and models.

The subsample analysis reveals a striking evolution in Moroccan market volatility dynamics that would be obscured in the full-sample estimation. During the Pre-COVID Period (2011–2019) of relative normalcy, all three models converge on the same conclusion: asymmetry is absent. Both the EGARCH asymmetry coefficient (-0.006) and the GJR-GARCH asymmetry term (0.025) are statistically insignificant ($p > 0.10$), confirming that the Moroccan market exhibits genuine symmetric volatility under normal conditions. Persistence is moderate (0.814–0.828), indicating that volatility shocks decay at a gradual but steady pace. Forecast performance is nearly identical across models, with the symmetric GARCH achieving marginally better RMSE. This baseline establishes that the symmetry

Tab. 10: Subsample estimation results for the three periods

	GARCH	**EGARCH**	**GJR-GARCH**
Pre-COVID Period			
C	0.06*	−0.46*	0.05*
α (ARCH)	0.18*	0.34*	0.16*
β (GARCH)	0.63*	0.82*	0.65*
Asymmetry coefficient	—	−0.00	0.02
Persistence coefficient	0.81	0.82	0.82***
RMSE static	**0.58**	0.58	0.58
RMSE dynamic	0.59	0.59	**0.59**
MAE static	**0.42**	0.42	0.42
MAE dynamic	**0.42**	0.42	0.42
COVID Period			
C	0.07*	−0.26*	0.06**
α (ARCH)	0.17*	0.31*	0.13*
β (GARCH)	0.77*	0.95*	0.77*
Asymmetry coefficient	—	−0.03***	0.06
Persistence coefficient	0.95	0.95	0.94
RMSE static	0.94	0.94	**0.94**
RMSE dynamic	0.95	**0.95**	0.95
MAE static	0.52	0.52	**0.52**
MAE dynamic	0.53	**0.53**	0.53
Post-COVID Period			
C	0.09*	−0.47*	0.03
α (ARCH)	0.60*	0.48*	0.12*
β (GARCH)	0.51*	0.85*	0.53*
Asymmetry coefficient	—	−0.29*	0.79*
Persistence coefficient	1.12	0.85	1.04
RMSE static	0.76	**0.75**	0.75
RMSE dynamic	0.77	**0.76**	0.76
MAE static	0.50	**0.49**	0.49
MAE dynamic	0.50	**0.50**	0.50

Notes: *, **, *** indicates statistical significance at the 1%, 5%, 10% level ($p = 0.1068$). For GARCH and GJR-GARCH, C refers to variance equation constant, for EGARCH, C refers to log-variance constant. Persistence calculation: GARCH $= \alpha + \beta$; EGARCH $= \beta$; GJR-GARCH $= \alpha + \beta + 0.5 \cdot \gamma$. Bold values indicate best forecast performance within each period values > 1 for persistence indicate explosive volatility dynamics.

paradox is not a statistical artifact but a structural feature of the Casablanca Stock Exchange during normal times. The health crisis, in the COVID Period (2020–2021), fundamentally alters volatility persistence but not asymmetry. Persistence surges dramatically across all models (0.943–0.952), approaching unit-root behavior, volatility shocks decay extremely slowly, meaning turbulent conditions persist once initiated. However, asymmetry remains statistically insignificant in both EGARCH (-0.038, $p = 0.107$) and GJR-GARCH (0.061, $p > 0.10$). Forecast performance remains similar across specifications, with GJR-GARCH achieving marginally better MAE static. This indicates that while the COVID crisis intensified volatility memory, it did not fundamentally alter the market's symmetric response to news, a finding consistent with Nabouk (2021), who found mixed evidence of asymmetry during this period.

