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Do the Green Bonds Markets React to Political Uncertainty and Financial Stress Alike?

Yousra Trichilli*, Moez Boujelbène, Mouna Boujelbène Abbes*****

Abstract: This study investigates the dynamic relationship between political uncertainty (EPU), financial stress, and green bond returns, utilizing the Range-DCC GARCH model and wavelet coherence analysis. The primary objective is to assess how these factors interact during periods of economic and geopolitical turmoil, specifically the 2014-2016 oil crisis and the COVID-19 pandemic. Our findings reveal a positive correlation between political uncertainty and green bond returns during these crisis periods, suggesting that green bonds act as a safe haven or diversification tool when facing heightened uncertainty. The Range-DCC GARCH model confirms that EPU significantly impacts green bond returns in times of crisis, while the wavelet coherence analysis uncovers a time-frequency co-movement between financial stress, political uncertainty, and green bond performance, particularly during major disruptions. These results contribute to the understanding of green bonds' role as a resilient investment asset during times of volatility. From a practical perspective, these findings offer valuable insights for investors and policymakers seeking to enhance risk management and sustainable investment strategies amid growing uncertainties. Future research could build on these insights by incorporating additional dimensions of uncertainty such as climate risk and environmental policy uncertainty to better understand their differentiated impacts on green bond market behavior and resilience.

Keywords: green bonds; policy uncertainty; Wavelet Coherence; range-DCC-GARCH; financial stress.

JEL classification: G0; G1.

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1. INTRODUCTION

Political instability or risk is a complex concept that presents difficulties in its definition, capture, and quantification across various dimensions (Burger *et al.*, 2016). Within economic literature, it is associated with political turmoil, abrupt shifts in political authority, and alterations in executive power through both violent and constitutional means (constitutional) (Barro, 1991; Fosu, 1992; Alesina *et al.*, 1996).

In accordance with Lipset (1959), political instability can be understood as the antithesis of political stability. A transition in government is characterized by Miljkovic and Rimal (2008) as an indication of political instability, implying a disruption in governance structures regardless of their nature. Butkiewicz and Yanikkaya (2006) categorize the main metrics for assessing the political ramifications of instability into 3 groups: political violence, government stability and social unrest/stability.

Political risk pertains to the uncertainty stemming from governmental actions and political dynamics within and across nations. This form of risk underscores the unpredictability surrounding potential shifts in government policies and their repercussions on the future economic landscape. Extensive research has established a strong correlation between political risk and the valuation of a country's sovereign bonds, with several studies proposing a direct influence of political risk on sovereign debt returns (Bekaert *et al.*, 2016).

In recent times, financial strategies like green finance, environmental finance, and sustainable finance, which prioritize environmental conservation and sustainable progress, have garnered increased attention and significance (Zhang *et al.*, 2021; Wei *et al.*, 2022; Yu *et al.*, 2022; Wang *et al.*, 2024).

Securing funding for environmentally conscious projects presents challenges despite the crucial role financing plays in advancing sustainable development. Green bonds serve as a financial tool enabling the financing of such initiatives, offering capital for enduring projects. We contend that fostering a conducive regulatory framework and enhancing transparency in disclosures are pivotal elements for the expansion of green bonds.

Inspired by the complex interconnections between political uncertainty, financial stress, and stock market returns, our study shifts the focus to green bond markets, an area that remains largely unexplored. While existing research has extensively analyzed the effects of political uncertainty and financial stress on traditional financial markets, little is known about their influence on green bonds. Understanding these interactions is crucial, as green bonds play an increasing role in sustainable finance and global investment strategies.

To address this gap, we adopt a dual-method approach, combining Wavelet analysis and Range-DCC-GARCH modeling. The Wavelet approach allows us to examine how these interactions evolve over time and across different frequencies, capturing both short-term fluctuations and long-term dependencies. At the same time, the Range-DCC-GARCH model, which integrates high, low, and closing prices rather than relying solely on closing prices, provides a more refined measure of volatility dynamics and time-varying correlations. This allows for a deeper understanding of how political uncertainty and financial stress impact green bond markets, beyond what traditional models can reveal.

By integrating these advanced analytical techniques, our study provides new empirical insights into the evolving relationship between political uncertainty, financial stress, and green bonds. To the best of our knowledge, this is the first study to apply Wavelet and Range-DCC-GARCH methodologies in this context, addressing a critical gap in the literature. Our

findings offer valuable implications for policymakers, investors, and market participants navigating the green finance landscape.

This study makes several significant contributions to the literature on the interplay between political uncertainty, financial stress, and green bonds.

First, we employ wavelet coherence analysis to examine the dynamic relationships between political uncertainty, financial stress, and green bonds within the time-frequency domain. This approach uncovers significant correlations that vary across different time periods and frequencies, offering a nuanced understanding of how these factors interact over time. Unlike traditional econometric methods, which typically assume static relationships, this technique reveals the temporal complexity of these interactions. This insight is particularly valuable for policymakers, as it enables them to assess the resilience of green finance in response to macroeconomic shocks and identify the timescales during which these interactions are most pronounced, thereby aiding the development of more robust climate finance policies.

Second, we introduce the Range-DCC GARCH model to analyze the time-varying correlations and mean-reverting behavior of these financial variables. By integrating Engle's DCC model with Molnár's Range-GARCH framework (2016), our methodology enhances volatility estimation with a superior daily price range-based estimator. This advanced approach significantly contributes to understanding the stability and predictability of the relationship between political uncertainty, financial stress, and green bonds. These insights are crucial for financial regulators tasked with assessing and mitigating systemic risks, and they underscore the role of green bonds as potential stabilizing assets during volatile market conditions. Furthermore, this methodology provides actionable tools for stakeholders looking to assess risk and stability in green bond markets.

Third, this study addresses a critical gap by analyzing the co-movement and volatility spillovers between political uncertainty, financial stress, and green bonds from a time-series perspective. In contrast to prior studies focused on traditional financial assets such as government bonds and cryptocurrencies, the exploration of green bonds as a distinct asset class adds a fresh dimension to the field. This perspective is particularly relevant for investors, as it offers new insights into potential hedging and diversification strategies during periods of heightened political and financial instability. By understanding the volatility spillovers between these factors, investors can better manage portfolio risks and enhance the resilience of their green bond investments.

Moreover, our findings hold important implications for policymakers involved in developing frameworks to support the stability and growth of green finance markets. We will expand the discussion in the revised version to highlight how these insights could be used to design policies that support the integration of green bonds into broader financial markets. For example, policymakers could leverage our findings to develop strategies that enhance the liquidity and stability of green finance markets during times of political uncertainty and financial stress.

By integrating both theoretical and practical aspects, this study not only fills a significant gap in the literature but also provides actionable insights that can help policymakers, investors, and financial regulators navigate the complexities of green finance during times of crisis.

In our study, Section 2 provides an extensive review of the literature. Section 3 delves into the methodology utilized, covering aspects such as data collection and its attributes. The analysis of the results is outlined in Section 4 and the robustness checks in Section 5. Lastly, Section 6 concludes the article by summarizing the findings obtained.

2. LITERATURE REVIEW

Political risk plays a crucial role in shaping country risk, with a significant impact on stock market behavior. The association between political instability and stock markets has been extensively studied, particularly following the recent financial crisis. A range of research explores the intricate relationship between financial markets and green bonds, providing insights into how these financial instruments interact with various forms of uncertainty. For instance, Mohammed *et al.* (2024) examine the effect of green bonds on climate risk indices, focusing on Economic Policy Uncertainty (EPU) and climate summit indices. Their findings indicate that green bonds have significant potential to mitigate climate risk, even amid economic and environmental policy uncertainty.

Building on this, Wang *et al.* (2024) explore the relationships between green bonds (GB), green stocks (GS), EPU, and Climate Policy Uncertainty (CPU) in China. Their results show that the negative predictive effects of EPU and CPU on the green finance market are primarily concentrated at extreme quantiles. They also find an interaction between CPU and EPU, suggesting that these two factors influence the green financial market in complex ways. Furthermore, a negative correlation between the GB and GS markets is observed in the short term, indicating that investors may be able to hedge risk and diversify their portfolios by investing in both green bonds and green stocks.

In a similar vein, Wei *et al.* (2022) investigate the wavelet-based quantile dependence between EPU and green bond markets over the period 2014–2021. Their findings reveal that the Granger causality from EPU to the green bond market is non-linear and varies across different time scales, which adds depth to our understanding of how economic uncertainty affects the green finance sector. Chau *et al.* (2014) also examined political uncertainty stemming from the "Arab Spring" and its impact on stock market volatility in MENA financial markets. They found a significant rise in the volatility of Islamic indices during periods of political turmoil, while conventional index volatility was largely unaffected by uprisings or exhibited minimal impact.

More recently, Moalla (2021) studied the effect of electoral uncertainty on the Canadian stock market, covering 13 federal elections from 1975 to 2019. His research concluded that electoral uncertainty affects market volatility differently depending on the composition of the market portfolio. For instance, it decreased the conditional variance of the equal-weighted portfolio (small caps) but had no effect on its average return. In contrast, electoral uncertainty reduced the return on the weighted portfolio (large caps) without significantly affecting its volatility. This highlights the complex ways in which political events can influence financial markets.

Batrancea (2021a) investigated the impact of financial performance on the assets and liabilities of 45 major banks across Europe, Israel, the United States, and Canada from 2006 to 2020. Using a panel generalized method of moments approach, the study revealed that asset and liability ratios significantly influence financial performance indicators. This underscores the broader impact of financial performance on market behavior, particularly during times of economic and political uncertainty. Similarly, Batrancea (2021b) examined how financial performance influences long-term financial equilibrium, analyzing data from 34 major companies listed on the New York Stock Exchange. His findings demonstrated that the short-term and long-term financial equilibria of these public companies, measured by indicators such as the current ratio, quick ratio, and debt-to-equity ratio, were significantly affected by

various financial performance indicators, particularly during crises like the 2008 financial collapse and the COVID-19 pandemic.

In the broader context of market diversification and risk hedging, Haq *et al.* (2021) explored the dynamic relationship between economic policy uncertainty, green bonds, clean energy stocks, and rare earth elements. They found that green bonds act more as a hedge than a safe haven during periods of economic uncertainty. Moreover, during crises such as COVID-19, green bonds served as diversifiers alongside clean energy stocks and rare earth elements, demonstrating their value in risk management. This aligns with the broader findings in the literature that show green bonds can offer diversification benefits, especially in uncertain times.

Moreover, limited research has examined the correlation between green bonds and various sources of uncertainty, as well as how these uncertainties impact green bond returns. For instance, Pham and Nguyen (2022) analyzed the impact of stock and oil volatilities, as well as EPU, on green bond returns. Their study revealed a dynamic and regime-dependent relationship, with varying impacts depending on market conditions. Similarly, Li *et al.* (2024) explored the asymmetric effects of U.S. EPU, geopolitical risks, and crude oil prices on green bond returns, demonstrating differing effects over the short and long term. These studies emphasize the multifaceted nature of green bond performance in response to global uncertainties.

Finally, Doğan *et al.* (2023) highlighted the role of green bonds as a safe haven asset during uncertain periods. Their research underscores the importance of green bonds in portfolio diversification and risk management, especially during times of economic distress. Si Mohammed *et al.* (2024) also supported the potential of green bonds in mitigating climate risk despite uncertainties in both economic and environmental policies. These findings advocate for an incentivizing framework to enhance the growth of green bonds and to support advancements toward Sustainable Development Goal 13, which focuses on climate action.

Batrancea *et al.* (2023) further contribute to the understanding of economic growth by exploring the relationship between well-being-related infrastructure and economic growth across 212 NUTS 2 regional subdivisions in the EU-28 from 2001 to 2020. Their study, which analyzed data from 151 regions in Western Europe and 61 regions in Central and Eastern Europe, utilized a panel data approach with the first difference generalized method of moments estimator. The results demonstrated how regional responses in Western Europe were influenced by factors such as disposable household income, inter-regional mobility, housing indicators, labor force participation, while in Central and Eastern Europe, factors like housing indicators, internet broadband access, and air pollution were more significant. This regional divergence highlights the varying factors that influence economic growth and stability, providing further insight into the complex dynamics of financial markets during uncertain periods.

The underlying hypotheses guiding this research are formulated as follows:

***H1**: Political uncertainty influences green bonds.*

***H2**: Financial stress influences green bonds.*

3. DATA AND METHODOLOGY

3.1 Data

We have utilized monthly closing prices for the following green bonds: S&P GREEN BOND INDEX, S&P GREEN BND SELECT IN, and S&P MUNI GREEN BOND. Their monthly returns are calculated by using the following equation:

$$R_t = In(\frac{P_t}{P_{t-1}}) \quad (1)$$

where P_t denotes the closing index price for month t and P_{t-1} represents the closing index price for the preceding month.

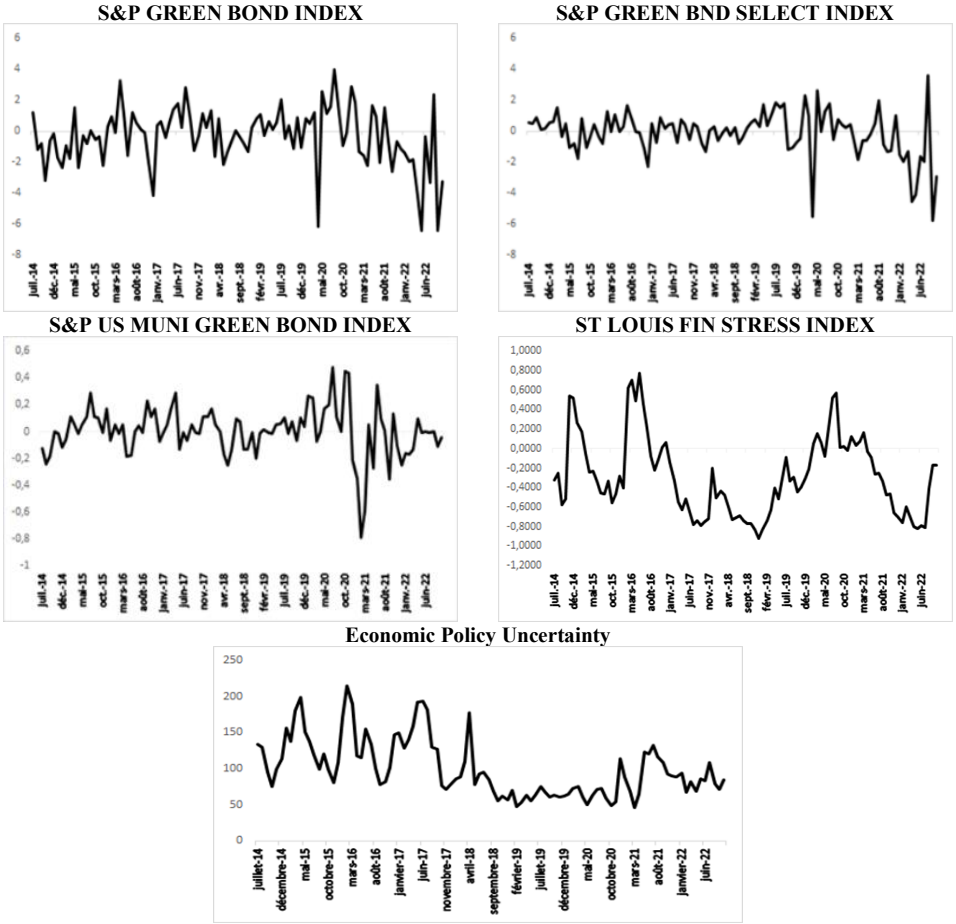

Figure no. 1 – The dynamics of green bond returns in relation to Political uncertainty and financial stress

For the Range-based DCC models, we specifically utilize the highest, lowest, opening, and closing prices of each month.We also incorporated policy uncertainty variables: ST LOUIS FIN STRESS INDEX (FSI) and Economic Policy Uncertainty (EPU). These data were obtained from the DataStream database for the period 2014-2022.

The examination of green bond returns, political uncertainty, and financial stress, as depicted in Figure no. 1, unveils intriguing patterns. In 2020, amid the pandemic crisis, green bonds experienced a notable decline, reflecting the market's response to the economic challenges posed by the global health emergency. Conversely, Economic Policy Uncertainty and the ST LOUIS FIN STRESS INDEX saw a surge during the oil crisis, indicating heightened geopolitical tensions, followed by a sharp decrease in response to the COVID-19 health crisis as governments focused on managing the pandemic. Fast forward to 2022, a discernible downward trend is observed in the curves, attributed to the ongoing conflict between Ukraine and Russia, underscoring how geopolitical events can impact financial markets and investment instruments such as green bonds.

3.2 Methodology

The methodology of our study is designed to provide comprehensive insights. Firstly, we utilize the Range-DCC GARCH to assess the effect of political uncertainty, financial stress on the dynamic of green bond market. This model introduces a novel approach, departing from conventional GARCH models by utilizing the intraday price range between peak and trough to capture volatility dynamics. Additionally, we employ the wavelet coherence model to investigate co-movements over time and frequency, enriching our comprehension of the connection between green bond yields and political uncertainty.

3.2.1 The Range-DCC GARCH

Integrating Molnár's (2016) Range-GARCH model into the DCC-GARCH model marks a notable progress. The RGARCH(p,q) model, with its precise formulation tailored to depict the range dynamics of the data, stands out as a sophisticated tool. By harnessing Molnár's novel methodology, this model excels in managing the complex interconnections and patterns inherent in financial or time series data.

By incorporating range dynamics, this specification provides a more sophisticated understanding of volatility, greatly enhancing the modeling capabilities. The comprehensive structure of the RGARCH(p,q) formulation allows for a detailed exploration of volatility patterns, resulting in more accurate forecasts and risk assessments. This integration of methodologies not only broadens the model's capabilities but also boosts its predictive precision, establishing a robust framework for analyzing complex financial data.

Thus, the RGARCH(p,q) model is formulated as the following specification:

$$\varepsilon_t \mid |\psi_{t-1} \sim Normal\ (0, h_t) \tag{2}$$

where $h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \sigma^2_{p_{t-i}} + \sum_{j=1}^{p} \beta_j h_{t-j}$

$\sigma_{p_t}^2$ represents the Parkinson (1980) estimator calculated using the low high opening and closing prices expressed as $\sigma_{p_{t-i}}^2 = \frac{[\ln (H_t)/L_t]^2}{4ln2}$

In order to preserve the positivity of h_t in the RGARCH model, similar to the GARCH model, certain parameter requirements must be met. Guaranteeing the stability and dependability of the RGARCH process entails satisfying specific criteria. One critical condition is that the sum of the squares of the parameters in the model must be less than one. This condition can be represented as:

$$\sum_{i=1}^{q} \alpha_i = \sum_{j=1}^{p} \beta_j < 1 \tag{3}$$

When the total sum of the squares of the parameters (α_i and β_j) is below one, it ensures the covariance stationarity of the RGARCH process. This criterion is essential for upholding stability within the model, enabling a thorough and dependable analysis of volatility dynamics in financial or time series data.

Adhering to this requirement not only ensures the covariance stationarity of the RGARCH process but also establishes a critical groundwork for precise volatility modeling and forecasting in diverse analytical scenarios. By meeting this inequality, the RGARCH model can adeptly capture and describe the underlying dynamics of data volatility, creating a more resilient and precise framework for risk evaluation and predictions.

Specifically, this enables us to concentrate on developing the new DCC-Range-GARCH model (DCC-RGARCH). The formulation of the $DCC(P,Q) - RGARCH(p,q)$model is as follows:

$$\begin{gathered} \varepsilon_t \,||\psi_{t-1} \sim Normal\,(0, cov_t\,), \\ cov_t = D_t\, cor_t D_t\,, \\ cor_t = Q_t^{*-1}\, Q_t Q_t^{*-1}\,, \end{gathered} \tag{4}$$

$$Q_t = \left(1 - \sum_{i=1}^{Q} \varepsilon_i - \sum_{j=1}^{P} \theta_j\right) s + \sum_{j=1}^{P} \varepsilon_i (Z_{t-i}^{RGARCH} (Z_{t-i}^{RGARCH})') + \sum_{j=1}^{P} \theta_j\, Q_{t-j} \tag{5}$$

Here $D_t = diag\left((h_{1t}^{RGARCH})^{1/2}, (h_{2t}^{RGARCH})^{1/2}, \ldots\ldots\ldots, (h_{Nt}^{RGARCH})\right)$ represents the diagonal matrix of conditional variances h_{kt}^{RGARCH} where $k = 1,2 \ldots\ldots, N$. Additionally, Z_t^{RGARCH} denotes the standardized $N \times 1$ residual vector containing the standardized residuals Z_{kt}^{RGARCH} computed from the RGARCH model $Z_{kt}^{RGARCH} = {\varepsilon_{kt}}/{(h_{kt}^{RGARCH})^{1/2}}$.

The parameter estimation process for the DCC-R-GARCH model employs an advanced two-stage approach, utilizing the quasi-maximum likelihood method. This method entails optimizing the log-likelihood function, which can be split into 2 essential components: the volatility component and the correlation component.

The total log-likelihood function, presented as $L^{DCC-RGARCH}$ included the sum of these two distinct parts, namely $L_{Vol}^{DCC-RGARCH}$ and $L_{Corr}^{DCC-RGARCH}$.

$$L_{=L_{Vol}^{DCC-RGARCH}}^{DCC-RGARCH} + L_{Corr}^{DCC-RGARCH} \quad (6)$$

The initial element, $L_{Vol}^{DCC-RGARCH}$ concerns the volatility component and is articulated as follows:

$$L_{Vol}^{DCC-RGARCH} = -\frac{1}{2}\sum_{k=1}^{n}\left(n\ ln(2\pi) + \sum_{t=1}^{n}\left(ln(h_{kt}) + \frac{\varepsilon_{kt}^2}{h_{kt}}\right)\right) \quad (7)$$

This segment of the log-likelihood function captures the intricacies of volatility dynamics by incorporating the logarithm of the conditional variances (h_{kt}) and the standardized residuals (ε_{kt}). It holds a crucial position in modeling the volatility of asset returns across time, making a substantial contribution to comprehending and predicting fluctuations in financial markets.

Conversely, $L_{corr}^{DCC-RGARCH}$ signifies the correlation component, as depicted by the subsequent equation:

$$L_{corr}^{DCC-RGARCH} = -\frac{1}{2}\sum_{k=1}^{n}(n\ ln|cor_t| + (z_t^{RGARCH})' cor_t^{-1} z_t^{RGARCH} - (z_t^{RGARCH})' z_t^{RGARCH}) \quad (8)$$

This section delves into the fluctuations of the conditional correlation matrix (cor_t) and the corresponding vectors (z_t^{RGARCH}). It encompasses terms involving the logarithm of the determinant of the correlation matrix and the quadratic form of the standardized residuals in the inverted correlation matrix. This crucial part aims to capture the interdependencies and connections among assets or variables, offering valuable insights into the co-movements and relationships within the dataset.