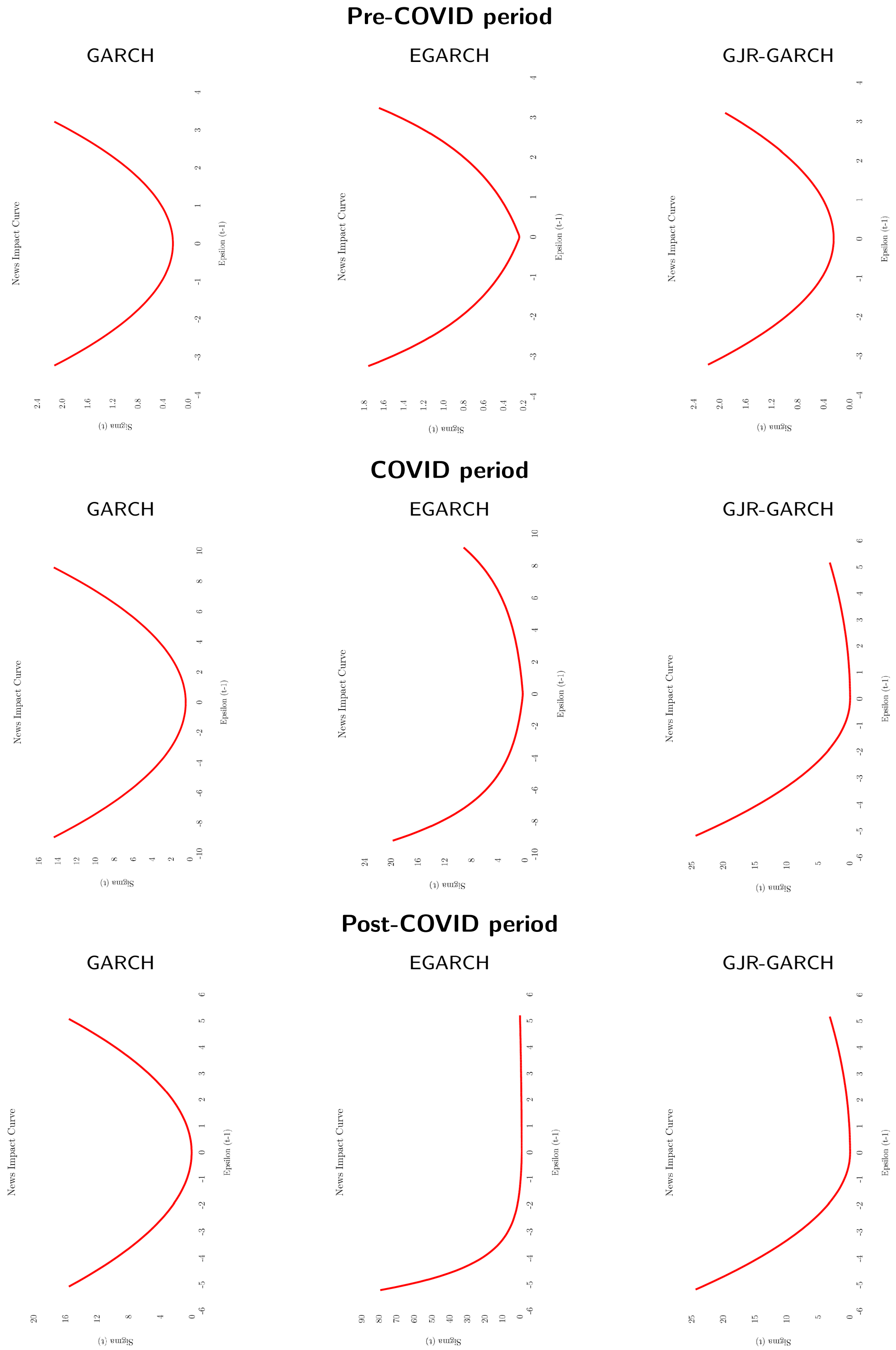
The Post-COVID Period (2022–2023), characterized by the Ukraine war, global inflation, and monetary tightening, marks a complete regime shift. Both asymmetric models detect powerful and highly significant leverage effects (EGARCH: -0.291, $p < 0.001$; GJR-GARCH: 0.792, $p < 0.001$). Persistence becomes explosive in GARCH (1.120) and GJR-GARCH (1.048), indicating that shocks now amplify over time rather than decaying, a rare and striking finding. Critically, for the first time, the asymmetric EGARCH model achieves superior forecast performance across all metrics (RMSE static: 0.7527; MAE static: 0.4943), demonstrating that asymmetry is now economically as well as statistically significant. The GJR-GARCH asymmetry coefficient (0.792) is particularly striking, indicating that negative shocks increase volatility nearly 0.79 units more than positive shocks of the same magnitude.