By optimizing these intertwined components employing the quasi-maximum likelihood model, the DCC-R-GARCH model can estimate parameters effectively, enhancing the understanding of both volatility and correlation dynamics in financial or time series datasets. The intricate and refined nature of these elements elevates the model's precision and efficiency in capturing the intricate structures inherent in market fluctuations and asset interrelations.

3.2.2 Wavelet Coherence

The wavelet coherence method integrates both the temporal and frequency dimensions of a time series, with the goal of evaluating the correlation between pair of temporal datasets across various time and frequency intervals. We utilize the wavelet coherence technique in accordance with the definition provided by implementing smoothing techniques in the time and frequency domains. Cross-wavelet examination is employed to explore the relationship between two signals within a common power spectrum. The cross-wavelet analysis of two signals $x = x\ (tn)$ and $y = y\ (tn)$ is characterized by:

$$W^{xy}(t,s) = W^{X}(t,s)W^{y*}(t,s) \quad (9)$$

with $W^{y*}(t,s)$ presents the conjugate complex of $W^{y}(t,s)$.

In Equation (7), the variables 's' and 't' refer to the scale and position indices, respectively. The continuous wavelet transform for any given pair of time series 'x' and 'y' can be expressed as $W^{X}(t,s)$ and $W^{y*}(t,s)$ where the symbol '*' denotes the complex conjugate operation applied to the series 'y'. Hence, the wavelet transform aims to examine the association between the two time series 'x' and 'y'.

Torrence and Compo (1998) proposed a wavelet coherence method for estimating cross-wavelet power, aiming to identify significant covariance between each two time points across the cross-wavelet power series per scale. While the objective of wavelet coherence aligns closely with that of cross-wavelet power, it might not exhibit high wavelet power. Hence, this paper adopts Torrence and Webster (1999) approach for calculating squared wavelet coherence between pairs, extending the original method by Torrence and Compo (1998). Consequently, the squared wavelet coherence in equation (10) can be expressed as outlined:

$$R^{2}(t,s) = \frac{|S[S^{-1}W^{Xy}(t,s)]|^{2}}{S[S^{-1}|W^{X}(t,s)|^{2}SS^{-1}|W^{y}(t,s)|^{2}]} \quad (10)$$

In equation (10), the smoothing operator 's' functions across both temporal and spatial dimensions, with $R^{2}(t,s)$ representing the localized squared correlation across time and frequency domains. Furthermore, the squared correlation coefficient varies from $0 \leq R^{2}(t,s) \leq 1$.

The value of $R^{2}(t,s)$ establishes the correlation between two time series, and a high (low) value of $R^{2}(t,s)$ indicates a high (low) co-movement.

4. EMPIRICAL RESULTS

4.1 Multicollinearity and descriptive statistics

We tested for multicollinearity using both the correlation matrix and the Variance Inflation Factors (VIF), as shown in Table no. 1.

The correlation matrix provides valuable insights into the relationships between the green bond indices (S&P Green Bond Index, S&P Green Bond Select Index, and S&P US Muni Green Bond Index) and key financial stress and uncertainty indicators (St. Louis Financial Stress Index - FSI and Economic Policy Uncertainty - EPU). The results reveal a strong positive correlation between the green bond indices, particularly between the S&P Green Bond Index and the S&P Green Bond Select Index (0.71), suggesting that these indices display similar market dynamics. Additionally, there is a significant positive correlation between the EPU and the green bond indices, with a high value of 0.93 for the S&P Green Bond Index. This highlights the sensitivity of green bonds to economic policy uncertainty and supports the idea that investors may view green bonds as a safe-haven asset during periods of heightened political and economic uncertainty. In contrast, the FSI shows a weaker, and in some cases, negative correlation with the green bond indices, such as the -0.19 correlation with the S&P Green Bond Select Index. This indicates that financial stress has a more

ambiguous effect on green bond performance, possibly due to differing investor sentiment and market conditions.

Overall, these findings underscore the role of green bonds in portfolio diversification and their responsiveness to macroeconomic uncertainty.

Additionally, as shown in Table no. 1, no correlation value exceeds 0.8, and no VIF value is close to 10. Therefore, we can conclude that the model does not exhibit multicollinearity.

Table no. 1 – Correlation Matrix and Variance Inflation Factor

	(1)	(2)	(3)	(4)	(5)
(1)	1				
(2)	0.710603820449917	1			
(3)	0.1121243177912375	0.1526506001985651	1		
(4)	-0.1914011127883334	-0.19969741407459	-0.04746034473441598	1	
(5)	0.9935213829956638	0.9026059291832366	0.7473757627783605	0.1722443390906292	1
(6)	2.093447	2.076348	1.023458	1.393482	1.326233

Note: (1) S&P GREEN BOND INDEX; (2) S&P GREEN BND SELECT INDEX; (3) S&P US MUNI GREEN BOND INDEX; (4) ST LOUIS FIN STRESS INDEX; (5) Economic Policy Uncertainty; (6) Variance Inflation Factors (VIF)

Table no. 2 presents summary statistics of monthly returns based on bond indices, political uncertainty and financial stress. The S&P US MUNI GREEN BOND index outperforms other green bonds. As for the kurtosis coefficient, the values are higher than 3 for all green bond markets, suggesting leptokurtic distributions. Furthermore, the skewness coefficient is negative for all the variables studied, indicating leftward asymmetry in the distribution. Therefore, normality is rejected. This result is further supported by the J-B statistic, which rejects normality at the 1% threshold for all distributions.

We also report the ARCH test in the last line of Table no. 2, which demonstrates the presence of autocorrelation and heteroskedasticity issues in the data. They are thus suitable for further statistical analysis.

Table no. 2 – descriptive statistics of green bonds return, Political uncertainty and financial stress

	S&P GREEN BOND INDEX	*S&P GREEN BND SELECT INDEX*	*S&P US MUNI GREEN BOND INDEX*	*ST LOUIS FIN STRESS INDEX*	*Economic Policy Uncertainty*
Mean	-0.355039	-0.136815	0.001297	-0.287532	100.5773
Std. Dev.	1.890016	1.483209	0.184921	0.404669	40.03594
Skewness	-0.824153	-1.214893	-0.722996	0.665643	0.908988
Kurtosis	4.556033	6.358660	6.439488	2.771542	3.058350
Jarque-Bera	21.40896	71.60191	58.00403	7.602146	13.78517
Probability	0.000022	0.000000	0.000000	0.022347	0.001015
ARCH	0.667573***	0.692523***	0.540746***	0.7068***	0.8974***

4.2 Range DCC- GARCH model: Dynamic correlation between Political uncertainty, financial stress and green bonds

In this section, we explore the dynamic correlation between green bond returns, political uncertainty, and financial stress using the Range DCC-GARCH model proposed by Engle (2002). Figure no. 1 illustrates these relationships, focusing on key economic indicators such

as the St. Louis Financial Stress Index (FSI) and Economic Policy Uncertainty (EPU), in relation to the S&P Green Bond Index, S&P Green Bond Select Index, and S&P Muni Green Bond Index.

Our results reveal a strong correlation between EPU and green bonds in 2015, with the exception of the S&P Green Bond Select Index. This can be attributed to the oil crisis, which positively influenced the co-movement between EPU and green bonds. Despite economic challenges during this period, interest in green bonds remained strong, underscoring the growing emphasis on sustainable investments even amidst financial turbulence. These findings contrast with those of Pham and Nguyen (2022), who suggest that during periods of low uncertainty, green bonds and EPU exhibit only a weak connection, implying that green bonds can serve as a hedge against uncertainty in such contexts. Similarly, Si Mohammed *et al.* (2024) highlight that, green bonds hold significant potential in mitigating climate risk, even in the face of uncertain economic and environmental policies.

However, the weak correlation during periods of low political uncertainty, as observed in our study, indicates that the relationship between political uncertainty and green bonds is not always consistent. These finding challenges hypothesis H1, suggesting that while political uncertainty can influence green bond returns in some contexts, it does not always lead to a clear or strong connection, especially when uncertainty levels are moderate or low.

During oil crises, we observe a negative correlation between the FSI and green bonds, suggesting that declining oil prices exert a non-economic financial impact on green bonds. This implies that investors tend to shift away from green bonds in favor of more traditional financial assets when uncertainty in the oil market rises.

In the context of financial stress, while our hypothesis H2 predicts a consistent influence of financial stress on green bonds, we find that financial stress does not always correlate positively with green bond returns. The negative correlation observed during the oil crisis and some periods of the COVID-19 pandemic suggests that financial stress can sometimes lead investors to move away from green bonds, questioning the stability of the relationship proposed in hypothesis H2.

In the context of health crises, particularly during the COVID-19 pandemic, the data indicates a positive relationship between EPU and green bonds. However, an exception is noted for the S&P Green Bond Index, which exhibits a negative correlation. This divergence highlights the complexity of interactions between economic and environmental factors during times of disruption. Conversely, the negative correlation between FSI and green bonds suggests that the pandemic significantly influenced investor behavior, reinforcing the perception of green bonds as a relatively stable investment during financial turmoil. The dynamic contagion effect observed in this study appears to be strongly shaped by pivotal events such as the oil crises of 2014–2016 and the COVID-19 outbreak. These findings contrast with those of Mohammed *et al.* (2024), who argue that financial stress positively impacts the middle quantiles of both conventional and green equities, while financial uncertainty negatively affects the upper quantiles. Additionally, Tsagkanos *et al.* (2022) challenge conventional financial stress theory by establishing a causal relationship from green bonds to financial stress, rather than the reverse.

Moreover, the positive correlation between EPU and green bonds supports the idea that green bonds play a diversification role in bond returns during global financial crises and the COVID-19 pandemic. This aligns with the findings of Pham and Nguyen (2022), which emphasize green bonds' potential as diversifying assets across different time horizons. In

contrast, the negative correlation between FSI and green bonds reinforces their role as a safe-haven asset, except for the S&P Green Bond Select Index. This result is consistent with Naeem *et al.* (2023), who argue that green bonds exhibit strong safe-haven characteristics, offering investors valuable diversification opportunities in uncertain economic environments.

Nevertheless, the periods of negative or weak correlation during certain crises challenge the uniformity of green bonds as a safe-haven asset, particularly in the case of financial stress and political uncertainty.

Furthermore, Dong *et al.* (2023) demonstrate that both conventional and green bonds serve as safe havens during periods of heightened geopolitical risk (GPR), with green bonds outperforming their conventional counterparts under increased EPU and CPU levels. Syed *et al.* (2022) also show that positive EPU shocks negatively impact green bonds, whereas negative shocks enhance green bond performance, as evidenced by their NARDL estimation. Additionally, Saud *et al.* (2023) highlight that political and regulatory uncertainties extend their influence to commodity markets, affecting oil and gasoline prices and potentially shaping the evolution of the cryptocurrency market. The persistent correlation between green bond returns and political uncertainty variables over the observed period further underscores these dynamics.

4.3 Relationship between Political Uncertainty, financial stress and Green Bonds: Wavelet Coherence

Wavelet coherence serves as a potent tool for visualizing the simultaneous movement in space-time frequency between policy uncertainty variables and green bond returns. Figure no. 2 illustrates the estimated wavelet coherence between political uncertainty, financial stress and green bond returns, with the horizontal axis representing time and the vertical axis denoting the period. The color code, displayed to the right of each figure, suggests performance levels, with blue representing low performance and red indicating high performance. Inter-wavelet coherence allows for the examination of distinct characteristics in the co-movement between uncertainty variables and green bond performance within the time-frequency domain. Additionally, dotted arrows depict the phase difference of the wavelets, offering insights into the lead-lag structure in the time-frequency domain.

The wavelet co-movement between political uncertainty, financial stress and green bond returns highlights a notable correlation during the periods 2014-2016, coinciding to the oil crisis, and the period of the COVID-19 health crisis. Moreover, black contours on the left and right sides of several scales reveal a positive co-movement at the 5% significance level in both the long run and the short run. This suggests that during crisis periods, political uncertainty and financial stress have a positive co-movement with green bonds, reinforcing hypothesis H1 and H2 during times of high uncertainty. However, the wavelet coherence analysis also indicates that the strength of these correlations weakens during low-uncertainty periods. This contrasts with hypothesis H1, which suggests that political uncertainty continuously impacts green bonds, and hypothesis H2, which assumes a consistent link between financial stress and green bonds. However, the wavelet coherence analysis also indicates that the strength of these correlations weakens during low-uncertainty periods. This contrasts with hypothesis H1, which suggests that political uncertainty continuously impacts green bonds, and hypothesis H2, which assumes a consistent link between financial stress and green bonds.

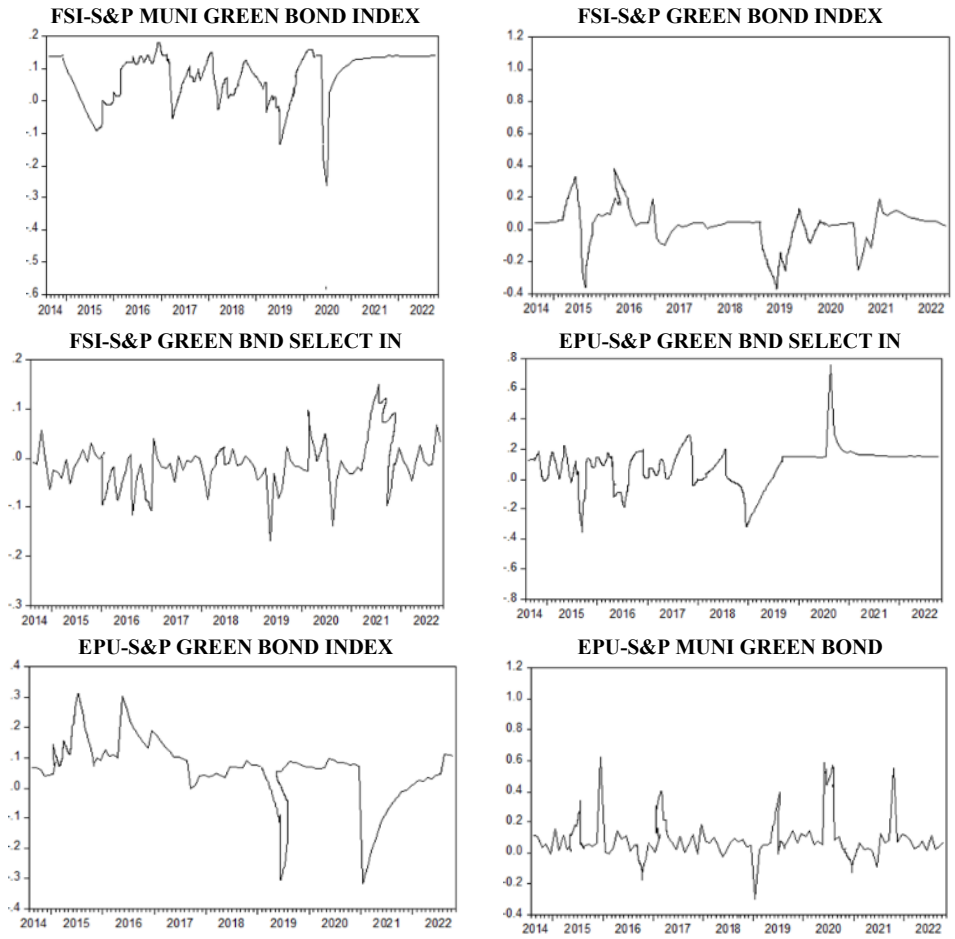

Figure no. 2 – The dynamic correlation between green bond's return, Political uncertainty and financial stress: Range DCC- GARCH model

This indicates that political uncertainty and financial stress have a positive co-movement on green bonds during crisis periods. The significant correlation underscores the influence of the oil crisis on green bonds, suggesting a shock transmission between financial stress, economy policy uncertainty and green bonds. These findings are consistent with the study by (2015), which revealed a positive correlation between government bond yields and international political risk. However, they contrast with the research of Arif *et al.* (2022), who proposed that the green bond index offers substantial hedging and safe-haven opportunities for long-term investors in traditional financial instruments.

Moreover, the wavelet analysis results support the Range-DCC GARCH outcomes, highlighting a notable positive correlation between Economic Policy Uncertainty and green bond returns during crises. This result contradicts the findings of Haq *et al.* (2021), who suggested that green bonds act more as a hedge than a safe haven in the face of EPU.

Conversely, the Range-DCC GARCH model's results indicate a negative correlation between the financial stress index and green bonds. These findings further contribute to the mixed evidence on the role of green bonds in periods of financial stress, especially when examining them across different time periods.

Additionally, in low-uncertainty periods like the COVID-19 pandemic, the connection between green bonds, financial stress, and political uncertainty weakens. This suggests that green bonds could potentially serve as a hedge contrary to uncertainty during such times (Pham and Nguyen, 2022) As emphasized by Guo and Zhou (2021), green bonds are purposefully crafted to emphasize long-term sustainable investments, positioning them as a crucial hedging tool against climate risks, financial uncertainties, and unforeseen events like the COVID-19 epidemic.

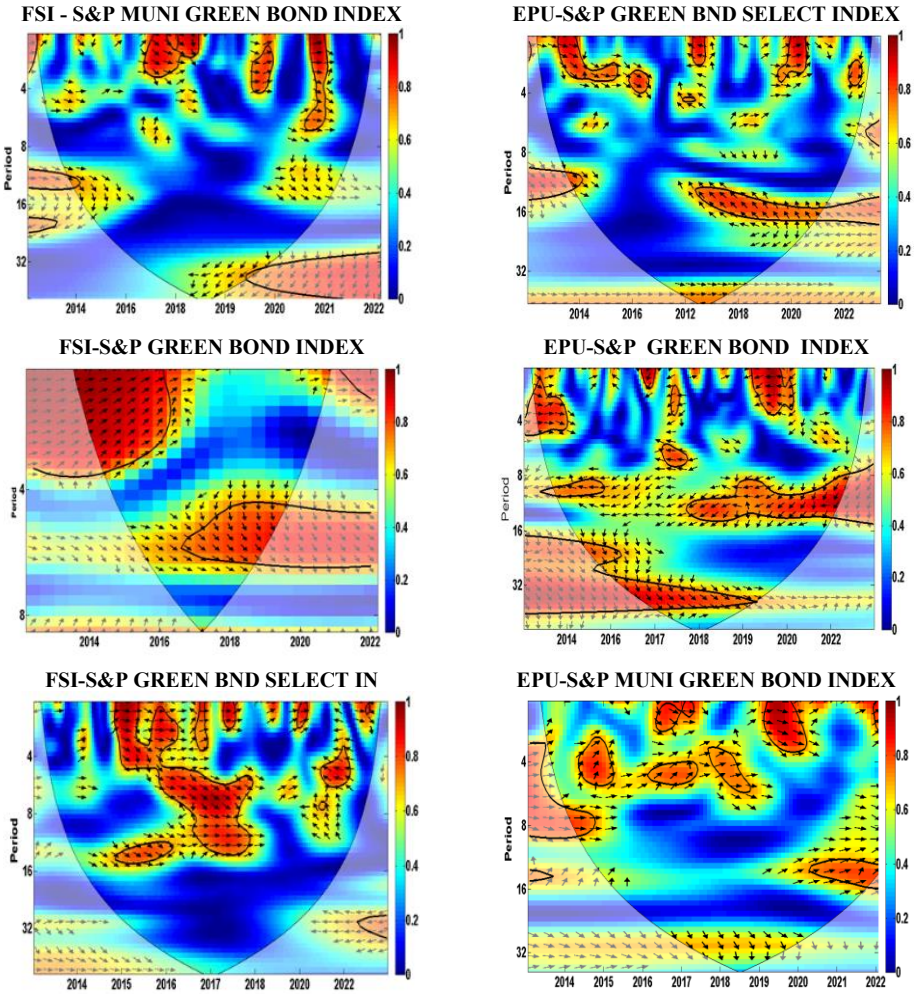

Figure no. 3 – Wavelet coherence between political uncertainty, financial stress and green bond returns

5. ROBUSTNESS CHECK

5.1 Unit Root test

Table no. 3 presents the results of the Augmented Dickey-Fuller (ADF) unit root test for various green bond indices, financial stress indices, and economic policy uncertainty. The ADF test examines whether the time series are stationary by testing the null hypothesis of the presence of a unit root against the alternative hypothesis of stationarity. The reported test statistics are compared to the critical values at the 1%, 5%, and 10% significance levels. Since the test statistics for all variables are lower than the critical values at conventional significance levels and the corresponding p-values are close to zero, the null hypothesis of a unit root is strongly rejected. These results indicate that all series are stationary, implying that they do not require further differencing to achieve stationarity.

Table no. 3 – ADF Unit root test

Variables	Augmented Dickey-Fuller	Critical values 1% level	5% level	10% level	Prob
S&P GREEN BOND INDEX	-8.183837	-3.501445	-2.892536	-2.583371	0.0000
S&P GREEN BND SELECT INDEX	-8.821770	-3.500669	-2.892200	-2.583192	0.0000
S&P US MUNI GREEN BOND INDEX	-13.16217	-3.498439	-2.891234	-2.582678	0.0001
ST LOUIS FIN STRESS INDEX	-9.621204	-3.498439	-2.891234	-2.582678	0.0000
Economic Policy Uncertainty	-7.838345	-3.499910	-2.891871	-2.583017	0.0001

5.2 Cointegration Analysis of Green Bonds, Financial Stress, and Economic Policy Uncertainty

In this section, we examine the long-term cointegration between green bond indices, financial stress, and economic policy uncertainty (EPU). The optimal lag length for the vector autoregression (VAR) model is set to one ($p = 1$), as determined by the Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC), both of which reach their minimum values at $p = 1$.

Table no. 3 presents the results of the Johansen cointegration test, which assesses the presence of long-term relationships between green bond indices, financial stress, and economic policy uncertainty (EPU). The trace and max statistics indicate that, in most cases, at least one cointegrating relationship exists, as the test statistics exceed the corresponding critical values. This suggests that these variables are not entirely independent in the long run, meaning that financial stress and economic policy uncertainty influence the movement of green bond indices over time.

The presence of cointegration between financial stress and green bonds implies that fluctuations in financial stability have persistent effects on the valuation of green bonds. This can be explained by shifts in investor sentiment and liquidity constraints during periods of financial distress, which may reduce demand for green assets. The long-term relationship also suggests that green bonds are not completely insulated from broader financial market stress, challenging their potential role as a safe-haven asset. This dynamic is supported by the Range DCC-GARCH model's findings, which show how financial stress influences the returns of green bonds over time.

Similarly, the cointegration between economic policy uncertainty (EPU) and green bond indices highlights the sensitivity of the green bond market to regulatory and macroeconomic uncertainties. Given that green investments are often influenced by policy incentives and climate regulations, uncertainty in these areas can create sustained volatility in green bond prices. The existence of a long-term relationship suggests that investors adjust their expectations based on evolving policy frameworks, reinforcing the importance of regulatory stability for green finance. The Range DCC-GARCH model further confirms this by showing the changing correlation between EPU and green bond returns throughout different periods of uncertainty. These results are also validated by Wei *et al.* (2022), who propose a quantile-based framework to analyze the dependence between EPU and green bond markets under various market conditions. Their findings reveal that the Granger causality from EPU to the green bond market is nonlinear and varies across time scales. These insights provide policymakers with valuable guidance in designing strategies to mitigate systemic volatility caused by external shocks in the green bond market.

From a portfolio optimization and hedging perspective, these findings emphasize the need to account for financial stress and policy uncertainty when constructing green investment strategies. Given that green bonds exhibit a long-term dependence on these factors, diversification into assets less sensitive to financial turbulence and regulatory shifts may be necessary to enhance portfolio resilience. These results are further validated by Syed *et al.* (2022), who provide insights into the hedging and diversification properties of Bitcoin and the influence of U.S. economic policy uncertainty on green bonds. Additionally, Broadstock and Broadstock and Cheng (2019) present evidence that the relationship between green and black bonds is highly sensitive to fluctuations in financial market volatility, economic policy uncertainty, daily economic activity, oil prices, and uniquely constructed sentiment indicators reflecting positive and negative news on green bonds.

Table no. 4 – Cointegration test

		Eigenvalue	Trace Statistic	Critical Value	Max-Statistic	Critical Value
S&P GREEN BOND INDEX-ST LOUIS FIN STRESS INDEX	None *	0.156045	23.85807	15.49471	16.45663	14.26460
	At most 1 *	0.073465	7.401447	3.841465	7.401447	3.841465
S&P GREEN BOND INDEX-Economic Policy Uncertainty	None *	0.169151	26.49542	15.49471	17.97486	14.26460
	At most 1 *	0.084093	8.520562	3.841465	8.520562	3.841465
S&P GREEN BND SELECT INDEX -ST LOUIS FIN STRESS INDEX	None *	0.154793	23.70789	15.49471	16.31289	14.26460
	At most 1 *	0.073403	7.394994	3.841465	7.394994	3.841465
S&P GREEN BND SELECT INDEX -Economic Policy Uncertainty	None *	0.136791	23.31707	15.49471	14.26855	14.26460
	At most 1 *	0.089065	9.048519	3.841465	9.048519	3.841465
S&P US MUNI GREEN BOND INDEX - ST LOUIS FIN STRESS INDEX	None *	0.242810	34.13022	15.49471	26.97966	14.26460
	At most 1 *	0.071066	7.150555	3.841465	7.150555	3.841465
S&P US MUNI GREEN BOND INDEX - Economic Policy Uncertainty	None *	0.215888	32.37600	15.49471	23.59075	14.26460
	At most 1 *	0.086589	8.785249	3.841465	8.785249	3.841465

5.3. VECM Analysis of Green Bonds, Financial Stress, and Policy Uncertainty

The VECM estimation results provide valuable insights into the relationship between green bonds, financial stress (S&P US Financial Stress Index), and economic policy uncertainty (EPU). The presence of a negative and significant error correction term (ECT) confirms the existence of a long-term equilibrium among these variables, indicating that any short-term deviations due to external shocks will gradually correct themselves over time. The impact of financial stress on green bonds is particularly revealing. A negative coefficient on financial stress suggests that increased market instability leads to a decline in green bond prices, as risk-averse investors shift away from relatively volatile assets. This aligns with traditional flight-to-safety behavior, where capital moves towards more stable investment options during periods of financial turmoil. However, a positive coefficient would imply that green bonds are perceived as a safe-haven asset, attracting investors seeking stability in uncertain financial conditions. This result is further confirmed by the Range DCC-GARCH model, which highlights the negative correlation between financial stress and green bonds, especially during economic crises such as the oil crisis and COVID-19 pandemic, reinforcing their role as a hedge in uncertain times.

Similarly, the effect of EPU on green bonds varies depending on investor sentiment. A negative coefficient indicates that rising economic uncertainty discourages investment in green bonds, as investors prioritize liquidity and opt for more traditional safe assets, such as government bonds or cash reserves. Conversely, a positive coefficient would suggest that green bonds are regarded as resilient, potentially benefiting from their long-term sustainability appeal, which aligns with investor preferences for stable, socially responsible investments during uncertain times. This finding is consistent with the dynamic correlations observed in the Range DCC-GARCH model, which shows that EPU positively correlates with green bonds in certain periods, such as the COVID-19 crisis, confirming that green bonds can serve as a diversification tool in times of high uncertainty.

In the short run, the lagged effects of financial stress and EPU demonstrate that past fluctuations in these variables significantly shape present green bond valuations. The speed and magnitude of these adjustments depend on the estimated coefficients, shedding light on how quickly investors react to macroeconomic instability and policy shifts. The results suggest that both financial stress and economic policy uncertainty play a crucial role in shaping the green bond market. While financial stress generally reduces green bond investment, EPU can have mixed effects depending on investor perceptions. These findings, confirmed by the time-varying correlations of the Range DCC-GARCH model, underscore the importance of macroeconomic conditions and investor sentiment in determining the behavior of green bonds in both stable and volatile environments.

Table 5. Vector Error Correction Model (VECM)

Error Correction	D(S&P GREEN BOND INDEX)	D(S&P GREEN BND SELECT INDEX)	D(S&P US MUNI GREEN BOND INDEX)	D(ST LOUIS FIN STRESS INDEX)	D(Economic Policy Uncertainty)
	-0.425781	0.326015	-0.032261	-0.030971	-5.145087
COINTEQ1	(0.21838)	(0.18468)	(0.02273)	(0.02799)	(3.14705)
	[-1.94974]	[1.76531]	[-1.41912]	[-1.10658]	[-1.63489]
D(S&P GREEN	-0.357712	-0.217101	0.027881	0.025955	3.638346
BOND INDEX (-1))	(0.19651)	(0.16619)	(0.02046)	(0.02519)	(2.83194)

Error Correction	D(S&P GREEN BOND INDEX)	D(S&P GREEN BND SELECT INDEX)	D(S&P US MUNI GREEN BOND INDEX)	D(ST LOUIS FIN STRESS INDEX)	D(Economic Policy Uncertainty)
	[-1.82030]	[-1.30636]	[1.36294]	[1.03053]	[1.28475]
D(S&P GREEN BOND INDEX (-2))	0.074159	0.038930	0.030015	0.021235	2.819347
	(0.14342)	(0.12128)	(0.01493)	(0.01838)	(2.06676)
	[0.51709]	[0.32098]	[2.01044]	[1.15531]	[1.36414]
D(S&P GREEN BND SELECT INDEX (-1))	-0.393431	-0.537462	-0.038485	-0.012439	-3.980938
	(0.21528)	(0.18205)	(0.02241)	(0.02759)	(3.10232)
	[-1.82757]	[-2.95221]	[-1.71733]	[-0.45083]	[-1.28321]
D(S&P GREEN BND SELECT INDEX (-2))	-0.558579	-0.376251	-0.026711	-0.011340	-3.645915
	(0.18023)	(0.15241)	(0.01876)	(0.02310)	(2.59724)
	[-3.09932]	[-2.46861]	[-1.42372]	[-0.49094]	[-1.40376]
D(S&P US MUNI GREEN BOND INDEX(-1))	2.120774	1.945139	-0.321279	0.157553	33.21446
	(0.99646)	(0.84269)	(0.10373)	(0.12771)	(14.3600)
	[2.12831]	[2.30826]	[-3.09725]	[1.23368]	[2.31299]
D(S&P US MUNI GREEN BOND INDEX(-2))	3.901357	1.836151	-0.135933	-0.013961	17.32263
	(1.02354)	(0.86558)	(0.10655)	(0.13118)	(14.7501)
	[3.81165]	[2.12129]	[-1.27578]	[-0.10642]	[1.17441]
D(ST LOUIS FIN STRESS INDEX (-1))	-0.671866	-0.734817	-0.103615	0.011585	13.05820
	(0.84007)	(0.71043)	(0.08745)	(0.10767)	(12.1062)
	[-0.79977]	[-1.03432]	[-1.18484]	[0.10760]	[1.07863]
D(ST LOUIS FIN STRESS INDEX (-2))	0.584866	-0.056024	-0.127473	-0.082955	-1.292261
	(0.85280)	(0.72119)	(0.08878)	(0.10930)	(12.2896)
	[0.68582]	[-0.07768]	[-1.43591]	[-0.75899]	[-0.10515]
D(Economic Policy Uncertainty(-1))	0.017647	0.013228	-5.73E-05	-0.000111	6.59E-05
	(0.00726)	(0.00614)	(0.00076)	(0.00093)	(0.10467)
	[2.42963]	[2.15355]	[-0.07572]	[-0.11923]	[0.00063]
D(Economic Policy Uncertainty(-2))	0.004873	0.003078	-0.001543	-0.001131	-0.153687
	(0.00745)	(0.00630)	(0.00078)	(0.00095)	(0.10732)
	[0.65430]	[0.48869]	[-1.99102]	[-1.18450]	[-1.43206]
C	-0.047285	-0.069410	0.000540	0.003929	-0.260299
	(0.18263)	(0.15444)	(0.01901)	(0.02341)	(2.63181)
	[-0.25892]	[-0.44942]	[0.02843]	[0.16786]	[-0.09891]
R-squared	0.641541	0.581072	0.731158	0.667989	0.545749
Adj. R-squared	0.582211	0.413917	0.531661	0.552624	0.535199
Sum sq. resids	274.3513	196.2094	2.973036	4.506458	56976.20
S.E. equation	1.796570	1.519324	0.187021	0.230255	25.89031
F-statistic	9.127604	7.163574	2.323268	0.563699	1.318402
Log likelihood	-188.0624	-171.8039	31.39165	11.21914	-446.8574
Akaike AIC	4.124998	3.789771	-0.399828	0.016100	9.460978
Schwarz SC	4.443519	4.108292	-0.081307	0.334621	9.779499
Mean dependent	-0.025667	-0.039465	0.001374	0.004207	-0.116428
S.D. dependent	2.496707	1.984590	0.200699	0.224425	26.35837
Determinant resid covariance (dof adj.)		4.343460			
Determinant resid covariance		2.244253			
Log likelihood		-727.3913			
Akaike information criterion		16.33796			
Schwarz criterion		18.06329			
No. of coefficients		65			

6. CONCLUSION

In conclusion, this study offers valuable empirical insights into the transmission of volatility within the green bond markets, using both the Range-DCC GARCH model and wavelet coherence analysis. Our results demonstrate the significant impact of political uncertainty and financial stress on green bond performance, particularly during crisis periods. The Range-DCC GARCH model highlights a strong correlation between Economic Policy Uncertainty (EPU) and green bonds during the 2015 oil crisis, while a negative correlation is observed between the Financial Stress Index (FSI) and green bonds during oil price declines. Additionally, during the COVID-19 pandemic, a positive relationship between EPU and green bonds is evident, although exceptions such as the S&P Green Bond Index illustrate the complexity of the observed dynamics. Wavelet coherence analysis further corroborates these findings, showing significant correlations between political uncertainty, financial stress, and green bond returns during both the oil crisis and the COVID-19 pandemic.

However, the results of this study should be interpreted in light of certain limitations. The reliance on specific indices, particularly those from certain geographic regions, may limit the generalizability of the conclusions to a broader range of global economic contexts. This suggests that future studies could expand the geographical scope to better understand the global relevance of the observed relationships. Moreover, while this paper has suggested that green bonds can serve as a hedge against financial uncertainties, the results also indicate periods of negative correlation, particularly during financial stress. This observation highlights that the hedging function of green bonds is context-dependent and may not be uniformly evident across all crisis scenarios.

It is therefore essential to adopt a nuanced perspective regarding the role of green bonds as a hedging instrument, taking into account the specific contexts of different crises. Wavelet coherence analysis provides additional insights into the dynamic evolution of the relationships between green bonds and uncertainty variables, offering avenues for investment strategies tailored to periods of high or low uncertainty.

This study contributes to the literature by highlighting the dynamic interaction between green bonds, political uncertainty, and financial stress during crisis periods. Future research could extend this analysis by incorporating other dimensions of uncertainty, such as climate-related or environmental policy risks, to further understand their influence on green bond dynamics and resilience.

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Political Connections and M&As Outcomes: Bibliometric Analysis and Research Agenda

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Abstract: Mergers and acquisitions (M&A) are a common strategy to accelerate firms' growth, but they also carry future risks due to substantial expenditures, uncertain payback, and irreversible nature. This study examines current and future research trends concerning the influence of political connections on M&A by utilizing a systematic literature review and the bibliometric tools CiteSpace and VOSviewer. We examine prominent authors to gain insight into significant contributors and to identify major research domains, knowledge sources, theories, and keyword trends to uncover primary research themes. Analysis of 308 relevant articles published from 1986 to 2023 reveals a significant growth in publications on this topic, with an increasing focus on emerging countries. Greater attention is paid not only to business and economic areas such as market and financial performance, internationalization, and corporate governance but also to the impact of politically affiliated firms in implementing M&A to help achieve sustainable development goals. The findings of this study offer valuable insights for decision-makers seeking to leverage political connections as a non-market strategy to drive organizational growth. The literature review suggests that managers with political affiliations may enjoy greater access to resources and opportunities for M&A. However, these connections can also facilitate rent-seeking behaviour, undermining government oversight and sustainable M&A practices. Politically connected executives may also face conflicts of interest between the increasing shareholders value and political agendas. In the current climate of deglobalization and protectionism, political connections can serve as either an asset or a liability, especially for state-owned enterprises engaged in cross-border M&A.

Keywords: political connections; mergers & acquisitions; bibliometric; systematic literature review; CiteSpace; VOSviewer.

JEL classification: G34; G38; M21.

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1. INTRODUCTION

Mergers and acquisitions (M&A) are investment strategies that companies adopt to accelerate growth or enhance their competitive position. In the traditional M&A framework, the main reason for M&A is synergy, where the combined capabilities of two companies create more value than they could separately. Companies also conduct M&A due to other reasons, such as 1) management considerations, including optimizing technology and operations (Capron and Guillén, 2009; Zhang *et al.*, 2020; Li and Wu, 2022); 2) opportunistic reasons, where well-capitalized acquiring firms take advantage of bargain deals by taking over target firms during economic distress (Yang and D Stoltenberg, 2014); 3) financial reasons such as tax benefits and interest deductions associated with an increase in the debt-equity ratio of the combined enterprise (Auerbach and Reishus, 2013); and 4) behavioural reasons such as managerial self-interest in economic compensation (Agrawal and Walkling, 1994; Liu *et al.*, 2019), the drive for empire-building (Bonaime *et al.*, 2018), and executives' overconfidence in their ability to better manage the target firms (Roll, 1986; Haleblian *et al.*, 2009). However, as a strategic decision, M&A also increases the risk to companies' future performance since they involve high resource outflow, uncertain payback in the long term, and at least partially irreversible nature of the investment.

The importance of personal connections for business success is a well-known concept worldwide. Faccio's survey (2010) of 532 companies across 42 countries revealed that 40.2% of major shareholders and 59.8% of top directors have political connections. In the US, both local and foreign firms try to influence government stakeholders through increased campaign contributions and lobbying (Boschelli *et al.*, 2024). In emerging economies, where financial systems are often relationship-based, political connection plays a substantial role. The emphasis on ”guanxi” in China and ”quem indica” in Brazil underscores the value of social networks and highlights how political connections can shape interpersonal and inter-organizational dynamics (Desai and Olofsgård, 2011; Chen *et al.*, 2017; Fornes *et al.*, 2022). Ahmed and Hussainey (2023) and Carboni (2017) conducted a systematic literature study to identify various channels of political connections that impact the firm's performance.

In this study, we take a narrower focus on examining how political connections might affect the M&A outcome. Being affiliated with the government may influence the outcomes of M&A for two fundamental reasons. First, long-term and sizeable investments such as M&A require firms to have better access to financial and other resources. From a sociological perspective, political connections provide executives with social capital that can be leveraged to 1) access information about target firms' potential and their industries, which reduces information asymmetry between the involved parties (Yang and Zeng, 2024) 2) enjoy preferential access to financing (Boubakri *et al.*, 2012; Houston *et al.*, 2014); and 3) have better opportunities for subsidies and penetrating lucrative industries (Ding *et al.*, 2014). Second, the role of regulators in M&A is significant. Governments can disallow a merger to prevent a monopoly, encourage others to create (or protect) a ”national strategy,” or devise rules and regulations to confer market power to connected firms (Li and Qian, 2013)

On the downside, government involvement often leads to rent-seeking behavior, where firms seek subsidies or exclusive rights that are accompanied by corruption (Shleifer and Vishny, 1994), which may harm firms' value creation and efficiency by hindering competition and firms' ability to serve consumers better. The connected firms are also expected to repay any benefits gained from the politician, and this reciprocity may lead to higher operational costs and

a higher probability of investments failing (Bertrand *et al.*, 2018). Boubakri *et al.* (2013) suggest that politically connected firms exhibit higher corporate risk-taking behavior and Fidrmuc *et al.* (2018) further show that political connections can be leveraged to manage regulatory costs and risks associated with the M&A process. Connected executives may also pursue M&A to advance government agendas or their own personal ambitions, which may be unprofitable from the shareholders' perspective (Arnoldi and Muratova, 2019; Tao *et al.*, 2019; Li *et al.*, 2022). Furthermore, in light of deglobalization trends reshaping cross-border M&A, connected firms face more vulnerabilities, such as legitimacy concerns (Zhao and Jia, 2022), political risks (Serdar Dinc and Erel, 2013), and socio- political stigma (Tsui-Auch *et al.*, 2022).

Several scholars have reviewed the existing literature on the influence of government regulations on M&A (Fidrmuc *et al.*, 2018; Liang *et al.*, 2021) and the determinants of cross-border M&A of state-owned enterprises (Redding *et al.*, 2018). However, there is still a limited comprehensive review covering the relationship between political connections and M&A outcomes, especially focusing on bibliometric analysis using CiteSpace and VOSviewer. In particular, the objective of this paper is to i) analyze the research trends, ii) identify the theories that have been applied to the study of political connections and M&A, iii) identify future research in the field of Political Connections and M&A, which could assist researchers in pursuing new avenues of study.

To address the above questions, we employ a systematic literature review and bibliometric analysis on peer-reviewed articles from the Web of Science (WoS) and Scopus with the help of CiteSpace and VOSviewer. This study has several contributions to M&A and political connections research by i) providing a comprehensive and analytical review, as well as theoretical arguments covering the main issues, ii) contributing a systematic literature review methodology by reviewing past and present M&A and political connections research, and iii) offering insight for future research areas by summarizing the empirical results on the impact of political connections to M&A outcomes

The remainder of this paper is organized as follows: Section 2 discusses the materials and methods for data collection extraction. Section 3 presents the findings and discussion of the bibliometric analysis. Finally, the conclusions, limitations, and future research agenda are presented in the last section.

2. MATERIALS AND METHODS

In this research, we utilized the literature from Clarivate's Web of Science and Scopus databases, which are widely recognized for their broad coverage and high-quality data. This allowed us to conduct a comprehensive and reliable bibliometric analysis. By utilizing two reputable databases instead of one, we also aimed to reduce potential bias stemming from reliance on a single database.

In analyzing the data collection, this research employs both qualitative and quantitative methodologies. In qualitative analysis, we employed publication analysis using Systematic Literature Review (SLR) that is considered the "gold standard" method to identify, assess, and synthesize the findings of articles to answer the research questions (Kraus *et al.*, 2022), and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) as screening tools for the selection of the most appropriate studies. Meanwhile in conducting the quantitative method we use the and bibliometric software to conduct (1) performance analysis, which provides an overview of the data regarding productivity, including the number of

publications and number of citations, and (2) science mapping analysis, which explores the relationships between research constituents to identify the structure and dynamic patterns of knowledge within the topics of political connections and M&A (see Figure no. 1).

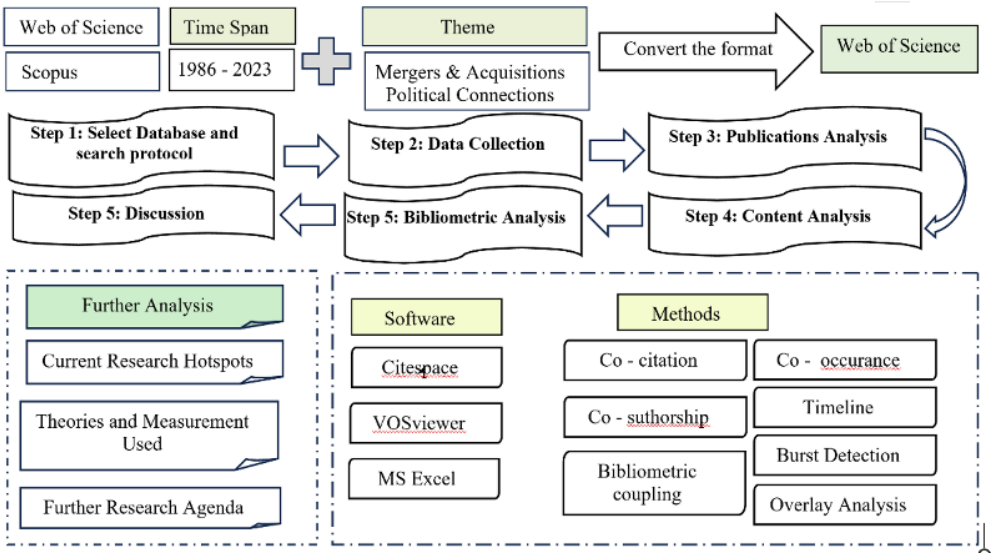

Figure no. 1 – Research Framework

This study combines two bibliometric tools, CiteSpace 6.3.R2, which was initially established by Dr. Chen Chaomei from Drexel University, and VOSviewer 1.6.20, which was developed at Leiden University's Centre for Science and Technology Studies. We use VOSviewer since it is relatively easy to use and has superior mapping capabilities with much easier interpretations (Donthu *et al.*, 2021), and CiteSpace since it is considered a powerful bibliometric tool to generate burst detection analysis, which is a valuable indicator of the most active research topics, and the timeline view analysis, which allows identification of development and emerging research trends in the topic of research (Chen, 2016).

The steps for determining the search range using the PRISMA method include the following: First, we apply the same search query to the Web of Science Core Collection and Scopus database without constraining the time range. This study applies four criteria to retain articles for our analysis. For document types, we focus solely on peer-reviewed journals and select only "Article" and "Review Article". Second, the article must be in English. Third, the search term must appear in the research topics (titles, abstracts, and keywords). Fourth, the study must investigate the effects of political connections on the performance of Mergers and Acquisitions.