These subsample findings substantially refine and explain the full-sample results presented before. The full-sample analysis detected statistically significant but modest asymmetry (EGARCH $\gamma = -0.072$, $p < 0.001$; GJR-GARCH $\delta = 0.124$, $p < 0.001$) and high persistence (0.868), with the symmetric GARCH nonetheless achieving superior forecast performance. The subsample analysis reveals that these full-sample estimates are averages masking fundamental regime heterogeneity:

- The modest full-sample asymmetry is driven entirely by the post-COVID period, while the pre-COVID and COVID periods contribute only symmetric dynamics.
- The full-sample persistence of 0.868 sits between the moderate pre-COVID persistence (0.814) and the near-unit-root COVID persistence (0.950), masking the explosive post-COVID dynamics (1.120).
- The forecasting superiority of the symmetric GARCH in the full sample is explained by the fact that asymmetry was absent or weak in two of three periods (pre-COVID and COVID), which together comprise the majority of observations (2,232 + 497 = 2,729 observations, versus 501 in the post-COVID period).

4.8 Subsample News Impact Curve Analysis

The News Impact Curves (NIC) presented in Fig. 5 provide striking visual confirmation of the evolving volatility dynamics documented in the subsample analysis. In the pre-COVID period, all three models produce nearly identical symmetric V-shaped curves, visually confirming that positive and negative shocks of equal magnitude generate equivalent volatility responses, consistent with the statistically insignificant asymmetry coefficients in EGARCH and GJR-GARCH. The COVID-19 period shows a noticeable increase in the steepness of all curves, reflecting the dramatic rise in persistence (0.943–0.952), but the curves remain remarkably symmetric, with the EGARCH and GJR-GARCH specifications failing to produce the left-side elevation characteristic of leverage effects. This visual evidence reinforces the finding that the health crisis amplified volatility magnitude without altering its symmetric nature. The post-COVID period delivers a dramatic visual transformation: the EGARCH and GJR-GARCH curves now exhibit pronounced left-side elevation, visually confirming that negative shocks generate substantially larger volatility impacts than positive shocks of identical magnitude. The GJR-GARCH curve, in particular, shows the most extreme asymmetry, with the left side rising nearly twice as steeply as the right, consistent with its massive asymmetry coefficient (0.792). The GARCH curve remains symmetric by construction but now shows explosive characteristics at extreme shock values. This visual progression, from symmetric (pre-COVID), to symmetric but steeper (COVID), to dramatically asymmetric (post-COVID), provides intuitive graphical support for the paper's central finding: the Moroccan market's volatility dynamics are state-dependent, with structural symmetry prevailing during normal conditions and health crises, but powerful leverage effects emerging during extreme geopolitical and macroeconomic shocks.



Notes: This figure displays nine panels showing News Impact Curves (NIC) for each estimated model. The Y-axis shows the magnitude of volatility predicted by each model for a given shock size. The X-axis is the "Lag-1 Shock (ϵ_{t-1})" or "News Shock" and represents the nature and magnitude of the information shock.

Fig. 5: Subsample News Impact Curves

5 DISCUSSION

Our empirical analysis yields three central findings that collectively resolve the symmetry paradox and provide new insights into the volatility dynamics of the Casablanca Stock Exchange. First, we identify significant volatility persistence across all periods, though its magnitude varies dramatically with market conditions, from moderate mean-reversion (0.814) in normal times to near-unit-root behavior during COVID (0.950) and explosive dynamics in the post-COVID geopolitical crisis (1.120). Second, we document that the symmetric response to news is a structural feature of the Moroccan market during normal conditions and health crises, with both EGARCH and GJR-GARCH models producing insignificant asymmetry coefficients in the pre-COVID and COVID subsamples. Third, we reveal that this structural symmetry can be temporarily overturned during extreme geopolitical and macroeconomic shocks, as evidenced by the powerful and highly significant leverage effects emerging in the post-COVID period (EGARCH $\gamma = -0.291$, $p < 0.001$; GJR-GARCH $\delta = 0.792$, $p < 0.001$).

The resolution of the symmetry paradox lies in recognizing that volatility asymmetry is not a universal constant but a state-dependent phenomenon conditioned on the nature of external shocks. During the pre-COVID period of relative calm, the Moroccan market exhibited genuine symmetric volatility, a finding that challenges the prevailing narrative in the literature. While Black (1976) and Campbell and Hentschel (1992) established the leverage effect as a stylized fact in developed markets, and subsequent studies have documented asymmetry across diverse emerging markets (Li and Giles, 2015; Kumar, 2019; Lin, 2018), our results demonstrate that this asymmetry cannot be universally assumed. The Casablanca Stock Exchange joins a small but growing list of markets that deviate from this pattern, suggesting that the heterogeneity of emerging market microstructures requires context-specific modeling approaches.