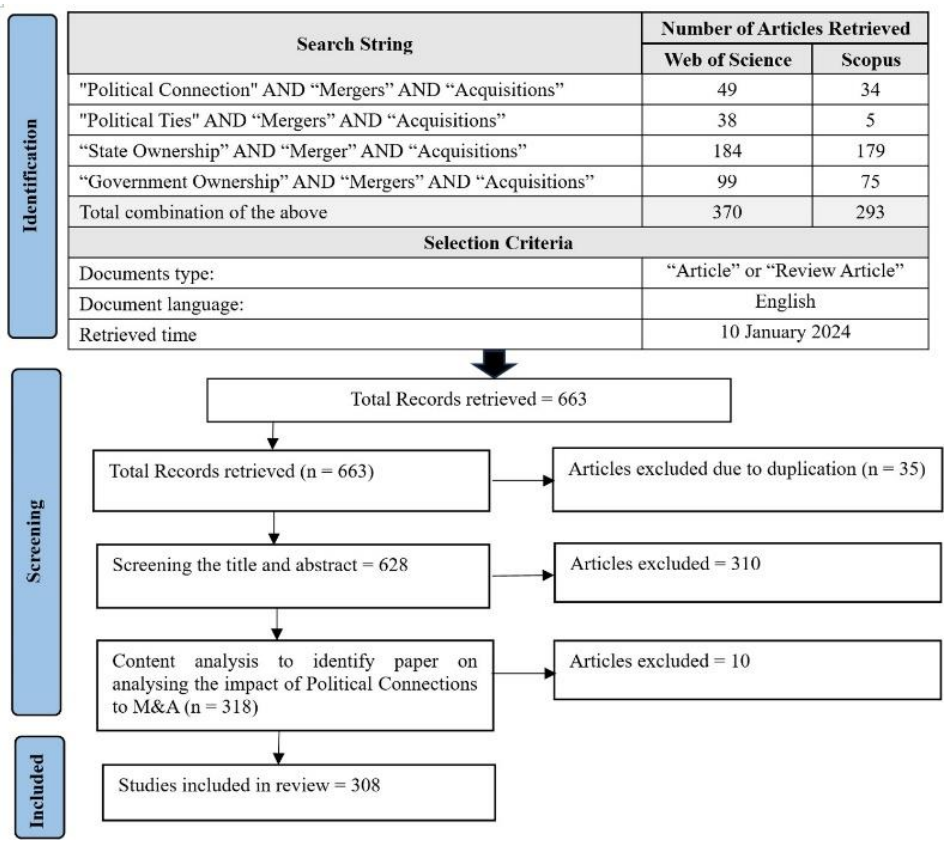

Figure no. 2 – Identification of studies via databases and registers

Thus, on 10 January 2024, a basic search for title, abstract, and keywords on Political connections and M&A was conducted on Web of Science Core Collections and Scopus databases. Our dataset originally contained 663 references, with the proportion of articles 370 (56%) from WoS and 293 (44%) from Scopus. From these articles, we retrieved their titles, abstracts, and other bibliographic information, such as details, authors' names and affiliations, journal names, and year of publication. We exported all the information to an MS Excel spreadsheet. After removing duplicate articles, we read the papers' Abstract, Introduction, and Conclusion parts. We removed the ones that were not related enough from our list. In conducting SLR we designed a worksheet to map the key features of the articles selected, including the research questions, hypothesis, theoretical foundations, methodology, sample characteristics, independent and dependent variables, mediating or moderating variables, and primary findings. At the end of the process, 308 articles published from 1986 to 2023 were inspected, of which 7 papers were review articles. Figure no. 2 summarizes the literature review and PRISMA processes and the number of articles involved in the selection process.

3. RESULTS AND DISCUSSION

3.1 Current Status of Research in Political Connections and M&A Outcomes

Research exploring the link between political associations and M&A results has consistently expanded over the last 37 years. Figure no. 3 illustrates the quantity and progression of publications in this area from 1986 to 2023, indicating a continuous increase in scholarly interest in the topic. Most papers in the sample (239 out of 308 articles) have been published in the last decade. On the one hand, the slow economic growth since the year 2000, weak demand, cheap money, tax arbitrage, and the rise of emerging markets multinationals, especially from China, are the five major factors leading to the explosion of M&A (Liner, 2016). On the other hand, the outbreak of Asian financial has triggered further studies on the impact of political connections on corporate economic outcomes, including on long-term investments such as M&A. Up until 2007, the amount of related literature was relatively small. However, starting in 2008, the annual number of publications grew significantly and peaked at 40 articles by 2023.

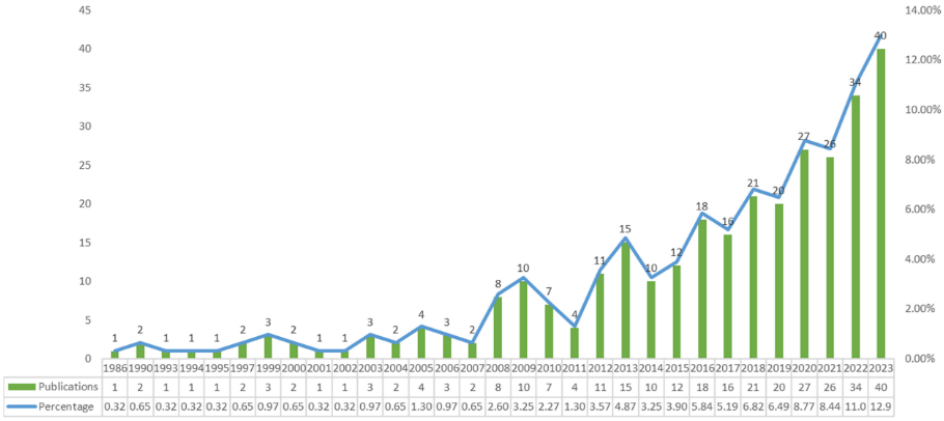

Figure no. 3 - The number of published articles per year (1986 - 2023)

Research on Political Connections and M&A has become multidisciplinary according to the category's distribution. Tabel no. 1 summarizes the top 15 categories in the political connections and M&A research area. According to the disciplinary distribution, 'Business' and 'Economics' are the most popular categories, with 74 and 69 publications, respectively, followed by management for 17.59% of the total publications, Business, Finance (54) and Environmental Science, Environmental Studies and Green & Sustainable Science and Technology.

This reflects that scholars have explored the impact of political connections to M&A not only on business and economic perspectives such as finance, management, and international relations but more recently, with the increasing trend of sustainable development, scholars have started to examine the impact of politically affiliated firms in implementing green M&A (M&A activities that incorporate the environmental rationalized elements, such as selecting a target firms that contribute to achieving sustainable development such as energy conservation, emissions reduction, and environmental protection) since they have a more significant

probability of receiving legitimacy benefits (such as access to financing and subsidies) as well as the likelihood of avoiding penalties for not implementing environmental governance (Li *et al.*, 2020b; Li and Wu, 2022; Zhao and Jia, 2022).

Tabel no. 1 – Top 15 Subject Categories

Rank	Web of Science Categories	Number Count	Percentage of Total
1	Business	74	19.42%
2	Economics	69	18.11%
3	Management	67	17.59%
4	Business, Finance	54	14.17%
5	Environmental Sciences	17	4.46%
6	Environmental Studies	15	3.94%
7	Green & Sustainable Science & Technology	12	3.15%
8	International Relations	10	2.62%
9	Development Studies	8	2.10%
10	Law	7	1.84%
11	Political Science	6	1.57%
12	Area Studies	6	1.57%
13	Energy & Fuels	4	1.05%
14	Communication	3	0.79%
15	Geography	3	0.79%

The number of citations can indicate the impact and influence of a publication within its field. Tabel no. 2 lists fifteen articles with the highest citation reports on M&A and Political connections (1986 to 2023). The most cited paper on the list is by Bonaime *et al.* (2018), with over 400 citations, which analyses factors that are negatively related to M&A activity. Their findings show that uncertainty regarding government regulations can substantially shape the business landscape, and sudden policy changes may prompt acquirer to adjust their strategic direction and increase target firms' negotiation power. Meanwhile, Giannetti *et al.* (2015) study the moderating effects of political ties of individual board members that can enhance firms' productivity and performance, including international mergers and acquisitions. Furthermore, a significant number of citations for other relevant papers, such as Du and Zhang (2018) that study the impact of Chinese SOEs and SOEs cross border M&A in response to Government One Belt One Road policies with 342 citations; Claessens and Van Horen (2014) (268 citations) and Lin and Zhang (2009)(265 citations) that studying acquisitions and performance in banking sectors that is the most highly regulated industries; and Chen and Young (2010) that study conflict between controlling shareholders and politically oriented managers in the context of corporate takeovers (205 citations).

3.2 Research Frontiers Analysis

3.2.1 Country-Wise Comparison of Research on Political Connections and M&A

Based on the geographical distribution of academic cooperation obtained from CiteSpace, total nodes of 41 (representing countries) and 82 links make up the country

collaboration network, with an overall density of 0.1, which suggests that the cooperative network among countries is relatively close. It is worth noting from Figure no. 4, that the top 10 countries include both developed and developing countries. Contrary to the perception that political connection is more prominent in developing countries or transitioning economies since it can reduce corporate uncertainty and reduce transaction costs due to the lack of well-functioning markets and market-supporting institutions, in the M&A context both emerging and developing countries has been equally paying big interest on research on this topic and has become a global topic.

Tabel no. 2 – Articles with highest citation

Title	Authors	Year	Journals	No. of Citations
Does policy uncertainty affect mergers and acquisitions	Bonaime, Alice; Gulen, Huseyin; Ion, Mihai	2018	Journal of Financial Economics	403
The Brain Gain of Corporate Boards: Evidence from China	Giannetti, Mariassunta; Liao, Guanmin; Yu, Xiaoyun	2015	Journal of Finance	396
Does One Belt One Road initiative promote Chinese overseas direct investment?	Du, Julan; Zhang, Yifei	2018	*China Economic Review*	342
Foreign Banks: Trends and Impact	Claessens, Stijn; Van Horen, Neeltje	2014	Journal of Money, Credit and Banking	268
Bank ownership reform and bank performance in China	Lin, Xiaochi; Zhang, Yi	2009	Journal of Banking & Finance	265
Cross-border mergers and acquisitions by Chinese listed companies: A principal–principal perspective	Chen, Yuan Yi; Young, Michael N.	2010	Asia Pacific Journal of Management	205
Principal-principal conflicts under weak institutions: A study of corporate takeovers in China	Li, Jiatao; Qian, Cuili	2013	Strategic Management Journal	186
Waking from Mao's Dream: Communist Ideological Imprinting and the Internationalization of Entrepreneurial Ventures in China	Marquis, Christopher; Qiao, Kunyuan	2020	Administrative Science Quarterly	118
State Ownership, Institutional Effects and Value Creation in Cross-Border Mergers & Acquisitions by Chinese Firms	Du, Min; Boateng, Agyenim	2015	International Business Review	139
Institutional Logics and Power Sources: Merger and Acquisition Decisions	Greve, Henrich R.; Man Zhang, Cyndi	2017	Academy of Management Journal	135
Institutions and the performance of politically connected M&A	Brockman, Paul; Rui, Oliver M; Zou, Huan	2013	Journal of International Business Studies	116

Title	Authors	Year	Journals	No. of Citations
Economic Nationalism in Mergers and Acquisitions	Serdar Dinc, I.; Erel, Isil	2013	The Journal of Finance	109
Portfolios of Political Ties and Business Group Strategy in Emerging Economies	Zhu, Hongjin; Chung, Chi-Nien	2014	Administrative Science Quarterly	101
Balancing Private and state ownership in emerging markets' Telecommunications Infrastructure: Country, Industry, and Firm Influences	Doh, Jonathan P; Teegen, Hildy; Mudambi, Ram	2004	Journal of International Business Studies	91
The liability of opaqueness: State ownership and the likelihood of deal completion in international acquisitions by Chinese firms	Li, Jiatao; Li, Peixin; Wang, Baolian	2019	Strategic Management Journal	90

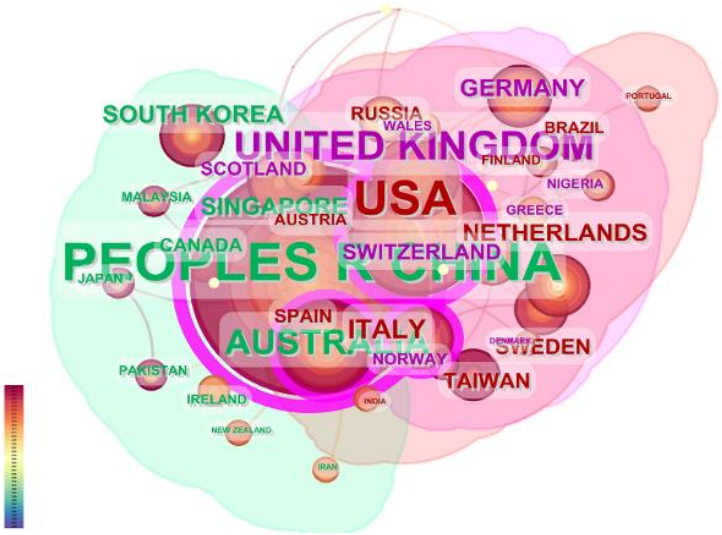

Figure no. 4. – A visualization of the country collaboration network

The most cited countries and institutions are reported in Table no. 3. China holds a central position with the highest number of publications (100) and the strongest link strength, followed by the USA (60) and the UK (30). Although M&A is a common strategy for a firm to expand, and political connection is also a common anecdote worldwide, the USA and UK started the study on Political Connections and M&A earlier. Later on, the greater intention was paid attention to China since the policymakers have been pushing a structural change in their economy, identifying specific sectors within the Five Year Plans and recognizing the role of M&A in transforming the features of firms and markets (Barbieri *et al.*, 2021). The

prominent role of government policy in shaping the business, the nature of the companies, which mostly are state-owned enterprises, and the importance of social networking of guanxi have also attracted the academic world to research Chinese M&A (Wang *et al.*, 2023).

Tabel no. 3 – Top 15 countries/regions ranked by the number of published papers

Rank	Country	Documents	Citations	Total Link Strength
1	Peoples R. China	100	2.995	65
2	USA	60	2.326	46
3	United Kingdom	30	957	22
4	Australia	5	490	6
5	Italy	6	407	7
6	Germany	18	377	18
7	France	6	354	8
8	Netherlands	4	222	2
9	Singapore	6	178	4
10	South Korea	4	147	3
11	Taiwan	9	129	10
12	Sweden	7	119	16
13	Switzerland	5	108	11
14	Canada	3	95	3
15	Russia	4	93	2

3.2.2 Most active source for publications related to Political Connections and M&A Research

Our final sample contains 308 articles published in 169 journals. Approximately 30% of these articles were published in the top 15 journals. Figure no. 5 shows that research on Political Connections and M&A has been published in various reputable journals with impressive impact factors, making them a valuable resource for understanding the topics and showing that they are important for business strategy, politics, economics, and environmental improvements.

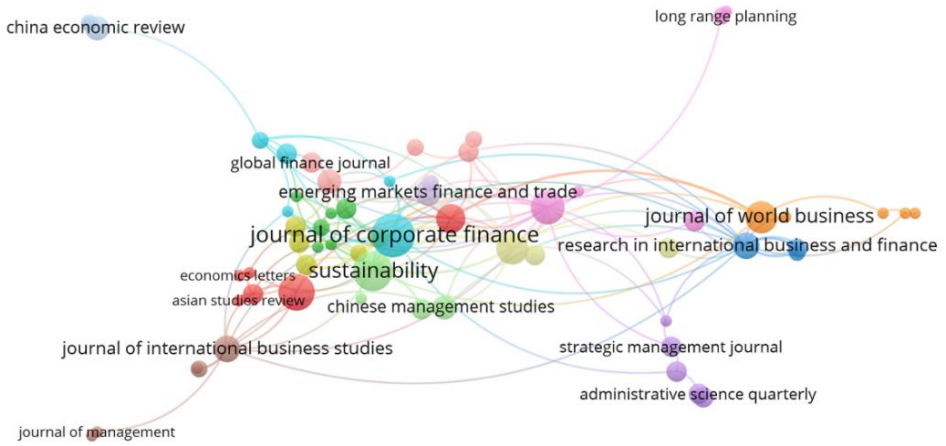

Figure no. 5 – Most Productive Source in publications

Table no. 4 lists the 15 most productive sources in this research field according to the number of articles, the total number of citations, and the impact factor recorded for each journal. The first position in the number of publications in this field is the Journal of Corporate Finance (13 publications), followed by the Sustainability Journal (11 publications). However, the most highly cited journal is the Journal of Finance (ranked 14), with the most citations (568) for 3 publications. Meanwhile, according to the 2022 impact factors, the Journal of International Business Studies stands out with an impact factor of 11.6.

Tabel no. 4 – Top 15 Most active source for publications

Rank	Source of Articles	No. of Articles	Total Citations	Impact Factor (2022)	Publisher
1	Journal of Corporate Finance	13	366	6.1	Science Direct
2	Sustainability	11	58	3.9	MDPI
3	Journal of Banking & Finance	9	515	3.7	Science Direct
4	Asia Pacific Journal of Management	8	295	5.4	Springer Link
5	International Business Review	7	341	8.7	Science Direct
6	Journal of World Business	7	321	8.9	Science Direct
7	Journal of Business Research	6	166	11.3	Science Direct
8	Journal of International Business Studies	5	283	11.6	Palgrave MacMillan
9	Research In International Business and Finance	5	122	6.5	Science Direct
10	Emerging Markets Finance and Trade	5	20	4	Taylor & Francis
11	China Economic Review	4	459	6.8	Science Direct
12	Pacific-Basin Finance Journal	4	83	4.6	Science Direct
13	Chinese Management Studies	4	25	2.2	Emerald
14	Journal of Finance	3	568	8	Wiley
15	Strategic Management Journal	3	329	8.3	Wiley

3.2.3 Institution Collaboration Network Analysis in Political Connections and M&A Research

Academic partnerships between institutions are depicted in Figure no. 6, offering insight into the impact of these collaborations within the academic community. The visualization of institutional networks was generated using CiteSpace and VOSviewer software with a time frame spanning from 1986 to 2023, and the node type panel was specified as "institutions," while other settings were set as system default. The node size indicates the number of articles published by the institution (the larger the node, the more documents are distributed by the organization) and the line between the nodes indicates the strength of cooperation between different institutions.

The institution collaboration network consisted of 336 nodes 441 links, and the overall density was 0,0078. Among them, the node representing institutions in China (University of Nottingham Ningbo, Wuhan University, Xi'an Jiaotong University, University of International Business and Economics, Beijing Institute of Technology, Renmin University, and Southwestern University of Finance and Economics) contributed to the highest number of publications in this field, along with the University of Zurich Switzerland, University of New South Wales Australia University of Illinois System USA. Figure no. 6 also shows the links that represent the cooperation relationship between the organizations. The more links,

the closer the cooperation between the organizations. Using institution mapping from VOSviewer, we can see that the colour is mainly green and yellow, indicating that most of the research has been carried out in recent years. Tabel no. 5 tabulates the top productive institutions in Political Connections and M&A-related research.

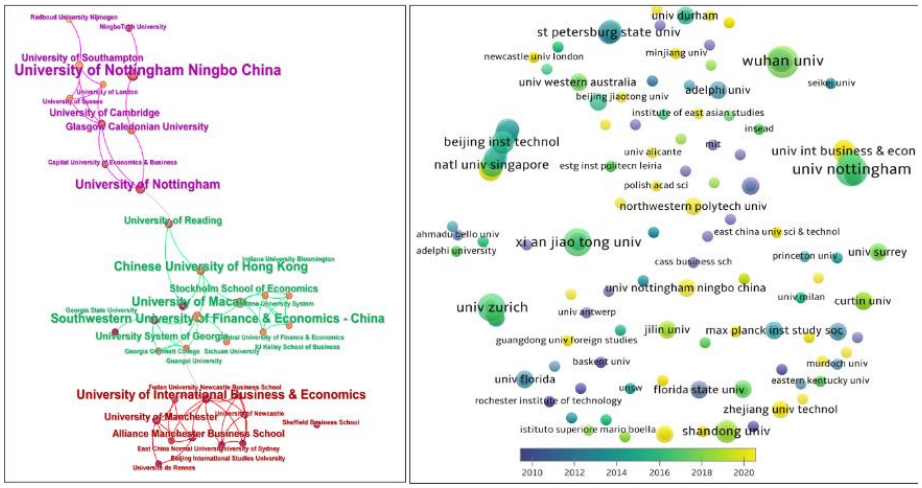

Figure no. 6 – Visualization results of the institutional cooperation network

Tabel no. 5 – The top ten most productive institutions

Rank	Institutions	Country	Documents	Citations
1	University of Nottingham Ningbo China	China	5	34
2	Wuhan University	China	5	1
3	University of Zurich	Switzerland	4	16
4	Xi'an Jiaotong University	China	4	5
5	University of International Business & Economics	China	3	63
6	Beijing Institute of Technology	China	3	43
7	Renmin University of China	China	3	15
8	Southwestern University of Finance and Economics	China	3	105
9	University of New South Wales	Australia	3	26
10	University of Illinois System	United States	3	9
11	The Chinese University of Hong Kong	Hong Kong	3	396
12	University of Hong Kong	Hong Kong	3	77
13	Hong Kong Polytechnic University	Hong Kong	3	71
14	National University of Singapore	Singapore	3	21
15	Shandong University	China	3	55

3.2.4 Author Collaboration Network

We conduct co-authorship analysis to examine the intellectual collaboration between researchers based on the number of publications authored. Since 1986, 354 authors published at least one publication on Political Connections and M&A. Tabel no. 6 presents the top 15 authors with the highest number of publications in the field of political connections and M&A outcomes.

Tabel no. 6. – Top 15 most prolific authors

Authors	Number of Articles	Citations	Connectivity
Boateng, Agyenim	5	248	57
Yang, Monica	4	148	24
Li, Jingjing	4	38	4
Li, Jiatao	3	246	21
Xie, Zhenzhen	3	64	15
Bi, Xiaogang	3	63	27
Wu, Xianming	3	20	4
Li, Shuangyan	3	8	21
Du, Min	2	168	38
Chung, Chi-Nien	2	142	10
Liu, Xiaohui	2	140	12
Luo, Yadong	2	95	5
Li, Donghui	2	82	0
Li, Bin	2	62	14
Pan, Ailing	2	62	14

By examining the primary authors of the study, their collaboration, and total publications, we can better understand their academic standing in the field. The top three authors with the highest number of publications in this field are Boateng Agyenim, Yang Monica; and Li Jingjing, respectively. The connectivity shows the cooperative frequency of the scholars. We can see from Tabel no. 6 that Boateng Agyenim is the most productive author who actively collaborates with other researchers in the field of Political connections and M&A, including Du, Min and Bi, Xiaogang. However, based on the total citations in Tabel no. 2, authors with high productivity in numbers are not parallel in producing highly impactful publications. The most cited scholar in the field of research was Bonaime Alice, who co-authored with Gulen, Huseyin and Ion, Mihai (403 citations), followed by Giannetti, Mariassunta, who co-authored with Liao, Guanmin and Yu, Xiaoyun (396 citations) have been observed to show a higher impact than the authors with the highest numbers of articles.