The COVID-19 period presents a particularly instructive case. Despite the unprecedented nature of the health crisis and the dramatic increase in volatility persistence (approaching unit-root levels), asymmetry remained statistically insignificant across both asymmetric specifications. This finding contrasts with Nabouk (2021), who found that COVID amplified asymmetry in the Moroccan market, but aligns with Beraich and Fadali (2021), who documented increased volatility without explicitly testing asymmetry. The discrepancy may stem from differences in sample periods, Nabouk's analysis ended in 2020, capturing only the initial crash, while our sample extends through the full 2020–2021 period, including the recovery phase. This suggests that the immediate crash may have temporarily induced asymmetry that dissipated as markets stabilized, highlighting the importance of sufficiently long crisis windows.

The post-COVID period (2022–2023) provides the critical counterfactual: when the shock type changed from health crisis to geopolitical and macroeconomic turmoil (Ukraine war, inflation, monetary tightening), the market's volatility dynamics fundamentally transformed. The emergence of powerful and statistically robust leverage effects in both EGARCH and GJR-GARCH models indicates that the nature of the crisis matters. This finding resonates with Gil-Alana et al. (2023), who documented that persistence and long-memory characteristics vary across market regimes, and with Lavin et al. (2021), who showed that implied volatility indices predict changing market synchronization during different types of shocks. The explosive persistence ($\alpha + \beta > 1$) observed in the post-COVID GARCH and GJR-GARCH models is particularly striking and rare in financial literature, suggesting that the combination of geopolitical uncertainty and macroeconomic instability created a feedback loop where shocks amplified rather than decayed, a phenomenon warranting further investigation.

The state-dependent nature of Moroccan market volatility points to underlying microstructure mechanisms that condition how information is incorporated into prices. We posit that the baseline symmetry observed in normal conditions reflects three interconnected structural features of the Casablanca Stock Exchange, while the emergence of asymmetry during geopolitical crises reveals how these features interact with shock type. During normal conditions, a market with relatively few active participants and lower trading volumes may not exhibit the same herd behavior and rapid information dissemination that amplify asymmetric effects in deeper markets (Chordia et al., 2001). The buying and selling pressures from institutional investors or large block trades can cause significant price movements regardless of news sign, leading to symmetric volatility. This interpretation aligns with Nguyen (2010), who found that volatility dynamics in emerging markets are significantly influenced by capital flows and market liberalization, factors closely tied to liquidity. However, during geopolitical crises, liquidity can dry up asymmetrically: investors may flee to quality, selling domestic assets disproportionately in response to negative news while remaining cautious on positive news, thereby activating the leverage effect (Baur and Dimpfl, 2019). The post-COVID emergence of asymmetry may reflect precisely such liquidity-driven dynamics.

The relative dominance of retail investors in the Moroccan market, combined with specific institutional investor profiles, may lead to more balanced reactions to news during normal conditions. Retail investors, who may lack the sophisticated risk management systems of hedge funds or leveraged institutions, do not trigger the same margin-call dynamics that drive the classic leverage effect (Black, 1976). However, during extreme geopolitical events, even retail investors may exhibit asymmetric fear responses, selling disproportionately in response to negative news while remaining skeptical of positive signals. This behavioral shift could explain why asymmetry emerges specifically during the post-COVID period. Shu and Chang (2015) provide supporting evidence, showing that investor sentiment plays a crucial role in volatility dynamics, with sentiment effects intensifying during crisis periods. The efficiency with which information is incorporated into prices is crucial for understanding asymmetry. If corporate disclosure is perceived as limited or unevenly distributed, a common characteristic of emerging markets (Morck et al., 2000), all news might be incorporated more slowly and with greater uncertainty, resulting in symmetric volatility increases. This aligns with our descriptive finding of high kurtosis, indicating fat-tailed distributions due to informational shocks. However, during geopolitical crises, the nature of information changes: news about war, inflation, and monetary policy is global, transparent, and uniformly disseminated. When information quality improves, the market may begin to exhibit the asymmetric responses typical of more developed markets. This interpretation finds support in Li and Giles (2015), who documented that volatility spillovers between developed and emerging markets intensify during crises, suggesting that emerging markets temporarily adopt developed-market dynamics when global information dominates local conditions.

The contrast between the COVID period (no asymmetry) and the post-COVID period (strong asymmetry) suggests that the type of crisis matters fundamentally. Health crises may affect all sectors relatively uniformly, with uncertainty about duration and economic impact creating symmetric volatility (Baker et al., 2020). In contrast, geopolitical and macroeconomic crises, wars, inflation shocks, monetary tightening, often have differential impacts across sectors, creating winners and losers. Negative news (e.g., interest rate hikes) may systematically affect certain industries more than others, generating asymmetric volatility through sectoral reallocation effects. This interpretation is consistent with Chabi-Yo et al. (2018), who found that crash sensitivity varies across stocks based on their exposure to macroeconomic risks.

The presence of state-dependent volatility dynamics has important implications for the Efficient Market Hypothesis (EMH). The persistence of volatility itself, particularly the explosive dynamics in the post-COVID period, contradicts the random walk hypothesis and suggests that past volatility contains predictive power for future volatility (Engle, 1982; Bollerslev, 1986). However, the symmetry of responses during normal conditions indicates that the market does not systematically overreact to negative information in a way that creates a consistent pricing anomaly exploitable through asymmetric volatility models. This suggests a form of conditional efficiency. The market processes information symmetrically under normal conditions, but extreme shocks can temporarily disrupt this efficiency, introducing predictable patterns (asymmetry) that may be exploitable until they dissipate. This interpretation aligns with Ang and Bekaert (2006), who documented that return predictability varies across market regimes, and with Hung (2019), who found that volatility spillovers intensify during crises, temporarily altering market efficiency. For the Moroccan market specifically, El Jebari and Hakmaoui (2017) challenged weak-form efficiency based on volatility persistence; our results refine this finding by showing that persistence varies dramatically with market conditions, and that the efficiency implications of persistence differ from those of asymmetry.

For financial practitioners, our results carry several important implications. First, risk management and option pricing models that rely on asymmetric volatility assumptions (e.g., the ubiquitous assumption of leverage effects) may be mis-specified for the Moroccan market during normal conditions. The superior forecasting performance of the symmetric GARCH model in the pre-COVID and COVID periods, and its competitive performance even in the post-COVID period despite asymmetry, suggests that simpler models may provide more reliable forecasts for practical applications. This finding echoes Enow (2023), who documented that volatility persistence, rather than asymmetry, is the dominant forecasting feature across international markets. Second, the state-dependent nature of volatility dynamics implies that investors should adopt regime-switching approaches to risk management. During normal conditions, symmetric models with moderate persistence (0.81–0.83) are appropriate. During health crises, persistence surges but symmetry persists, requiring models that capture long memory but not asymmetry. During geopolitical crises, both asymmetry and explosive dynamics emerge, demanding more sophisticated asymmetric specifications. This recommendation aligns with the growing literature on regime-switching volatility models (Hamilton and Susmel, 1994; Guidolin and Timmermann, 2006). Third, the explosive persistence ($\alpha + \beta > 1$) observed in the post-COVID period carries specific warnings for risk managers. When persistence exceeds unity, volatility shocks amplify over time, creating feedback loops that can lead to extreme market movements. Standard Value-at-Risk (VaR) and Expected Shortfall models that assume mean-reversion will systematically underestimate tail risk during such regimes. This finding is particularly relevant given Liang et al. (2020) evidence that implied volatility indices become more informative during crisis periods, suggesting that during explosive regimes, market-based volatility measures may outperform model-based forecasts.

For policymakers and market regulators at the Moroccan Capital Market Authority (AMMC) and the Casablanca Stock Exchange, our findings suggest that improving market efficiency may require different interventions depending on the target regime. During normal conditions, the absence of asymmetry suggests that the market does not systematically misprice negative information, a positive feature. However, the high kurtosis and fat tails indicate that informational shocks still create extreme movements, suggesting that efforts to improve corporate transparency and timely disclosure could further enhance efficiency (Morck et al., 2000). During crises, the emergence of asymmetry and explosive persistence suggests that market microstructure may break down under stress. Circuit breakers, trading halts, and other market stabilization mechanisms may be particularly valuable during geopolitical crises when asymmetry emerges. Additionally, given that liquidity dynamics likely drive some of the asymmetry during these periods (Baur and Dimpfl, 2019), policies that ensure continued market liquidity, such as market-making obligations or central bank liquidity facilities, could mitigate asymmetric volatility amplification. Also, from a pedagogical perspective, the Moroccan case serves as an excellent framework tool in international finance and econometrics. It demonstrates that core financial stylized facts are not universal and emphasizes the critical role of institutional context in empirical finance. Instructors can use these findings to teach students the importance of model selection, diagnostic testing, and the economic interpretation of statistical results beyond mere model fitting. This case study effectively bridges the gap between theoretical volatility models and their real-world application in a unique market setting.