3.2.5 Literature Co-citation Analysis

To identify the core literature in the field of Political Connections and M&A research, we analysed the authors' co-citations. Co-citation analysis refers to the fact that two documents establish links with one or more other documents and can be used for research on document relations, literature retrieval, and literature structure research (Zhou *et al.*, 2019). The network contains 993 nodes and 15.566 links and has an overall density of 0.0316, which is illustrated in Figure no. 7.

The analysis of 990 references in the data set reveals the 15 most cited references listed in Tabel no. 7. The early reference that is widely used in the study is Jensen 1976 and Jensen Meckling 1976 discussing the conflict of interest between managers and shareholders in M&A deals. Meanwhile, research on political connections gained prominence during the Asian Crisis, stemming from Fisman's pioneering studies that demonstrated the heightened sensitivity of politically connected firms to negative information measured by the market value of Indonesia public firms surrounding the rumour of President Suharto's health. The early studies on Political connections are then mostly studied the unique benefits of Political Connections as well as the

liabilities they have to a particular firm (Faccio, 2006; Fan *et al.*, 2007; Li *et al.*, 2008). In the later developments, scholars' focus has shifted toward the question of how institutional boundary setting, particularly political regime, influences the willingness and ability of a firm to expand (Cui and Jiang, 2012; Du and Boateng, 2015; Zhou *et al.*, 2015).

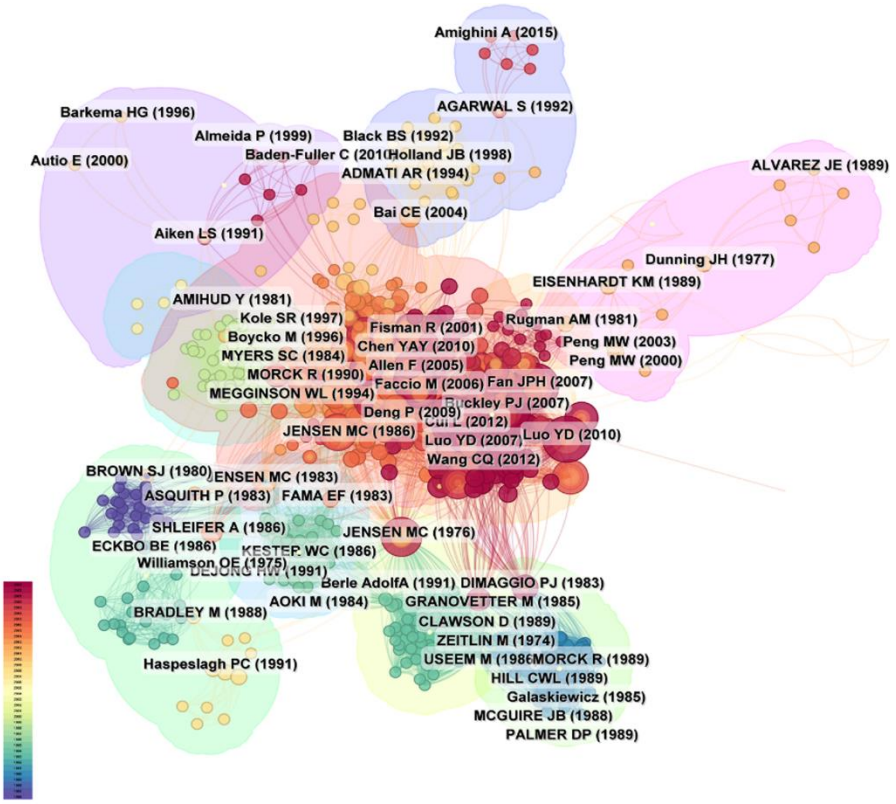

Figure no. 7 – Visualisation of the author co-citation network

Tabel no. 7 – Top 15 most cited authors based on citation frequencies

Rank	Title	Authors	Year	Source	Citations counts
1	Politically connected CEOs, corporate governance, and Post-IPO performance of China's newly partially privatized firms	Fan, Joseph PH, Tak Jun Wong, and Tianyu Zhang	2007	Journal of financial economics	31
2	The determinants of Chinese outward foreign direct investment	Buckley, Peter J., L. Jeremy Clegg, Adam R. Cross, Xin Liu, Hinrich Voss, and Ping Zheng	2015	Routledge	30

Rank	Title	Authors	Year	Source	Citations counts
3	International expansion of emerging market enterprises: A springboard perspective	Luo, Yadong, and Rosalie L. Tung	2007	Journal of international business studies	28
4	Agency costs of free cash flow, corporate finance, and takeovers	Jensen, Michael C	1986	The American economic review	26
5	Theory of the firm: Managerial behaviour, agency costs and ownership structure	Jensen, Michael C., and William H. Meckling	1976	Journal of Financial Economics	25
6	Politically connected firms	Faccio, Mara.	2006	American economic review	24
7	State ownership effect on firms' FDI ownership decisions under institutional pressure: A study of Chinese outward-investing firms	Cui, Lin, and Fuming Jiang	2012	Journal of international business studies	24
8	. "How emerging market governments promote outward FDI: Experience from China."	Luo, Yadong, Qiuzhi Xue, and Binjie Han	2010	Journal of world business	23
9	Exploring the role of government involvement in outward FDI from emerging economies."	Wang, Chengqi, Junjie Hong, Mario Kafouros, and Mike Wright	2012	Journal of International Business Studies	22
10	Political connections and corporate bailouts.	Faccio, Mara, Ronald W. Masulis, and John J. McConnell	2006	The journal of Finance	21
11	Politicians and firms	Shleifer, Andrei, and Robert W. Vishny. "	1994	The quarterly journal of economics	20
12	Firm size and the gains from acquisitions	Moeller, Sara B., Frederik P. Schlingemann, and René M. Stulz	2004	Journal of financial economics	20
13	"Estimating the value of political connections	Fisman, Raymond	2001	American economic review	20
14	Why do Chinese firms tend to acquire strategic assets in international expansion	Deng, Ping.	2009	Journal of world business	20
15	Strategy in emerging economies	Hoskisson, Robert E., Lorraine Eden, Chung Ming Lau, and Mike Wright	2000	Academy of management journal	19

3.2.6 Theoretical Application in Political Connection and M&A Outcomes

In addition to analysing the most influential journals, articles, and authors, as an attempt to provide a better understanding of theoretical applications in the study of Political Connections to M&A outcomes, we also analyse the dominant theoretical perspectives adopted by scholars when examining the Political Connections on M&A. Some studies apply the existing theoretical perspective in analysing political connections to domestic M&A, while others utilize the theoretical perspectives to study M&A in the cross-border context. In

this study, we provide a holistic assessment of the literature and highlight some theoretical insights on the impact of political connection impact on M&A both in domestic and international settings.

Tabel no. 8 – Theoretical Application in Political Connection and M&A Literature

Outcome	Key Arguments	Theory	Source
Value Creating	Political connection as a competitive advantage for the acquirers to help break through administrative barriers and access essential resources	Resource Based View Theory	Kling and Weitzel (2011), Deng *et al.* (2012) Wang *et al.* (2019), Du *et al.* (2021)
	Acquirers need to develop relationships with external agencies to reduce environmental uncertainties.	Resource Dependency Theory	(Zhu and Chung, 2014; Zhou *et al.*, 2015; Kopoboru *et al.*, 2020; Li *et al.*, 2022)
	Dual dependency relationships exist between firms and institutions to provide stability and performance growth both for the acquirers and the target firms, especially in a weak legal system.	Institutional Based Theory	(Gu *et al.*, 2020; Tu *et al.*, 2021; Wang *et al.*, 2023)
	Enterprises establish close links with various stakeholders of the firms. Particularly in Cross Border M&A, firms should pay attention to the policy orientation of their domestic as well as host country's governments	Stakeholders Theory	(Li *et al.*, 2022; Ma *et al.*, 2024)
	Political networking is an important governance mechanism that lessens the institutional voids between the acquirers and the target firms in cross-border M&A	Social Capital Theory	(Li *et al.*, 2018; Li *et al.*, 2020a)
	Political connections can be seen as the government's implicit endorsement of enterprise development, which may positively impact M&A values.	Signaling Theory	(Chen, 2022; Ding *et al.*, 2022)
Value Destroying	M&A is intended for political objectives (both meeting government agenda or political goals of the politicians) as opposed to increasing firm values	Agency Theory	(Fidrmuc *et al.*, 2018; Arnoldi and Muratova, 2019; Gao *et al.*, 2019; Liu *et al.*, 2019)
	In cross-border M&A, politically connected firms could be seen as semi-governmental organization, and host country governments' concerns toward M&A could be motivated by nationalist motives than anti-competition issues.	Institutional Based Theory	Serdar Dinc and Erel (2013)
	Although political connections facilitate trust, information, and resource exchange between the government and acquirers, they can also become a reciprocated burden and may backfire in the firm's operation.	Social Exchange Theory	Sun and Ai (2020)
	Government capability to stimulate policies on M&A (e.g., by lowering the cost of financing or selective expansive industrial policies) might induce firms to conduct conglomerate M&A to exploit policy advantages or conduct horizontal M&A to take advantage of greater facilitation from the government for the larger firms.	Transaction Cost Theory	(Yang, 2015; Barbieri *et al.*, 2021)

Outcome	Key Arguments	Theory	Source
	Given the natural political connections of SOE might offset legitimacy-benefit and shelter illegitimacy-penalty when conducting more sustainable M&A	Legitimacy Theory	Zhao and Jia (2022)
	Stigmatization associated with sociopolitical liabilities and political risks can trigger public disapproval of cross-border M&A in the target nations	Stigmatization Theory	Tsui-Auch *et al.* (2022)
	Institutional investors use investors' lack of knowledge of undisclosed connections to trade on private information, causing the lack of visibility of politically connected firms and leading to a significant delay in the market incorporating the data into prices.	Mosaic Theory	Hope *et al.* (2022)

Ferreira *et al.* (2014) concluded that no single theory is dominant in M&A research. However, we found that most M&A research is based on four theoretical perspectives: agency theory, institutional theory, transaction cost theory, and resource-based view. Table no 8 summarizes the core elements of each theory that have explicitly or implicitly formed the basic explanation about the impact of political connections on the outcomes of M&A**.** Some theories that are used as the basis to rationalize the role of government affiliation might add value to M&A – and some theories that highlight how political connection might destroy the outcome of M&A have been put forward in explanation.

Generally speaking, research has shown that institutional environments generate various constraints under which a rational economic actor makes a decision, consequently affecting firms' behaviours and outcomes (La Porta *et al.*, 1997; Yang *et al.*, 2015). The value-increasing school explains that corporate boards must develop relationships with external agencies with the necessary resources and capabilities to reduce environmental uncertainties and address uncertain institutional environments (Brockman *et al.*, 2013). As a result, well-connected boards of acquiring firms have better access to valuable market- and industry-wide information to better assess target firm value and potential synergy between acquirers and targets (Zhu and Chung, 2014; Kopoboru *et al.*, 2020). Having political connections also helps companies break through administrative barriers and access essential resources (Deng *et al.*, 2012; Du *et al.*, 2021), and affiliations with prominent organizations or actors (e.g., governments and venture capitalists) can transmit a signal to the outside world about a firm's legitimacy and potential (Muratova *et al.*, 2018; Chen, 2022).

Meanwhile, according to the value-destroying schools, since the goals of politicians and shareholders may conflict, an agency problem is likely to occur. Therefore, political connections may diminish the effectiveness of corporate monitoring in the M&A process, and connected executives may take advantage of these connections to pursue government agenda or their interests instead of increasing shareholders' value (Arnoldi and Muratova, 2019; Tao *et al.*, 2019; Li *et al.*, 2022). This impact is more pronounced in a weak-governed environment (Yang *et al.*, 2022) and in countries with higher government intervention (Yang and Zhang, 2015). Political connections are also reciprocal in nature, which potentially produces rent-seeking practices, and the connected firms are expected to repay any debts accrued for the benefits gained that may increase the operational cost and the likelihood of investments failing (Bertrand *et al.*, 2018; Sun and Ai, 2020). Zhao and Jia (2022) conclude that SOEs (with inherent political connections) are less likely to engage in environmental governance after participating in green M&A since they have lower pressure to meet social responsibility

practices. In a multinational arena, Tsui-Auch *et al.* (2022) and Serdar Dinc and Erel (2013) find evidence that political ties with home-country governments (both formal and equity-based, such as through state ownership, or informal and relations-based, such as personal relationships between firm leaders and government officials) faced various levels of disapproval by a wide range of stakeholder groups completed acquisitions in target nations.

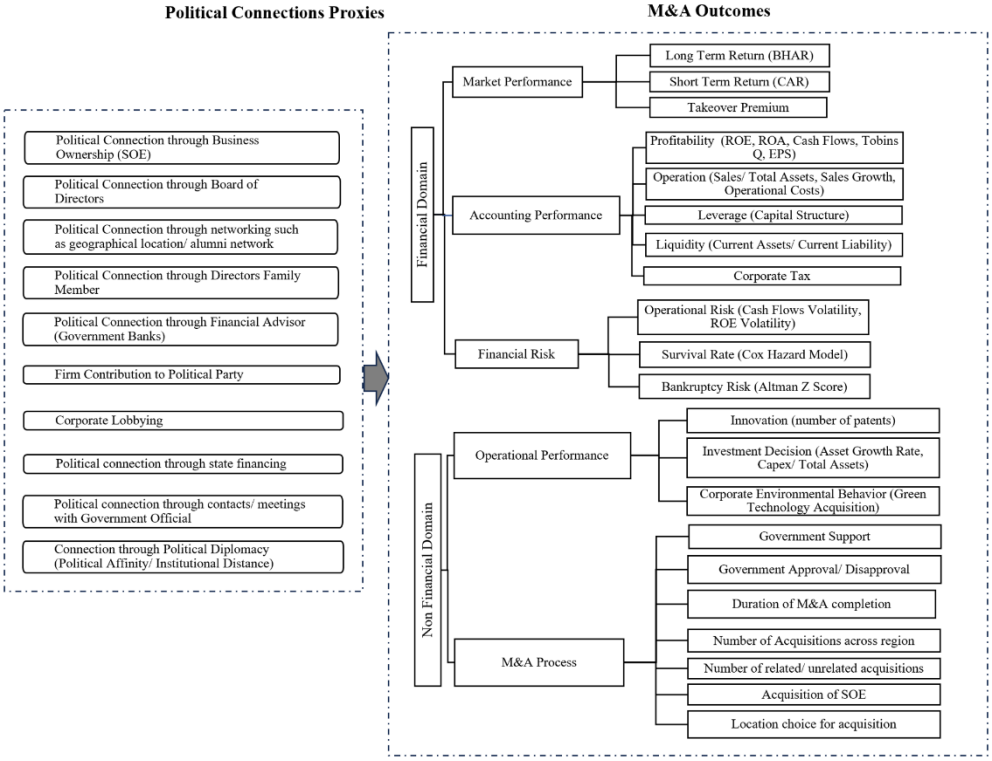

Figure no. 8. - Political Connections impact to M&As' Outcomes

For further analysis, this paper also tries to identify the different ways political connections are used in M&A studies by distinguishing different proxies of political affiliations as well as categorizing some indicators used in measuring the impact of political connections on M&A. Through the study of literature reviews political connections by the firms is established through various channels such as state ownership; having businesspeople in the legislative, public, and party organizations or vice versa; political donations; lobbying, friendship; or family ties among others that is often proxied using dummy variables. It is important to note that since different political connections might have different power, and different countries/industries might have different political sensitivity, especially in the countries that adopt regional autonomy, connections with government officials can come from different administrative levels (province, city, and country). Therefore, the measurement of

political connections should be adjusted to better capture the contextual dynamics of the research.

In the measurement of M&A outcome, our findings show that scholars employ various measurements, with each indicator reflecting different time scales and units of analysis. This shows that M&As are complex phenomena and that the various performance measurement methods tried to capture such complexity, and having political connections may generate advantages or constraints to the outcome. Our analysis shows that the research that dominates the field has been trying to measure M&A performance using one dimension and a single or few indicators. Therefore, in order to offer a more nuanced analysis of the issue of dimensionality, we have categorized M&A performance measures in terms of both financial and nonfinancial domains (Figure no. 8).

3.2.7 Keywords Analysis

This section further investigates research hotspots in this field. From the sample of 308 articles, we conduct an analysis of the relevant terms they use in their abstracts and titles using VOSviewer and CiteSpace to map the primary keywords, choosing the type of analysis as 'co-occurrence' and unit of analysis as 'all key words'. As illustrated in Figure no. 9, based on the density map of high-frequency keywords are "performance", "state ownership", "privatization", "market", "emerging economy", and "internationalization".

Figure no. 9. - Density map of keywords generated by VOSviewer

We also use burst analysis in CiteSpace to analyse the dynamic characteristics of the research interest (research hotspot) over a period of time (Chen, 2006). By investigating temporal trends in keyword bursts, scholars and stakeholders can identify core research topics

or areas at a particular point in time. **Error! Reference source not found.** lists the top 15 k eywords with the strongest burst, emergent intensity, and duration in the research, which enables researchers to understand the evolutionary development trend of the relationship between political connections and M&A outcomes. When a time period in burst detection is red, it means that the element is experiencing a reference burst during that time period, which may indicate an underlying trend in the field. **Error! Reference source not found.** shows t hat the topics on emerging economies, R&D investment, outward Foreign Direct Investment, and innovation surrounding Political Connections and M&A started to grow in the last 5 years.

Tabel no. 9. - Top 15 Keywords with the mot robust citation Burst from 1986 – 2023

Keywords	Strength	Begin	End	1986 – 2023
United States	3.38	1990	2014	
Efficiency	2.26	1990	2009	
Takeovers	2.21	1994	2015	
Privatization	3.69	2000	2010	
Policy	2.31	2003	2013	
Information	2.06	2005	2013	
Governance	2.36	2009	2013	
Institutional Theory	2.09	2012	2017	
Cross-Border M&A	2.4	2014	2017	
Government Ownership	2.09	2014	2016	
Connections	2.04	2017	2018	
Emerging Economies	1.89	2019	2020	
R&D	3.77	2020	2023	
Outward FDI	3.52	2020	2023	
Innovation	2.32	2020	2023	

3.2.8 Future Research Directions

We further conduct co-occurring keywords using CiteSpace to find major clusters in this research field that can be important for researchers to focus on significant aspects for future research. Co-occurrence keywords analysis on CiteSpace consists of 1.139 nodes and 10.138 links, with a modularity index of 0,5282 and silhouette index of 0.8292, suggesting high homogeneity and well-divided clustering. The findings of the analysis on the recurring topic categories using Cite Space are illustrated in Figure no. 10. The network is categorized into 11 clusters based on the number of counts and centrality. These primary clusters are denoted by index terms and are outlined with '#' on the right side to signify the research frontiers and the development in this field. The labels of these clusters were generated based on the log-likelihood ratio (LLR) algorithm, and the terms are clustered in colours based on their co-occurrence, where warm colours, like red, orange, yellow, and green, indicate research clusters that are carried out in more recent years.

From the bibliometrics analysis, we learned that the interplay between political connections and M&A, particularly in emerging economies with significant government interventions, is still an active area of research. Politically affiliated executives, especially in state-owned enterprises, often have a dual role, serving as both organizational leaders and political figures tasked with implementing the government's agenda. This dual identity creates a dynamic where personal aspirations, political objectives, and organizational goals converge, ultimately influencing M&A strategies and outcomes. Additionally, the government policies that takes into account geopolitical factors and economic rivalries would also add complexities and costs associated with both cross-border trade and M&A. This impact may be especially pronounced for state-owned enterprises as they confront greater concerns regarding the legitimacy of their cross-border M&A activities.

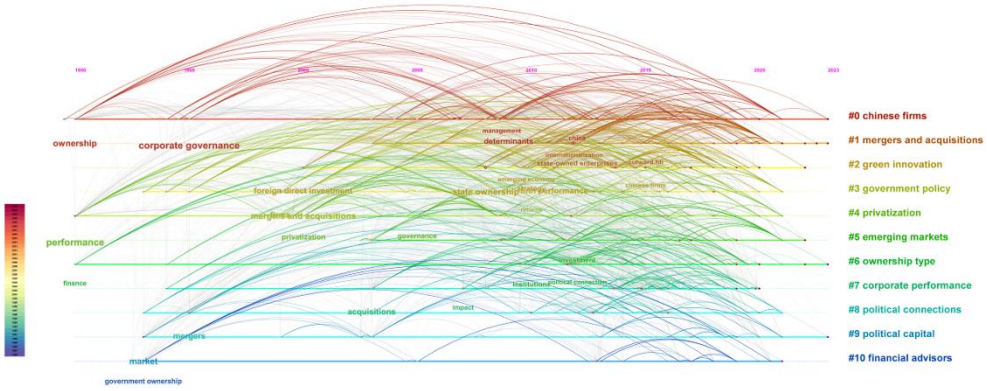

Figure no. 10 - Timeline map of the references in Political Connections and M&A Outcome

The issue of sustainability sustainability-focused M&A with political connections is also an area of growing research interest. The ongoing economic recovery from the COVID-19 pandemic and the environmental challenges posed by ecological imbalance and global warming have emphasized environmentally sustainable practices as a strategic advantage for businesses. This, in turn, has motivated firms to pursue green mergers and acquisitions as a means of promoting more sustainable development. For example, recently, scholars have started to examine the impact of politically affiliated firms in implementing Green M&A, given their higher likelihood of receiving legitimacy benefits, such as access to financing and subsidies (Li and Wu, 2022), as well as the likelihood of politically connected firms of avoiding illegitimate penalties for not implementing environmental governance (Zhao and Jia, 2022).

Additionally, in exploring the bibliometric analysis of the relationship between the impact of Political Connections and M&A outcome, most of the literature in the sample focuses on the firm value based on acquiring shareholders' perspective. Further research can explore the impact of the political connections from the perspective of target firms and consider the impact of political connections on the risk and the resilience of target firms for being acquired. Furthermore, different countries (developing and emerging) and different industries might have varying political sensitivities and this may yield diverse impact of political connections to M&A outcomes, future meta-analyses study could statistically integrate accumulated research on diverse types of political connections, such as ownership,

affiliated CEOs, personal relationships, and political contributions or lobbying, to better understand the degree and strength of political connections' effects on M&A performance.