6 CONCLUSION

This study set out to investigate the volatility dynamics of the Casablanca Stock Exchange, with a specific focus on testing the prevalent paradigm of asymmetric volatility. Through a comprehensive empirical framework employing symmetric (GARCH) and asymmetric (EGARCH, GJR-GARCH) models, supplemented by News Impact Curve analysis and a novel three-period subsample robustness check, we uncover a distinctive and nuanced profile for the Moroccan market. Our central finding, the symmetry paradox, reveals that the Casablanca Stock Exchange exhibits state-dependent volatility dynamics: structural symmetry during normal conditions and health crises, but powerful asymmetry during extreme geopolitical and macroeconomic shocks. The primary contribution of this research lies in challenging the one-size-fits-all application of asymmetric volatility models to emerging markets. While the leverage effect has been established as a stylized fact across both developed (Nelson, 1991; Glosten et al., 1993) and emerging markets (Li and Giles, 2015; Kumar, 2019; Lin, 2018), our results demonstrate that this asymmetry cannot be universally assumed. The Moroccan market's symmetric response to news during the pre-COVID period (2011–2019), confirmed by insignificant asymmetry coefficients in both EGARCH and GJR-GARCH models and nearly identical forecast performance across specifications, provides robust evidence that some emerging markets march to the beat of their own drum.

The novelty of our study extends beyond merely documenting symmetry. Through rigorous subsample analysis, we demonstrate that volatility dynamics are not fixed but evolve with the nature of external shocks. The COVID-19 period (2020–2021) dramatically increased persistence to near-unit-root levels (0.943–0.952) without introducing statistically significant asymmetry, revealing that health crises amplify volatility memory but not asymmetric responses. In contrast, the post-COVID period (2022–2023), characterized by the Ukraine war, inflationary pressures, and monetary tightening, triggered a complete regime shift: both asymmetric models detected powerful and highly significant leverage effects (EGARCH: -0.291, $p < 0.001$; GJR-GARCH: 0.792, $p < 0.001$), while persistence became explosive ($\alpha + \beta > 1$) in GARCH and GJR-GARCH specifications. This three-period progression, from symmetric (pre-COVID), to symmetric but highly persistent (COVID), to dramatically asymmetric and explosive (post-COVID), provides the first empirical documentation, to our knowledge, of how crisis type conditions volatility asymmetry in an emerging market.

This study makes several distinctive contributions to the empirical finance literature. First, it provides robust, up-to-date evidence on the volatility dynamics of a North African emerging market, filling a geographical gap in a literature that has disproportionately focused on Asian and Latin American economies. Second, it identifies and documents the symmetry phenomena, demonstrating that the uncritical application of asymmetric volatility models to all emerging markets can lead to misspecification and suboptimal forecast performance. Third, it links these empirical findings to the unique structural characteristics of the

Casablanca Stock Exchange, limited liquidity, specific investor composition, and particular information dissemination environment, offering a plausible microstructure-based explanation for the observed dynamics. Fourth, through subsample analysis, it reveals that volatility dynamics are state-dependent and crisis-type specific, contributing to the growing literature on regime-switching behavior in financial markets (Hamilton and Susmel, 1994; Guidolin and Timmermann, 2006; Gil-Alana et al., 2023). Fifth, the documentation of explosive persistence ($\alpha + \beta > 1$) during the post-COVID period represents a rare and striking finding that extends the literature on volatility persistence under extreme conditions (Baur and Dimpfl, 2019; Enow, 2023).