4. CONCLUSIONS, IMPLICATIONS, AND LIMITATIONS

This study was conducted to perform a bibliometric analysis of the literature review related to Political Connections and M&A. Based on the analysis of co-authorship, co-citation, and keywords co-occurrence, we are able to map and visualize the prominent authors (at the micro-levels), institutions (at the meso-level) as well as the country (macro-level) that are prominent in the research area of political connections and M&A. To our knowledge, this study provides the first extensive and thorough bibliometric analysis of the specific correlation between political connections and M&A outcomes, thus adding academic value that was absent in previous studies.

Our findings make a theoretical and practical contribution. Among the theoretical contributions, this qualitative and quantitative analysis of the literature review enables us to provide an overview of the theories and identify various channels of political connections that can benefit or threaten M&A outcomes. Although the bibliometric tools, VOS Viewer and CiteSpace, that is used for quantitative analysis in this study visually represent references and the research hotspots to help researchers have a better understanding of the current research status and future directions, bibliometric tools are limited in analysing the research logic and the relationships between variables. Therefore, this paper also uses systematic literature reviews to better narrate the findings of relevant articles, enabling the development of a comprehensive conceptual framework that investigates how political connections may variously impact the outcomes of M&A and draw insights from various perspectives to comprehend the latest developments in the area of study.

The practical implication of this study is that it provides valuable insights for decision-makers who aim to utilize political connections as non-market strategies to grow and enhance their firms' competitive advantage through M&A. Political connections are often viewed as more prominent in developing or transitioning economies, where they can reduce corporate uncertainty and transaction costs due to lacking well-functioning markets and institutions. However, research on this topic has become a global focus, with both emerging and developed countries showing keen interest. This literature review reveals that political ties do matter as they impact the process and the success of M&A strategies adopted by firms. On one hand, being politically affiliated can enable managers to better leverage resources and opportunities, leading to more successful M&A outcomes. On the other hand, political connections may also attract unfavourable behaviour, such as rent-seeking that involves corruption and reciprocal exchange of favours between firms and political agents, potentially resulting in lower governmental supervision and less motivation to engage in sustainable M&A practices. The dual role of politically connected executives can also lead to higher agency problems, as they serve both as heads of the organization and as political figures, which can result in M&A decisions that support government agendas and political ambitions rather than increasing shareholder value. Being affiliated with the government can also provide an advantage of greater support from the government for internationalization, but in the new wave of deglobalization and increased protectionism between nations, it can also be a liability, especially for state-owned enterprises conducting cross-border M&A.

However, this study also has some limitations. (1) For the bibliometric analysis, the articles studied were selected from two databases (WoS) and Scopus, which may have affected the number of relevant articles collected. Future studies should consider additional databases such as Google Scholar and Dimensions for a more comprehensive bibliometric review. (2) Despite including criteria in the literature search, the wide variation in content and definitions of Political Connections and M&A literature may result in overlooking other relevant terms during the search process and possibilities of a certain degree of personal subjectivity. Therefore, future studies should ensure the comprehensiveness and completeness of the concepts and adopt more objective criteria for cleaning and organizing the literature.

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Hedge and Safe Haven Properties of Green Bonds and Clean Energy Stocks during COVID-19 and Russian-Ukraine War: A Comparison With Gold

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Abstract: Successions of crises are currently affecting the world, which have had an impact on the worldwide financial market. Indeed, the COVID-19 pandemic and the Russia-Ukraine war have caused significant disruption, slowing global economic and financial developments. As safe havens for their portfolios, foreign investors are focusing on more dependable assets. This paper examines the safe-haven and hedging characteristics of gold, green bonds, and clean energy. According to the Dynamic Conditional Correlation (DCC)-GARCH model, the hedging ratio and hedging effectiveness index show the hedging potential of gold, green bonds and clean energy in stable and volatile market phases. Our research shows that clean energy assets can effectively reduce portfolio risk during financial uncertainty by providing stronger hedging effects than gold. However, gold remains the more cost-effective option, balancing affordability with risk mitigation. During the COVID-19 pandemic and the Russia-Ukraine conflict, both gold and clean energy assets displayed weak safe-haven characteristics, which highlighted their ineffectiveness in protecting investors during extreme market turbulence. These insights underscore the need for cautious evaluation by investors and policymakers when considering these assets for crisis portfolio strategies.

Keywords: green bonds; clean energy; safe haven; hedging ratio; hedging effectiveness.

JEL classification: G01; G11.

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1. INTRODUCTION

The global economy has indeed faced considerable challenges due to recent crises, including the COVID-19 pandemic and geopolitical conflicts. Amidst these disruptions, investors and researchers have turned their attention to hedge assets, particularly green bonds and clean energy stocks. These financial instruments have gained prominence as a new asset class, especially among environmentally responsible investors (Kuang, 2021a; Rehman *et al.*, 2023). Green bonds, in particular, have seen increased demand as they align with sustainable and renewable energy initiatives. Additionally, the COVID-19 outbreak has influenced the dynamics between green bonds, clean energy, and stock prices. Research indicates that clean energy influences stock prices positively, especially during economic retrieval periods. Moreover, the rise of renewable energy have contributed to the growing interest in green bonds. Overall, these developments highlight the importance of environmentally conscious investments in today's volatile markets.

Unlike traditional assets (gold for example), which are typically used as a hedge against common hazards, green bonds are a valuable instrument for sustainable investing that may be used to protect against financial risk, climate risk, and uncommon calamities like COVID-19 (Guo and Zhou, 2021). For instance, Yousaf *et al.* (2022) found that green is a safeguard against substantial stock market changes caused by the recent COVID-19 outbreak. For the more, during this earlier epidemic, Mensi *et al.* (2023) indicate that green bonds are haven assets for US investors. Dong *et al.* (2023) show the dominance of green bonds over conventional bonds as a safe haven in the presence of high level of economic uncertainty and climate policy risk. Karim *et al.* (2023) show that green bonds have the diversification, hedge and safe haven properties whatever the financial market situation.

Numerous studies have been prompted by the rising popularity of clean energy stocks to examine how they interact with other assets, potentially having an impact on the stocks' potential for diversification, hedging, and safe-haven status during crisis periods (Kuang, 2021a). However, they yielded mixed results. Furthermore, while some studies have explored their properties in the context of conventional stock markets, these investigations have primarily focused on the COVID-19 pandemic. Notably, absent from the literature is an examination of green bonds and clean energy assets as hedges and safe havens during the recent Russia-Ukraine conflict.

This paper seeks to fill a critical gap in the literature by offering new insights for investors and policymakers. Specifically, it examines the effectiveness of green bonds and clean energy stocks in mitigating global stock market volatility. Furthermore, it investigates their roles as safe-haven assets during periods of heightened uncertainty, particularly during the COVID-19 pandemic and the Russia-Ukraine war. The central question guiding this study is: How do green bonds and clean energy stocks compare to gold as safe-haven assets during times of crisis, such as the COVID-19 pandemic and the Russia-Ukraine conflict? By addressing this question, we aim to enhance understanding of these assets' potential to provide stability and protection in turbulent market conditions.

This article contributes to the existing literature in three keyways. First, this study examines both green bonds and clean energy stocks that have different price determinants, as hedge and safe haven instruments. The markets for corporate and government bonds are linked to the green bond market, while the markets for stock and energy commodities are not as strongly linked (Reboredo, 2018). Henriques and Sadorsky (2008) proved that technology

stock and oil each individually Granger causes the clean energy stocks. Second, we will reassess the ability of green bonds and clean energy stocks to act as a hedge and safe haven amid the COVID-19 pandemic and the conflict between Russia and Ukraine. Third, we contrast the performance of green bonds and clean energy stocks with gold, which has always been seen as a safe haven and hedging asset (Baur and Lucey, 2010).

The findings herein have important policy implications for investors and policymakers. The current geopolitical crises and macroeconomic turmoil make it unlikely that financial stress around the globe will decrease in the near future. Our study offers an important guideline on the hedge and safe-haven potentials of certain novel assets during financial distress. The findings indicate that clean energy assets have a stronger hedging effect than gold for investors, making them more effective in reducing portfolio risk in certain scenarios. However, it is important to note that their effectiveness is limited in other scenarios. Therefore, investors should carefully consider their investment goals and strategies before making any decisions. Nevertheless, gold remains the more cost-effective option, balancing affordability with risk mitigation. Importantly, both gold and clean energy assets showed only weak safe-haven characteristics during the COVID-19 pandemic and the Russia-Ukraine conflict, highlighting their limited ability to protect investors in extreme market turbulence. This information can be used to construct policies aimed at promoting financial stability and resilience. This study has the potential to guide the creation of financial products by revealing opportunities to create investments that have enhanced abilities to mitigate various forms of financial instability and serve as reliable refuges during times of economic distress.

The remainder of this paper is organized as follows. Section 2 develops the literature review while Section 3 the methodology. Section 4 describes the data and discusses the empirical outcomes while Section 5 includes the robustness analysis. Section 6 concludes the paper and gives policy implications.

2. LITERATURE REVIEW

Put differently, this study investigates the relationship between green stocks and other assets, offering valuable information to investors who are concerned about their portfolios.

Díaz *et al.* (2022), for example, studied the impact of incorporating clean energy stocks into a portfolio of traditional stocks and other assets that are often considered safe havens during the COVID-19 disease. The results indicate that clean energy stocks can contribute a significant amount of diversification to the overall equity market. In addition, these stocks can be utilized to diversify and hedge investments in commodities, cryptocurrencies, and Treasury securities. Kuang (2021b) compared the performance of clean energy stock portfolios with that of the equity market benchmark and dirty energy stocks between 2010 and 2021. Clean energy stocks are typically more profitable than dirty stocks, even though they tend to underperform the overall equity market. Naeem *et al.* (2023) delved into the extreme quantile dependence between clean energy stocks and green bonds, as well as their relationship with the GCC (Gulf Cooperation Council) stock market from 2014 to 2021. Notably, their results highlighted the following: clean energy stocks exhibit significant co-movements with GCC stocks, which indicates a degree of correlation. In contrast, climate bonds demonstrate no co-movements with other assets, suggesting that green bonds may serve as a distinct diversification option. Additionally, green bonds are viewed as a suitable option for diversifying into GCC equities, which could potentially increase portfolio stability. Returning

to Kuang (2021b), the study focused on the risk management aspects: both green bonds and clean energy stocks contribute to risk diversification for investors who hold dirty energy stocks. However, there is an interesting divergence: green bonds tend to reduce risk, acting as a stabilizing force, while clean energy stocks generally increased risk within international stock index portfolios. This higher risk profile may be attributed to the inherent volatility of the clean energy sector. In recent research, Mensi *et al.* (2024) examine the relationship between energy futures and green bonds at times of high and low volatility. This study combines the quantile connectivity approach with the Diebold and Yilmaz (2012) spillover measure. They found that green bonds offer diversification benefits, making them attractive for investors seeking to balance risk and returns. These bonds, which fund environmentally friendly projects, provide an opportunity to align investments with sustainability goals.

Additionally, Elsayed *et al.* (2024) investigate the links between green bonds, clean energy, socially conscious stocks, and variations in oil shocks using wavelet quantile correlation and cross-quantilogram analysis. Empirical results highlight that green bonds act as safe havens against oil shocks, both in the short and long run. When oil prices experience sudden fluctuations, green bonds remain resilient, providing stability to portfolios. Investors interested in risk management and sustainable finance can benefit from incorporating green bonds into their strategies. In the context of the COVID-19 pandemic, Hamma *et al.* (2024) examine the safe-haven qualities of green bonds, gold, and bitcoin for the renewable energy markets. They use a Rvine copula to account for reliance between the returns of green bonds, gold, and cryptocurrency and renewable energy commodities. The findings demonstrate that green bonds serve as a refuge for renewable energy markets. While gold and Bitcoin fail to exhibit the same safe-haven properties, green bonds shine during times of crisis. Notably, as the pandemic intensifies, the safe-haven impact of green bonds on the stock market becomes stronger. These findings provide valuable insights for portfolio managers and renewable energy investors, emphasizing the importance of considering green bonds as part of a diversified investment approach.

In previous studies, the integration of gold and environmentally focused stocks yielded varying results. Consequently, this question remains open for further empirical investigation. By employing diverse models, we can enhance our understanding of how these assets behave across different market conditions. This empirical exploration contributes valuable insights to the ongoing discussion about safe-haven assets and risk management strategies.

3. RESEARCH METHODOLOGY

The hedge and safe haven properties have been generally examined by referring to the popular framework developed by Baur and Lucey (2010); Baur and McDermott (2010). According to these authors, “A strong (weak) hedge is defined as an asset that is negatively correlated (uncorrelated) with another asset or portfolio on average” and “A strong (weak) haven is defined as an asset that is negatively correlated (uncorrelated) with another asset or portfolio in certain periods only, e.g. in times of falling stock markets”. Hence, these properties are best investigated using the DCC–GARCH model of Engle (2002).

3.1 Dynamic Conditional Correlation (DCC)-GARCH model

In the first step of our analysis, we use Engle (2002) DCC-GARCH model to measure the time-varying correlations between the return series of the international stock market and the green bonds (clean energy stocks). This model is presented in the following manner:

$$\begin{aligned} r_{t.} \mid \Omega_{t-1} &\sim N(0, H_t) \\ H_t &= D_t R_t D_t \\ \varepsilon_t &= D_t^{-1} r_t \end{aligned} \tag{1}$$

where r_t is a 2 by 1 vector of returns of the international stock market and green bonds (clean energy stocks) at time t; H_t is the conditional covariance matrix; ε_t is a vector of standardized residuals; and D is the 2 × 2 diagonal matrix containing time-varying standard deviations. These earliers are obtained from the following univariate GARCH model with $\sqrt{h_{i,t}}$ on the ith diagonal:

$$h_t = \omega + a\varepsilon_{t-1}^2 + bh_{t-1}^2 \tag{2}$$

where h_t indicates the conditional variance, ω denotes a constant, and a and b represent ARCH and GARCH effects, respectively.

$R_t=[\rho_{ij,t}]$ represents the conditional correlation matrix:

$$R_t = diag\{Q_t\}^{-1} Q_t diag\{Q_t\}^{-1} \tag{3}$$

$Q_t=[q_{ij,t}]$ is a symmetric positive definite matrix that represents the time-varying unconditional correlation matrix of ε_t. The following equations can be used to calculate the estimator of the time-varying correlation:

$$Q_t = (1-\alpha-\beta)\tilde{Q} + \alpha\varepsilon_{t-1}\varepsilon_{t-1}^{'} + \beta Q_{t-1} \tag{4}$$

$$\rho_{ij,t} = \frac{q_{ij,t}}{\left(\sqrt{q_{ii,t}}\sqrt{q_{jj,t}}\right)} \tag{5}$$

where: $\tilde{Q}$ represents the unconditional correlation matrix for the standardized residuals. The model complies with mean-reverting when $\alpha+\beta < 1$.

3.2 Hedge property

To assess the hedge property of green bonds and clean energy stocks, we follow Kroner and Ng (1998), Kroner and Sultan (1993), and Balcılar *et al.* (2016), to determine the optimal portfolio weights, optimal hedge ratio, and the hedging effectiveness, respectively. This

earlier task is done based on the conditional volatilities and covariance as the output of the DCC-GARCH model described previously.

First, following Kroner and Ng (1998), we determine the optimal portfolio allocation for x (MSCI world index) and y (green bond or clean energy) assets as follows:

$$w_t^{x/y} = \frac{h_t^y - h_t^{x/y}}{h_t^x - 2h_t^{x/y} + h_t^y}$$

$$w_t^{x/y} = \begin{cases} 0, if w_t^{x/y} < 0 \\ w_t^{x/y}, if\ 0 \le w_t^{x/y} \le 1 \\ 1, if\ w_t^{x/y} > 1 \end{cases} \quad (6)$$

At time t, $w_t^{x/y}$ indicates the weight of asset x (MSCI world index) in a one-dollar portfolio of both assets (x, y). The conditional covariance between the two assets is denoted by $h_t^{x/y}$. h_t^y represents the conditional variance for asset y (alternative asset) at time t.

In this portfolio, the weight of the second asset *y* (green bond or clean energy indices) corresponds to 1-$w_t^{x/y}$.

Second, we use Kroner and Sultan (1993) optimal hedge ratio to determine the rate at which is it possible to hedge a one-unit long position in the asset (x) with a similar short position in the alternative asset (y) to improve the overall risk/return profile of the portfolio. The hedge ratio is calculated as follows:

$$\beta_t^{x/y} = \frac{h_t^{x/y}}{h_t^y} \quad (7)$$

Finally, the percentage decrease in variance between the optimal and unhedged portfolios is used to assess the effectiveness of the hedging strategy. Balcılar *et al.* (2016) state that the following formula is used to calculate hedging effectiveness (HE):

$$HE = \left[\frac{variance_{unhedged} - variance_{hedged}}{variance_{unhedged}}\right] \quad (8)$$

The term '$variance_{unhedged}$'is used to represent the variance of unhedged portfolio returns as measured by the MSCI World index. In contrast, the term '$variance_{hedged}$' denotes the variance of optimal portfolio returns, which are further enhanced by a strategic position in an alternative asset. In terms of portfolio analysis, a portfolio that has higher HE (Hedging Effectiveness) value indicates that it is more effective at reducing risk.

William F. Sharpe's introduction of the Sharpe ratio in 1966 is the ultimate evaluation of the risk-adjusted performance of hedging strategies. The Sharpe ratio, which is calculated by dividing the portfolio's excess return by its standard deviation, gives valuable insight into the efficiency of the hedging approach.

3.3 Safe haven

In alignment with BenSaïda (2023), the safe haven property is evaluated by estimating the subsequent model given the dynamic conditional correlations:

$$DCCxy,_t = \theta_0 + \theta_1 DCC_{xy,t-1} + \theta_2 D_{COVID} + \theta_3 D_{war} + \varepsilon_{xy,t} \quad (9)$$

In the given context *DCCx y,t* symbolizes the pairwise dynamic conditional correlation between two financial assets: y is used to indicate green bonds or clean energy stocks, and *x*.

In the given context *DCCx y,t* symbolizes the is used to indicate the MSCI World index. The correlations are dynamic and change over time depending on market conditions. The dummy variables D_{covid} and *Dwar* represent the COVID-19 period and the Russia–Ukraine conflict, respectively. Each dummy variable equals one if the returns are during the crisis, and zero otherwise.

Equation (9) serves to identify an asset as a diversifier, hedge, or safe haven. The decision-making process is based on the following rules: if θ_0 is significantly positive (not equal to 1), we will consider asset y as diversifiers for the international stock market during the whole period of study. It is a weak hedging instrument if θ_0 is insignificantly different from zero, but a strong hedging instrument if θ_0 is significantly negative. If the values of θ_2 and θ_3 are zero or significantly negative, the asset j is a weak/strong safe haven during the COVID-19 and Russia–Ukraine conflict, respectively.

4. EMPIRICAL ANALYSIS

4.1 Data and descriptive statistics

This study's sample comprises daily log returns for several financial indices: the global stock market (MSCI World Index), green bonds (S&P Green Bond Index), and clean energy stocks (S&P Global Clean Energy Index). Additionally, we incorporate gold (S&P GSCI spot price index) for comparative analysis. To compute portfolio excess return, we use the 3-month US Treasury bill. The data originates from DataStream, spanning from January 3, 2019 to June 15, 2023. Notably, this comprehensive sample encompasses two pivotal crisis periods. The first was the COVID-19 pandemic, officially declared by the World Health Organization on March 11, 2020. The second crisis emerged from the Russia-Ukraine conflict, initiated by Russia's invasion of Ukrainian territory on February 24, 2022, and persisted until the trial period's conclusion on February 24, 2022. Table no. 1 presents the descriptive statistics of daily returns.

In Table no. 1, we present a brief summary of daily returns statistics. Notably, the clean energy index consistently exhibits the highest mean return over the entire study period, while green bonds yield the lowest mean return. This divergence underscores the inherent risk-reward trade-off within these asset classes. The robust mean return observed for the clean energy index is accompanied by heightened return volatility. This aligns with the research findings of Dutta *et al.* (2020) and Nguyen *et al.* (2021), who emphasize the clean energy market's propensity for significant fluctuations while maintaining its fundamental profitability. Remarkably, these results hold even during the challenging times of the COVID-19 pandemic crisis. However, during the Russia-Ukraine conflict, clean energy index returns turned negative, and the associated risks escalated. It's essential to recognize that all return

series exhibit negative skewness (except for the clean energy index during the Russo-Ukrainian war) and have kurtosis values greater than 3. Moreover, the Jarque-Bera test unequivocally rejects the assumption of normal distribution for all return series. Additionally, the Ljung-BoxQ (12) statistic indicates autocorrelation in the returned series. Standard unit root tests may be biased towards non-rejection of the null hypothesis due to the presence of a structural break. In our study, the results of the ADF test with Breaks are similar to those of the standard ADF test.

Table no. 1 – Descriptive statistics of daily returns

	MSCI world	Clean energy	Green bonds	Gold
Panel A : Total period				
Mean	0.0004	0.0007	-0.0001	0.0004
Std. dev.	0.0122	0.0196	0.0045	0.0113
Skewness	-0.9864	-0.4235	-0.4946	1.1138
Kurtosis	14.08	8.62	9.11	18.01
Jarque-Bera	5378.58*** (0.00)	1370.62*** (0.00)	1628.60*** (0.00)	9772.74*** (0.00)
ADF	-18.13*** (0.00)	-17.32*** (0.00)	-16.27*** (0.00)	-15.87*** (0.00)
Q(12)	23.757*** (0.00)	42.659*** (0.00)	46.833*** (0.00)	29.383*** (0.00)
$Q^2(12)$	819.15*** (0.00)	659.55*** (0.00)	198.14*** (0.00)	73.798*** (0.00)
ADF with break t-stat.	-30.8195(<0.01)	-27.7439(<0.01)	-27.1531(<0.01)	-33.2583(<0.01)
Panel B : COVID-19				
Mean	0.0014	0.0039	0.0002	0.0004
Std. dev.	0.0171	0.0271	0.0045	0.0156
Skewness	-1.0556	-0.7261	-1.3645	1.3250
Kurtosis	12.76	7.09	12.23	15.39
Jarque-Bera	868.77*** (0.00)	164.43*** (0.00)	807.76*** (0.00)	1399.20*** (0.00)
ADF	-14.28*** (0.00)	-13.42*** (0.00)	-9.07*** (0.00)	-15.30*** (0.00)
Q(12)	127.70*** (0.00)	89.50*** (0.00)	58.00*** (0.00)	73.58*** (0.00)
$Q^2(12)$	115.26*** (0.00)	140.56*** (0.00)	114.38*** (0.00)	60.89*** (0.00)
ADF with break t-stat.	-29.8904(<0.01)	-28.3292(<0.01)	-23.0325(<0.01)	-29.7599(<0.01)
Panel C : Russia-Ukraine war				
Mean	0.0001	-0.0006	-0.0005	0.0001
Std. dev.	0.0109	0.0187	0.0052	0.0096
Skewness	-0.4082	0.1172	-0.2145	-0.2979
Kurtosis	6.36	5.33	6.88	4.72
Jarque-Bera	273.63*** (0.00)	126.24*** (0.00)	348.78*** (0.00)	76.51*** (0.00)
ADF	-17.30*** (0.00)	-16.07*** (0.00)	-15.42*** (0.00)	-13.59*** (0.00)
Q(12)	113.35*** (0.00)	82.51*** (0.00)	106.37*** (0.00)	141.85*** (0.00)
$Q^2(12)$	142.28*** (0.00)	182.93*** (0.00)	112.99(0.00)	169.57*** (0.00)
ADF with break t-stat.	-35.0600(<0.01)	-34.4659(<0.01)	-36.6909(<0.01)	-38.7837(<0.01)

This table reports the descriptive statistics for the daily returns for the conventional stock market (MSCI world), clean energy stocks (S&P Global Clean Energy index) green bonds (S&P Green Bond Index), and gold. The study's period is from January 03, 2019, to June 15, 2023. Panel A shows results over the entire period, while Panel B includes the results during the COVID-19 outbreak and Panel C represents the results during the Russia-Ukraine conflict. Q (12) and Q2 (12) denote the Ljung-Box statistics up to 12th order in residuals and squared residuals, respectively. P-values are in parentheses. The Breakpoint Unit Root test is designed to identify breakpoints using Dickey Fuller min-t and innovation outlier.
Note: ***indicates statistical significance at 1%.

Table no. 2 presents the unconditional correlations for the entire sample and both crisis periods. In terms of pairwise correlations, gold demonstrates the lowest associations with both MSCI World Clean Energy and green bonds. Conversely, there is a consistent negative correlation between gold and conventional stock indexes, which persists not only over total period but also throughout the COVID-19 pandemic. Gold has the potential to be a safe haven during crisis times Baur and Lucey (2010).

Table no. 2 – Unconditional correlation matrix

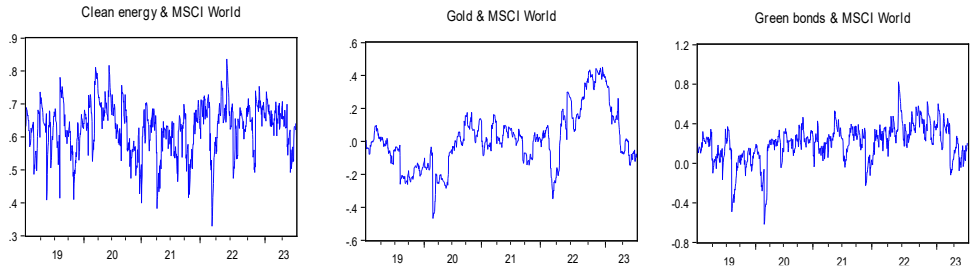
Panel A : Total period				
	MSCI world	**Clean energy**	**Green bonds**	**Gold**
MSCI world	1.00***			
Clean energy	0.69***	1.00***		
Green bonds	0.31***	0.28***	1.00***	
Gold	-0.01	0.07***	0.26***	1.00***
Panel B : COVID-19				
	MSCI world	**Clean energy**	**Green bonds**	**Gold**
MSCI world	1.00***			
Clean energy	0.77***	1.00***		
Green bonds	0.39***	0.35***	1.00***	
Gold	-0.07	0.02	0.20***	1.00***
Panel C : Russia-Ukraine war				
	MSCI world	**Clean energy**	**Green bonds**	**Gold**
MSCI world	1.00***			
Clean energy	0.61***	1.00***		
Green bonds	0.43***	0.33***	1.00***	
Gold	0.16***	0.20***	0.34***	1.00***

This table shows the unconditional correlation between the MSCI World index and clean energy, green bonds, and gold.
Note: ***indicates statistical significance at 1%.

4.2 Estimation results

4.2.1 DCC -GARCH estimations

We have employed the DCC-GARCH model to analyze time-varying correlations, as illustrated in Figure no. 1. These correlations exhibit remarkable fluctuations across various periods and markets. Notably, MSCI World, green bonds, clean energy stocks, and gold have consistently shown a downward trend in dynamic correlations until late 2019. However, since 2020 – amidst the COVID-19 pandemic and the Russia-Ukraine conflict in 2022 – these correlations have undergone a substantial increase. This shift highlights the impact of global events on market interdependencies and underscores the need for adaptive risk management strategies. The pronounced peak in conditional correlations across almost all markets during 2020 can be attributed to the pervasive uncertainty triggered by the COVID-19 pandemic. This observation aligns with findings from various studies, including those by Zhang *et al.* (2020) and Adekoya and Oliyide (2021).



Note: The figure illustrates the dynamic conditional correlations determined with the DCC-GARCH model between the MSCI World index and clean energy stocks, green bonds, and gold.

Figure no. 1 – The dynamic conditional correlations

Moreover, the financial markets, particularly in Russia and Europe, bore the brunt of the conflict between Russia and Ukraine. The resulting decline in stock prices was driven by investor caution, as they hesitated to allocate capital to these regions. Consequently, international investors are now compelled to refine their optimal asset allocation strategies. Notably, during crisis periods, the prices of gold and stocks tend to rise, making them attractive options for safeguarding wealth as highlighted by BenSaïda (2023).

4.2.2 Optimal portfolio weights

Table no. 3 provides a summary of the optimal portfolio design for conventional stocks, indexes, and other financial assets throughout the entire period, which encompasses the COVID-19 crisis and the Russia-Ukraine conflict.

Table no. 3 – Optimal portfolio weights

	Mean	S.D.	Min	Max
Panel A: Total period				
Clean energy	0.0724	0.1160	0.0000	1.0000
Green bonds	0.9084	0.0801	0.6239	1.0000
Gold	0.4847	0.1523	0.1124	1.0000
Panel B: COVID-19				
Clean energy	0.0228	0.0619	0.0000	0.3608
Green bonds	0.9335	0.0511	0.7791	1.0000
Gold	0.4394	0.1441	0.1124	0.7835
Panel C: Russia-Ukraine war				
Clean energy	0.0604	0.1048	0.0000	0.5967
Green bonds	0.8587	0.1048	0.6239	1.0000
Gold	0.5733	0.1482	0.2833	0.9414

Based on the findings, it can be concluded that in order to reduce risk while maximizing expected return, it is advisable to allocate more than 85% of the portfolio to green bonds and 40% for gold throughout the period, and sub-periods, on average. For clean energy, the optimal weights are low and do not exceed 10% for regardless of the period. The findings indicate that green bonds are the preferred option for minimizing risk in a portfolio that includes the MSCI Global Index, rather than clean energy or gold. According to the findings,

the optimal weights for gold increased during the Russian-Ukrainian conflict (57,33%), compared to the optimal weights during the entire period (48,47%) and the COVID-19 pandemic (43,94%).

4.2.3 Hedge property

Employing optimal hedge weights and ratios provides a broad understanding of constructing a hedge to minimize risk. However, these measures do not offer insights into the long-term effectiveness of the hedge. Therefore, Table no. 4 displays the Hedge Effectiveness (HE) index, which addresses this aspect.

Table no. 4 – Optimal hedge ratios and hedging effectiveness

	HR	HE (%)
Panel A : Total period		
Clean energy	0.3903	0.4640
Green bonds	0.4774	0.0986
Gold	0.0273	0.0499
Panel B : COVID-19		
Clean energy	0.3229	0.4954
Green bonds	0.6050	0.0514
Gold	-0.0186	0.0331
Panel C : Russia-Ukraine war		
Clean energy	0.4128	0.4377
Green bonds	0.6154	0.1837
Gold	0.1874	0.0760

This table represents the optimal hedge ratios (HR) and hedging effectiveness (HE) indices in percent clean energy stocks , green bonds, and gold during Total period, the COVID-19 pandemic and the Russia-Ukraine war.

Based on Table no. 4, in order to mitigate risk in the asset that requires hedging, investors must adopt opposing positions in both the hedging asset and the asset that needs to be hedged. Conversely, if investors have a negative HR (hedge ratio), they should take the same position, whether long or short, in both assets. For instance, to hedge a long position of $1 in the MSCI world, one would need to short 39.03 cents in clean energy. Similarly, to hedge a long position of $1 during the COVID-19 pandemic, one would need to take a long position of 1.86 cents in gold. According to López Cabrera and Schulz (2016), if the hedge ratio is lower in absolute value, the hedge is less costly. Results show that using gold as a hedge is less expensive than using clean energy or green bonds.

Asset coverage was less expensive throughout the entire period than during the COVID-19 pandemic and the Russia-Ukraine war (Akhtaruzzaman *et al.*, 2021). This result is in line with the literature, which shows that during times of crisis, as noted by Batten *et al.* (2021), higher hedge ratios are observed because of the significant rise in uncertainty surrounding the financial and economic future. According to Table no. 4, clean energy is more effective in hedging and reducing risks than gold and green bonds. This observation pertains to the entire sample and the crisis of COVID-19 and Russia-Ukraine conflict. Gold's hedging capacity is surprisingly low, particularly during the COVID-19 pandemic, despite its cheaper hedging cost (low HR).

Our findings have significant implications. The sample period's frequent fluctuations in hedging ratios imply that the covered positions ought to be revised on a regular basis. Therefore, disregarding any notable fluctuations in markets might lead to unfavorable decisions for foreign investors who want to diversify their portfolios and protect their investment. Moreover, despite the notion that gold performs better in these situations, the current crisis has led investors and portfolio managers to reassess their faith in precious metals (Baur and McDermott, 2010).

4.2.4 Safe haven property

In this part, we focus on the extreme negative variations in the MSCI world index to analyze the hedging, diversifier, and safe haven characteristics of these assets for a passive investor. The analysis is summarized in Table no. 5. Our first point of discussion is the estimations of θ_0, which is the coefficient that enables us to distinguish between diversifier and hedge properties. With the exception of the clean energy market, all markets have a negative and insignificant coefficient of θ_0. This suggests that, over the sample period, gold and green bonds could serve as a weak hedge against changes in the conventional stocks index. Nonetheless, Clean Energy functions as a diversifier against MSCI world volatility, as suggested by the asset's positive and noteworthy θ_0 estimate. This is in fact consistent with Kuang (2021b), who shows that investors can gain from risk diversification by investing clean energy stocks.

Table no. 5 – Hedge and safe haven features

	Hedge(θ_0)	**$DCC_{xy,t}$ (θ_1)**	**$COVID$ (θ_2)**	**War (θ_2)**
Clean energy	0.0751***(0.00)	0.8784***(0.00)	0.0008(0.75)	0.0026(0.36)
Green bonds	-0.0102 (0.17)	0.9078***(0.00)	0.0238 ***(0.00)	0.0423 ***(0.00)
Gold	-0.0015 (0.71)	0.9839***(0.00)	0.0002(0.96)	0.0042(0.39)

This table reports the estimation results of the safe haven model. P-values are in parentheses.
Note: ***indicates statistical significance at 1%.

Upon examining the remaining model coefficients ($\theta 2$ and $\theta 3$), we find that the estimates for gold and clean energy are insignificant and/or negative in all quantiles. This observation reinforces the assets' feeble safe haven features against severe MSCI world downturns, such as those that occurred during the COVID-19 pandemic and the conflict between Russia and Ukraine.

Our results reinforce the findings of Hood and Malik (2013), Dutta *et al.* (2020), Hussain Shahzad *et al.* (2020); Shahzad *et al.* (2020)and Akhtaruzzaman *et al.* (2021), who provide evidence of gold as a weak safe haven against the downside risk of portfolios. For green bonds, the coefficients θ_2 and θ_3 are found to be significantly positive indicating green bonds don't always provide a safe refuge amid severe market downturns.

5. ROBUSTNESS TEST

We conduct a robustness analysis utilizing the Safe Haven Index (SHI) developed by Baur *et al.* (2024); Baur *et al.* (2025) to validate our findings and assess the safe-haven

properties of green bonds, clean energy stocks, and gold. The SHI is a performance indicator that identifies the average price change for multiple safe-haven assets, as specified by:

$$SHI_t = \exp[ln(SHI_{t-1}) + R_t^b] \tag{10}$$

Let R_t^b represent the equally weighted return of n-assets, calculated as follows:

$$R_t^b = \frac{1}{n}\sum_{i=1}^{n} R_{it} \tag{11}$$

Here, R_{it}denotes the logarithmic return of the i[th] asset in the basket from time *t-1* to *t*, based on daily closing prices. Following Baur *et al.* (2024); Baur *et al.* (2025), the regression can be expressed as:

$$R_{i,t} = \mu_i + \theta_i \triangle SHI_t + \varepsilon_{i,t} \tag{12}$$

In this equation, $R_{i,t}$ indicates the return of asset i at time t , and $\triangle SHI_t$ represents the log-return of the safe haven index during that period. For each index, we estimate the parameters μ_i and θ_i . According to this model, an ideal safe haven index would yield μ_i= 0 and θ_i = 1. Baur *et al.* (2024); Baur *et al.* (2025) classify a strong safe haven index as one withμ_i = 0 and $\theta_i \geq 1$, while an index is considered a weak safe haven if \ μ_i = 0 and $0 < \theta_i < 1$. The results are presented in Table no. 5 – we determine the first SHI by using SHI0 = 100, as suggested by Baur *et al.* (2024).

Table no. 6 – Robustness check test

	μ	Theta (θ)
Panel A : COVID-19		
Clean energy	0.00(0.52)	1.8249***(0.00)
Green bonds	0.00(0.73)	0.1684*** (0.00)
Gold	0.00(0.47)	0.6215*** (0.00)
Panel B : Russia-Ukraine war		
Clean energy	0.00(0.36)	0.9293*** (0.00)
Green bonds	0.00*** (0.01)	-0.1970*** (0.00)
Gold	0.00(0.69)	0.3736***(0.00)

This table reports the estimated results for link between safe haven index (SHI) with D Clean energy, Green bonds and Gold during COVID-19 period and the Russia-Ukraine war.
Note: "***" and "**" indicate significance at the 1% and 5% level respectively. P-values are shown in parentheses.

Table no. 6 above illustrates the relationship between the Safe Haven Index (SHI) and the assets of clean energy, green bonds, and gold. In our analysis, the SHI comprises these three assets.

Panel A: COVID-19 Period:

Panel (A) of Table no. 5 presents the estimated coefficients for the relationship between the SHI and the three assets during the COVID-19 pandemic. Our findings indicate that all three assets exhibit non-zero but statistically insignificant values for μ_i, alongside significant

coefficients for θ_i that are less than one. This suggests that while these assets can provide some degree of safe haven, their effectiveness is weak during this health crisis.

Panel B: Russian-Ukraine War:

Panel (B) of Table no 6 details the estimated coefficients for the relationship between the SHI and the same assets during the Russian-Ukraine conflict. The results for clean energy and gold indicate that these assets can also offer a weak safe haven during the war. However, the findings reveal that green bonds have a significant and negative θ_i, indicating that they do not meet the criteria for a safe haven index during this geopolitical turmoil.

These results align with those obtained through the DCC-GARCH model, as well as the hedging ratio and hedging effectiveness index. Consequently, the robustness of our previous methodologies is reinforced by these findings.

6. CONCLUSION

Financial markets worldwide have been severely affected by the COVID-19 pandemic in 2020 and the Russian-Ukraine war in 2022. The necessity to explore alternative investment opportunities that can withstand these challenging circumstances has arisen due to the erosion of investor trust in traditional financial institutions. As a result, hedge assets that offer protections against extreme events, such as green bonds and clean energy stocks, have gained popularity among both investors and researchers. Our study directly compares the properties of clean energy, green bonds, gold hedging, and safe haven characteristics against the conventional stock index MSCI World. The sample period spans from January 3, 2019, to June 15, 2023. Utilizing the Dynamic Conditional Correlation (DCC)-GARCH model, we analyze hedge ratios and hedge effectiveness indexes. These metrics provide insights into the hedging potential of gold, green bonds, and clean energy assets across stable and volatile market condition.

Our analysis reveals that while clean energy and green bonds are more effective at hedging and reducing risks compared to gold, the latter remains a less expensive option for hedging. This finding aligns with the literature, particularly Batten *et al.* (2021), who note that higher hedge ratios emerge during crises due to increased uncertainty regarding financial and economic futures. Throughout the entire sample period, gold and green bonds were identified as weak hedges against fluctuations in the conventional stocks index. In contrast, clean energy serves as a diversifier against fluctuations in the MSCI World Index, consistent with Kuang (2021b), which indicates that investors can achieve risk diversification through clean energy stocks.

Our results suggest that both gold and clean energy exhibit weak safe-haven properties during extreme global downturns, such as the COVID-19 crisis and the Russia-Ukraine conflict. Green bonds fail to provide effective shelter during severe market downturns, reinforcing findings from Hood and Malik (2013), Dutta *et al.* (2020), Shahzad *et al.* (2020), and Akhtaruzzaman *et al.* (2021), who provide evidence of gold's limited safe-haven capabilities against portfolio downside risk.

These insights are crucial for governments, investors, and regulators seeking to mitigate losses during periods of high uncertainty. However, it is essential to approach these conclusions with caution, as the ongoing impact of the Russia-Ukraine war on global financial markets may obscure the full picture for some time. Additionally, our analysis highlights significant dynamic correlations among these assets, indicating their interdependencies and the necessity for investors to consider the broader context when making investment decisions.

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IFRS 13: What Certainty Equivalent Might be Requested when Deriving a Fair Value Based on Risk-Adjusted Expected Cash Flows?

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Abstract: The study raises the point to elicit thresholds for certainty equivalents when determining the fair value using Method 1of the present value techniques within the methodology of income approaches. Through applying the risk-measure Value at Risk as indicator for certainty equivalents, it becomes possible to utilise the experience gained from risk management practice. Based on the calculation of certainty equivalents (the risk-adjusted expected income and expenses) observable in AAA-, Baa- and high-yield-rated U.S. corporate bonds, the corresponding Values at Risk were assessed by modelling different probability distributions. The studies reveal that investors in U.S. corporate bonds had accepted certainty equivalents that approximately correspond to Values at Risk with a confidence level in the range between 50 and 75% when taking the yield premium as criterion. In risk management practice, Values at Risk with confidence levels of above 80% are recommended. However, the safety margins then to be demanded reach values of approx. 17-25% on the expected value, which is in drastic contrast to the historical certainty equivalent coefficients

Keywords: fair value; IFRS 13; certainty equivalent method; three-point scenarios; probability assessment.

JEL classification: M41; C18; C30; C44.

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1. INTRODUCTION

International Financial Reporting Standard 13 Fair Value Measurement (IFRS Foundation, 2022b) is applied for the measurement of a specific asset or a specific liability (IFRS Foundation, 2012). It applies to both initial and subsequent measurement if fair value is required or permitted by other IFRSs (IFRS13.8). IFRS defines fair value as the price that would be received to sell an asset or paid to transfer a liability in an orderly transaction between market participants at the measurement date under current market conditions (Özerhan and Sultanoğlu, 2017; IFRS Foundation, 2022a, 2022b; Hall *et al.*, 2023). This approach stands in contrast to an approach that focuses on historical costs (Lennard, 2018; Gilliam and Hofmann, 2018a, 2018b).

From the three valuation techniques in IFRS 13 to derive fair value (market approach, cost approach and income approach; IFRS13.61 to IFRS13.66), risk-adjusted expected cash flows are inputs to one of two methods within present value techniques which belong to the income approach (IFRS13.B23).

Method 1 within the income approach (IFRS 13.B25), the "certainty equivalent method" (Dayananda *et al.*, 2002), follows the utility theory paradigm of replacing possible cash flows (resp. income and expenses, following IFRS13.B10), which are uncertain, with a monetary value that reflects the (market participants') utility of these uncertain cash flows. Risk is removed by substituting possible, but uncertain cash flows with its certainty equivalent, i.e., the monetary valued utility of the uncertain outcomes. Formally, a 'cash risk premium' is subtracted from the expected value of possible future cash flows ('expected cash flows' in IFRS 13) leading to 'risk-adjusted expected cash flows', the certainty equivalent. In that case the market participant would be indifferent as to the asset held. As the certainty equivalent covers the systematic (i.e., market) risk and market participants are not compensated for the risk specific to a particular asset or liability, which is diversifiable ('unsystematic risk') (IFRS13.B24), the fair value is calculated by discounting the risk-adjusted expected cash flows at a risk-free interest rate.

Method 2 of the fair value measurement within the income approach, the "risk-adjusted discount rate method" (Dayananda *et al.*, 2002), uses the expected value of possible future cash flows, derived from market perspective, which are not risk-adjusted, and a discount rate which is adjusted to include the risk premium that market participants require (IFRS 13.B17, IFRS 13.B26). When deriving the expected value an entity may begin with its own data, but it shall adjust those data if 'reasonably available' information indicates that other market participants would use different data (IFRS 13.87-89). An entity shall take into account all information about market participant assumptions that is 'reasonably available'. To gain the fair value, the expected cash flows are discounted at a rate which incorporates a risk premium to the risk-free interest rate (further: 'risk-adjusted interest rate').

IFRS13.B36 mentions the possibility to derive possible future cash flows (resp. income and expenses; IFRS13.B10) from unobservable inputs when evaluating a cash-generating unit or a decommissioning liability assumed in a business combination. If derived from unobservable inputs (like projected cash flows), the measurement of fair value belongs to 'Level 3 inputs', the least prioritised category (Rohleder *et al.*, 2017). The highest priority should be given to quoted prices in active markets for identical assets ('Level 1 inputs'; IFRS 13.76), followed by including observable inputs other than quoted in Level 1 inputs ('Level 2 inputs'; IFRS 13.82-83).

The present value technique's significance, especially for Method 2 (risk-adjusted discount rate method), can be assessed following the exemplifications in IFRS 13.IE35-IFRS 13.IE39, as well as reports from the literature (i.e., for combining businesses: IFRS Foundation (2022a); for cash generating units: BDO (2022), EPRA (2013) and IPSAS (2024), for assets used in real estate industry or for investments in property under construction: (IFRS Foundation, 2012; Busso, 2014; Sundgren *et al.*, 2018; Baur *et al.*, 2025).

The applicability of Method 1 (certainty equivalent method) mainly suffers from comparative data and a methodology to derive certainty equivalents (from the market perspective) (Dayananda *et al.*, 2002; KPMG, 2011).