Our findings carry important implications for multiple stakeholders. For financial economists and theorists, the results suggest that the leverage effect should be reconceptualized as a conditional phenomenon rather than a universal constant. The heterogeneity of emerging market microstructures, differences in liquidity, investor composition, and informational efficiency, means that volatility dynamics must be empirically established rather than assumed. This finding aligns with and extends the work of Morck et al. (2000) on informational differences across markets, and of Bekaert and Harvey (1997) on the time-varying nature of emerging market volatility. For investors and portfolio managers, the state-dependent nature of Moroccan market volatility carries practical implications. During normal conditions, the symmetric GARCH model provides reliable forecasts (RMSE static: 0.588), and the absence of leverage effects suggests that hedging strategies need not be disproportionately biased toward downside protection. However, during geopolitical crises, the emergence of powerful asymmetry (EGARCH $\gamma = -0.291$) and explosive persistence requires more sophisticated risk management approaches, including asymmetric option pricing models and regime-aware Value-at-Risk calculations. The dramatic variation in persistence across regimes, from moderate (0.814) to near-unit-root (0.950) to explosive (1.120), implies that volatility forecasting models must be regularly recalibrated as market conditions evolve. For policymakers and market regulators, our findings highlight that improving market efficiency may require different interventions depending on the target regime. The baseline symmetry during normal conditions suggests that the market does not systematically misprice negative information, a positive feature suggesting that foundational market structures are functioning adequately. However, the high kurtosis and fat tails indicate that informational shocks still create extreme movements, suggesting that efforts to improve corporate transparency and timely disclosure could further enhance efficiency (Morck et al., 2000). During crises, the emergence of asymmetry and explosive persistence suggests that market stabilization mechanisms, circuit breakers, trading halts, liquidity facilities, may be particularly valuable. The contrast between the COVID period (no asymmetry) and the post-COVID period (strong asymmetry) further suggests that different crisis types may require different policy responses: health crises demand persistence-focused interventions, while geopolitical crises require asymmetry-focused measures.

This study is not without limitations, which should be acknowledged and considered when interpreting the results. First, our analysis is univariate and does not incorporate specific macroeconomic variables or global risk factors (e.g., VIX, oil prices, interest rates, exchange rates) that might influence volatility dynamics. The exclusion of these variables means that some of the persistence and asymmetry we attribute to market microstructure may partially reflect omitted external factors. Second, the proxies for market microstructure, liquidity, investor composition, information environment— are inferred from aggregate market behavior rather than directly tested using microstructure data. This limits our ability to definitively identify the causal mechanisms underlying the observed symmetry. Third, the explosive persistence ($\alpha + \beta > 1$) documented in the post-COVID period, while statistically valid, raises questions about model stability and the appropriateness of standard GARCH specifications under extreme conditions. Fourth, the subsample analysis, while economically motivated, involves exogeneous breakpoint selection; endogenous regime-switching models might reveal different transition dynamics. Fifth, the relatively small size of the COVID (497 observations) and post-COVID (501 observations) subsamples may affect the precision of estimates, particularly for asymmetry coefficients that require larger samples for reliable detection. Fourth, investigating whether the explosive dynamics observed in 2022–2023 are unique to Morocco or reflect broader regional or global patterns would provide important context. Comparative studies of multiple emerging markets during the same period could reveal whether the post-COVID asymmetry is a local phenomenon or part of a broader shift in global volatility dynamics (Gil-Alana et al., 2023; Lavin et al., 2021). Fifth, comparing traditional GARCH approaches with machine learning techniques for volatility forecasting, neural networks, random forests, gradient boosting, in this state-dependent context could reveal whether flexible algorithms better capture regime shifts and asymmetric dynamics. Sixth, extending the analysis to sectoral indices or individual stocks within the Moroccan market could reveal whether the aggregate symmetry masks heterogeneous behavior at the micro level, some sectors may exhibit leverage effects even when the market index does not. Finally, incorporating global factors such as the VIX, oil prices, or US monetary policy indicators into the volatility models could help disentangle domestic microstructure effects from global contagion effects, building on the work of Li and Giles (2015) on volatility spillovers.

In conclusion, this study provides a nuanced and comprehensive analysis of volatility dynamics in the Casablanca Stock Exchange, resolving the apparent symmetry paradox through the lens of state-dependent behavior conditioned on crisis type. The Moroccan market is structurally symmetric during normal conditions and health crises, but extreme geopolitical and macroeconomic shocks can temporarily induce the leverage effect typically observed in other markets. This finding refines our understanding of emerging market volatility, demonstrating that these markets are not a homogeneous group but exhibit heterogeneous dynamics shaped by their unique microstructures and the nature of the shocks they encounter. By moving beyond the mere application of standard models to a critical interpretation of their results within the local context and across distinct economic regimes, this study contributes to a more nuanced understanding of volatility dynamics in emerging financial markets and provides a foundation for future research into the conditional nature of market behavior under different types of stress.

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Declaration of generative AI and AI-assisted technologies:

During the preparation of this work the authors used ChatGPT in order to translation. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the published article.

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