This research is an attempt to contribute to the applicability of Method 1.

This study focuses first on the aspect which certainty equivalent could be accepted by an auditor, based on historic data, if an entity follows Method 1 instead of applying Method 2. This could result in formulating an expectation in cases of applying Method 1.

Derived are historic certainty equivalents from historic bond yield premiums under the assumptions that bond yields represent the interest rate used by market participants to find the net present value (IFRS Foundation, 2022b) and that the identity of the net present values when applying Method 1 or Method 2 of the expected present value techniques holds (Beccacece *et al.*, 2018; IFRS Foundation, 2022b).

Secondly, the paper raises the question as to which confidence level could be assigned to the derived historical certainty equivalents if the risk-measure Value at Risk is used as an operationalisation of the certainty equivalents. If this is successful, especially if the historical data leads to confidence levels that correspond to the conventions in risk management, then these results could enable better traceability and also better control of the statement, since not only the probability function as in Method 2 must be specified for the derivation of the Value at Risk, but also the confidence level on which the decision is based.

The certainty equivalent of possible but uncertain outcomes gives their utility (Bruner *et al.*, 1998; Fabozzi *et al.*, 2007; Crundwell, 2008; Zhang, 2010; Pagani, 2015). In risk management practice, a simplification is applied by measuring the utility in units of the target variable (e.g. loss, earnings) – as it is done in IFRS 13.B26.

In risk management, the usage of the expected value (the probability weighted sum of possible outcomes) as decision criterion is disputed even if one takes the view that the expected value can approximate the median (the value that will be exceeded by higher numerical values with a cumulative probability of 50% or less).

Empirical studies recommend that both, the expected value and the median, should be disregarded as a decision criterion (or, here, as a decision maker's certainty equivalent) unless a high number of comparable situations with very similar probability distribution exist or are created. These studies originate from the following areas: project budgeting (Flyvbjerg, 2007; Bodea and Purnus, 2012; Garvey *et al.*, 2012; Lee *et al.*, 2012; Thomas and Fitch, 2014) and assessing risk positions within a financial institution (Cruz, 2006; Gaudin, 2016; Pfeifer and Ragulina, 2018).

The same consideration can be found in studies evaluating the benefit of an investment by assessing net cash flows (Frey and Rubin, 1992; Kremers, 2002; Beisler, 2011; Hill, 2012; Gleißner *et al.*, 2021).

To illustrate this criticism: The expected value gives, in case of symmetrically distributed outcomes, the value which will be exceeded by the group of outcomes with higher numerical values or undercut by the group of outcomes with lower numerical values with a

probability of approximately 50% (Jorion, 2007; Huschens, 2017; Klugman *et al.*, 2019). Taken a situation with six equal probable outcomes, as it is when throwing a fair dice, the expected value of 3.5 (say, the fair value) will be undercut by the lower numerical outcomes of one, two and three with a cumulative probability of 50%. Further, the expected value of 3.5 will be exceeded by the higher numerical outcomes of four, five and six with a cumulative probability of 50%. The same applies to the median. In the given example, the median is equal to three, which means that higher numerical values exceed this value with a probability of less than 50% and that lower values occur with a probability of less than 50% (when excluding the probability of the median value itself).

This means, when basing a business decision on the median (or on the expected value under the assumption of a symmetrical probability distribution), the confidence in gaining the median value when implementing the decision can solely be labelled as 'more likely than not' (Bohušová *et al.*, 2014) or 'about as likely as not' (Mastrandrea *et al.*, 2010), since the probability of falling below or exceeding this value is about 50%.

For gaining a higher confidence level, the risk-measure Value at Risk is recommended (Jørgensen and Teigen, 2002; Jorion, 2007; GAO, 2009; Weapon Systems Acquisition Reform Act, 2009; Huschens, 2017; Klugman *et al.*, 2019). The risk-measure Value at Risk gives the value that is outperformed by more favourable (!) values with the probability of the selected confidence level. The Value at Risk with a confidence level of 90% (VaR90) gives the value that will be outperformed by more favourable values with a cumulative probability of (at least) 90%.

Formally, the utility of the possible but uncertain outcomes is derived by solely regarding the most unfavourable outcome of the group of outcomes which is defined by their cumulative probability of occurrence (determined by the selected confidence level), if all outcomes are considered in ascending order of advantage. No utility is ascribed to the outcomes which are more favourable and which are less favourable than the Value at Risk.

To illustrate: When selecting a VaR90 as certainty equivalent, no utility is attributed to more favourable outcomes that occur with a cumulative probability of less than 0.90, nor to less favourable outcomes that occur with the complementary probability of the confidence level (here: less than 0.10).

For deriving the Value at Risk, the probability distribution of possible future outcomes has to be assed (congruent to the exemplifications in IFRS Foundation (2022b) from B28 to IE63) and, based on it, its cumulative probability distribution has to be calculated. The percentiles of the cumulative probability distribution are the basis for deriving the Value at Risk. When applying the measure to cash flows resp. to income and expenses, then higher numerical values stand for more favourable outcomes. Therefore, the Value at Risk with a defined certainty level can (approximately) be derived from the percentile that is identical with the complementary probability of the certainty level (Jorion, 2007; Huschens, 2017; Klugman *et al.*, 2019). In case of VaR90, the percentile 10 of the cumulative probability distribution approximates the value which will be exceeded by more favourable values with a cumulative probability of 90%.

If a high number of situations with a very similar probability distribution of the possible future outcomes exists or is created, the median (the Value at Risk with a confidence level of 50% [VaR50]) is seen as acceptable in risk management practice (Flyvbjerg, 2004). However, if only a small number of projects with a similar probability distribution exists or is created (this could be the case when combining businesses or be the cases of evaluating assets in real estate

industry or investments in property under construction) higher confidence levels are proposed: between 80 to 90 % in project budgeting (Jørgensen and Teigen, 2002; Flyvbjerg, 2004; GAO, 2009; Weapon Systems Acquisition Reform Act, 2009) or between 95 to 99% for the valuation of risk positions within a financial institution (Hendricks, 1996; Jorion, 2007).

The following Section 2 focuses on the first aspect of this study: which certainty equivalent could be accepted by an auditor, based on historic data. It gives the mathematical basis of deriving certainty equivalents from the identity of the net present values when applying Method 1 or Method 2 as well as the results of applying this methodology to historic AAA- and Baa-rated U.S. corporate bond yields.

Section 3 and Section 4 deal with the second aspect: the question of which confidence level can be assigned to the derived historical certainty equivalents if the risk-measure Value at Risk is used as an operationalisation of the certainty equivalents.

Section 5 focuses on an analysis and discussion of the results gained. Within that section two further analyses are reported to check the plausibility of the results. Section 6 discusses the results and give explanations for the results found. Section 7 summarises the results and gives the author's conclusions regarding the applicability of Method 1 of the present value techniques within the income approach.

This study contributes to the theoretical discussion on the applicability of Method 1 of the present value techniques within the income approach. Further, this paper gives an overview of how to derive the risk-measure Value at Risk from probabilistic three-point scenarios based on the illustrative example in IFRS Foundation (2022b) B25.

2. DERIVING CERTAINTY EQUIVALENTS FROM HISTORIC BOND YIELD PREMIUMS

In order to assess which minimum certainty equivalents should be required when deriving a fair value using Method 1 of the expected present value techniques, the identity of the net present values when applying Method 1 and when applying Method 2 is utilised (Dayananda *et al.*, 2002; Beccacece *et al.*, 2018; IFRS Foundation, 2022b).

This relationship is used to calculate the certainty equivalents of historic bond yield premiums of Moody-AAA- and Moody-Baa-rated U.S. corporate bond yields in relation to market yields on U.S. treasury securities at 10-year constant maturity. The analysis is based on the assumption that bond yields represent the interest rate used by market participants to determine the net present value (IFRS13.B14).

Method 1 adjusts the expected cash flows of an asset for systematic (i.e., market) risks by subtracting an amount (the 'cash risk premium' in IFRS) from the expected value ('expected cash flows' in IFRS), to come to the certainty equivalent ('risk-adjusted expected cash flows' in IFRS 13). In Method 2, the expected value is discounted with an interest rate, which contains an interest rate risk premium on the risk-free interest rate that market participants demand when these expected cash flows are offered to them ('risk-adjusted interest rate').

The certainty equivalent (regarding a period) can be calculated from this as follows:
Let

CE / (1 + r_rf): Net present value of the certainty equivalent
EV / (1 + r_rf + r_rp): Net present value of the expected value

with:
CE: Certainty equivalent ('risk-adjusted expected cash flows')
EV: Expected value ('expected cash flows')
r_rf: Risk-free interest rate
r_rp: Interest rate premium

Let:
r_ra: Risk-adjusted interest rate

With:

$$r\_ra = (r\_rf + r\_rp) \tag{1}$$

From:

$$CE / (1 + r\_rf) = EV / (1 + r\_rf + r\_rp) \tag{2}$$

follows

$$CE / (1 + r\_rf) = EV / (1 + r\_ra) \tag{3}$$

$$<=> CE = EV * (1 + r\_rf) / (1 + r\_ra) \tag{4}$$

To rule out any influence from the numerical values of the certainty equivalent and the expected value, the certainty equivalent coefficient (CEC) is used as a reference standard: the ratio of the certainty equivalent to the expected value (Dayananda *et al.*, 2002; Crundwell, 2008; Zhang, 2010).

A certainty equivalent coefficient reaches the value of one if the certainty equivalent is identical with the expected value: a market participant regards the possible (uncertain) cash flows as risky as the corresponding risk-free cash flows. A certainty equivalent coefficient of 0.9 is to be interpreted as meaning that the certainty equivalent corresponds to 0.9 times the expected value or that a safety margin of 10% is applied on the expected value. A certainty equivalent coefficient cannot achieve values above 1, as this would mean that the possible (uncertain) cash flows are considered less risky than the corresponding risk-free cash flows.

The certainty equivalent coefficient is calculated as follows:

Let

CEC: Certainty equivalent coefficient

and

$$CEC = CE / EV \tag{5}$$

Then follows from (3):

$$CE / (1 + r\_rf) = EV / (1 + r\_ra)$$
$$<=> CE / EV = (1 + r\_rf) / (1 + r\_ra) \tag{6}$$
$$<=> CEC = CE / EV = (1 + r\_rf) / (1 + r\_ra)$$

The historic certainty equivalent coefficients are calculated by formula (6). Chosen are 9659 data points of Moody-AAA- (FRED, 2025a) and 9659 data points of Moody-Baa-rated U.S. corporate bond yields (FRED, 2025b) from 1986-01-02 to 2024-08-15, representing risk-adjusted interest rates. For the analysis, these data are set in relation to market yields on U.S.

treasury securities at 10-year constant maturity (FRED, 2025c) representing risk-free interest rates, similar Dayananda *et al.* (2002); BDO (2022). The certainty equivalent coefficients are derived by the author per data point on daily basis to eliminate seasonal effects, following the methodology of FRED (2025d, 2025e).

The 19,318 data points are regarded together and condensed in 11 classes with equal width intervals. Table no. 1 gives the group average per class, and its relative frequency. Location parameters are given in Table no. A1 in Annex 1. A regression analysis of the time series shows a negligible influence over time (slope: -4E-07; coefficient of determination r^2: 0.051) so that the data can be regarded as representative (see Figure no. A1 in Annex 1).

Class 1, the class with the highest certainty equivalent coefficients (group average: 0.9932, lower group bound 0.9923), does only include AAA bonds. For that reason, this class is selected for further analyses.

The weighted average of classes 9 to 11 (0.9494) is selected as representative of very low certainty equivalent coefficients, as only Baa-rated bonds in a recessionary phase (following the definition of FRED (2025a, 2025b)) are represented in these three classes.

The classification of the weighted average of the classes 9 to 11 as 'very low certainty equivalence coefficients' is justified by the fact that the certainty equivalence coefficient of less than 0.9661 (class 7) are 1.5-times the interquartile range below the first quartile. The definition of an outlier follows the convention, that values laying 1.5-times the interquartile range below the first quartile or laying 1.5-times the interquartile range above the third quartile can be classified as outliers (Cooper and Schindler, 2003; Anderson *et al.*, 2007; Howell, 2010).

Table no. 1 – Certainty equivalents coefficients for Moody-AAA- and Moody-Baa-rated bond yields to U.S. treasury securities at 10-year constant maturity (1986-01-02 to 2024-08-15)

	CEC (group average)	Relative frequency
Class 1	0.9932	0.0724
Class 2	0.9900	0.1974
Class 3	0.9848	0.3113
Class 4	0.9803	0.2281
Class 5	0.9751	0.1074
Class 6	0.9705	0.0652
Class 7	0.9662	0.0089
Class 8	0.9610	0.0014
Class 9	0.9553	0.0011
Class 10	0.9503	0.0039
Class 11	0.9459	0.0030

3. DERIVING VALUES AT RISK FROM ASSESSING PROBABILITIES TO THREE-POINT SCENARIOS

The risk-measure Value at Risk is gained from assessing the probability distribution of possible future outcomes and from calculating its cumulative probability distribution.

Examples of how to come to a probability distribution can be derived from the illustrations of the disclosure requirement (IFRS13.IE63) and IFRS13.B17, IFRS13.B27. Following these illustrations, the range of the possible future outcomes (cash flows resp. income and expenses, IFRS13.B10) is derived from assessing the range of the influencing factors which leads to an assessment of the minimum, the maximum and the most-likely outcome.

This approach corresponds to the technique of creating (probabilistic) three-point scenarios (Schnaars and Ziamou, 2001; Chermack and Coons, 2012). Within that research field, a solution for the situation can be found if many factors influence the outcome, too. Then, the three scenarios are derived from assuming (a) all influencing factors would reach the unfavourable value (leading to the worst-case scenario), (b) all would reach the most-likely value (most-likely-case scenario), and (c) all influencing factors would reach the favourable value (leading to the best-case scenario) (Purnus and Bodea, 2013).

After recognising these three possible outcomes, the corresponding probability of occurrence is determined. The probabilities of the three scenarios can be assessed directly (as in the example of IFRS13.B27) or indirectly (excellent reviews on the fulfilment of this task can be found at Stael Von Holstein and Matheson (1978); Garthwaite *et al.* (2005); Elfadaly (2012); Grigore *et al.* (2013); Goodwin and Wright (2014); Zondervan-Zwijnenburg *et al.* (2017). It should be mentioned that in order to determine the probability distribution on the basis of the three-scenario approach, it is advisable to estimate the probability of occurrence for two further points: for the value between the worst-case value and the most-likely value as well as for the value between the most-likely value and the best-case value (Kasprik, 2024).

Practical applications of deriving the fair value from probabilistic scenarios are reported in BDO (2022); IFRS Foundation (2022a); Škoda *et al.* (2023); Baur *et al.* (2025).

For illustration, the situation described in IFRS13.B25 is taken as example. It is assumed that the possible future cash flows are those of a cash-generating unit with a useful lifetime of four years. It is also assumed that the cash flows describe the average (and, therefore, identical) situation in each period over these four years. The data are derived from assessing the consequences of two influencing factors (e.g. rental value and occupancy rate in a real estate property portfolio) with three states (unfavourable, most-likely, favourable). Following the multi-factor three-scenario approach (see above), three scenarios are derived: (a) worst case: Currency Units (CU) CU500, (b) most-likely case: CU800, (c) best case: CU900. In a further assessment, the probabilities of the scenarios are derived by the entity's knowledge of the market: (a) worst case: point probability of 0.15, (b) most-likely case: point probability of 0.60, (c) best case: point probability of 0.25.

The probability assessment has to include the probability of the intermediate outcomes because otherwise distinguishable Values at Risk cannot be derived and also because of the difficult-to-accept assumption that no further outcomes are to be expected between the point estimates (working with three discrete scenarios means, in terms of probability theory, that no further events exist in the event space).

The author considers here two techniques for evaluating the probabilities of the outcomes between the point estimates. A first technique follows the view that the point estimates give the midpoint of an interval (Anderson *et al.*, 2007) and the assessed point probability is equal to the interval probability.

In that case, the interval width is derived from the smallest distance of the values gained from the scenarios: here CU100 (the difference between the best-case and the most-likely-case scenario). From this follows, that the most-likely-case scenario covers the values between CU750 and CU850 (with an interval midpoint of CU800), the best-case scenario values between CU850 and CU950 (with an interval midpoint of CU900). The worst-case point estimate (CU500), taken as midpoint, covers 2.5 intervals to the lower bound of the most-likely interval (CU750), therefore, it covers in total five intervals (the range between CU250 and CU750 with the midpoints CU300, CU400, CU500, CU600 and CU700). This means

(under the assumption of equal distributed class member), the assessed probability of 0.15 has to be shared on each interval, leading to a probability of 0.03 for each of the five intervals. Figure no. 1 gives the probability distribution when dividing the bandwidth in 693 equal width intervals in order to derive discriminating Values at Risk. The corresponding cumulative probability distribution is given in Figure no. 2.

For deriving the net present value, the confidence level required by market participants must be determined for each year. An increasing confidence level over the years corresponds to the increasing uncertainty in the assessment of possible conditions in the more distant future (Dayananda *et al.*, 2002).

Assuming that market participants are expected to select a confidence level of 80% (percentile 20, VaR80), for the second a VaR85 (percentile 15), the third a VaR86 (percentile 14) and the fourth a VaR87 (percentile 13), then the net present value is reached by discounting the cash flow of CU757.6 (first year), CU749.5 (second year), CU716.2 (third year) and CU682.8 (fourth year) with the (constant) risk free interest rate of 0.05. The net present value is CU2,583 over the four periods (when disregarding capital outlay).

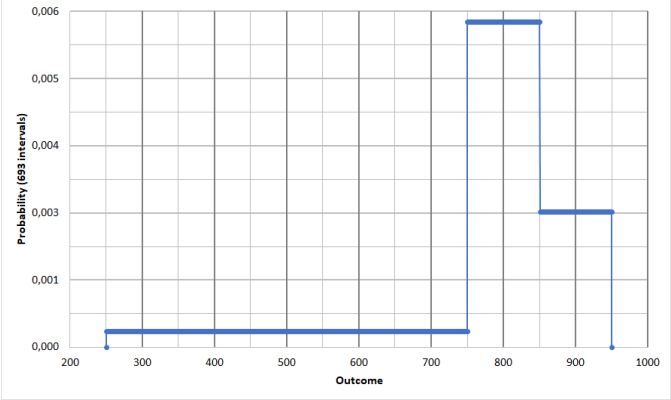

Figure no. 1 – Probability distribution (technique 1)

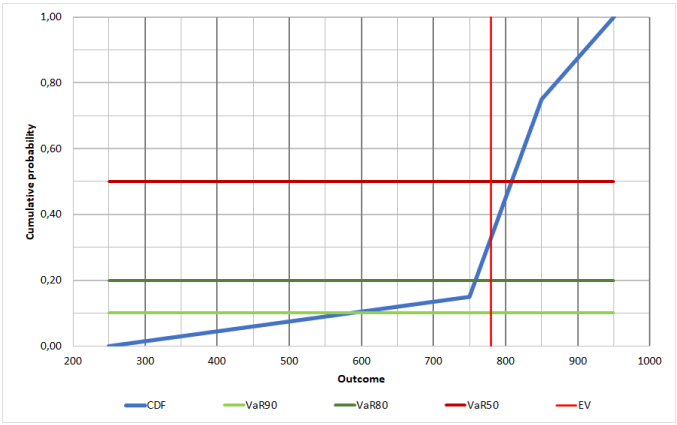

Figure no. 2 – Cumulative probability distribution (technique 1)

A second technique follows the view that the probabilities between the reference points (here: the point estimates of the three scenarios) follow the estimates in proportional sequence ('relative likelihood technique'). The estimates are regarded as likelihood assessments which fix the likelihood ratios between the reference points. The likelihood ratios of the intermediate values are gained by a linear interpolation between two likelihood assessments (Spetzler and Stael von Holstein, 1975; Stael Von Holstein and Matheson, 1978; Bonano *et al.*, 1990; Garthwaite *et al.*, 2005; Goodwin and Wright, 2014).

For implementing this technique, the bandwidth is divided in a high number of equal width intervals (here: 693 intervals) through which a granular calculation of likelihood ratios becomes possible. The probability distribution is gained by normalising the likelihood ratios to reach values between zero and one (Ludke *et al.*, 1977; Bonano *et al.*, 1990).

For the example in IFRS13.B25, the absolute lower limit is set (following the rationale described in technique 1) to CU250. The absolute upper limit is set to CU1354 in order to reach the identical expected value of CU780 as in IFRS13.B27. Four linear interpolations are realized: (a) between the absolute lower limit (CU250; likelihood ratio: 0) and the worst-case point estimate (CU500; likelihood ratio: 0.15), (b) the worst-case point estimate and the best-case estimate (CU800; likelihood ratio: 0.6), (c) the best-case estimate and the worst-case estimate (CU800; likelihood ratio: 0.25), (d) worst-case estimate and the absolute upper limit (CU1354; likelihood ratio: 0). Figure no. 3 shows the probability distribution derived, Figure no. 4 the cumulative probability distribution.

Assuming that market participants are expected to select a confidence level of 80% for the first period (percentile 20, VaR80), for the second a VaR85 (percentile 15), the third a VaR86 (percentile 14) and the fourth a VaR87 (percentile 13), then the net present value is reached by discounting the cash flow of CU613.9 (first year), CU575.7 (second year), CU566.1 (third year) and CU556.6 (fourth year) with the (constant) risk free interest rate of 0.05. The net present value is CU2,054 (when disregarding capital outlay).

As digression: the net present value following Method 2 is reached by discounting the expected value with a risk-adjusted interest rate. The net present value is equal to CU2,583 under the assumptions of a constant risk-adjusted interest rate of 0.08 and a constant probability distribution over the four periods (when disregarding capital outlay).

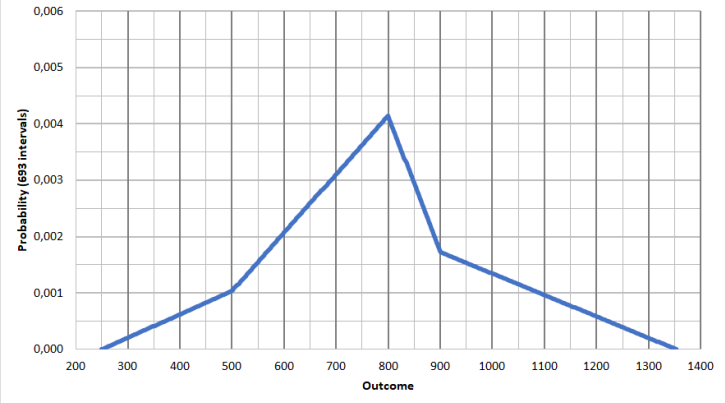

Figure no. 3 – Probability distribution (technique 2)

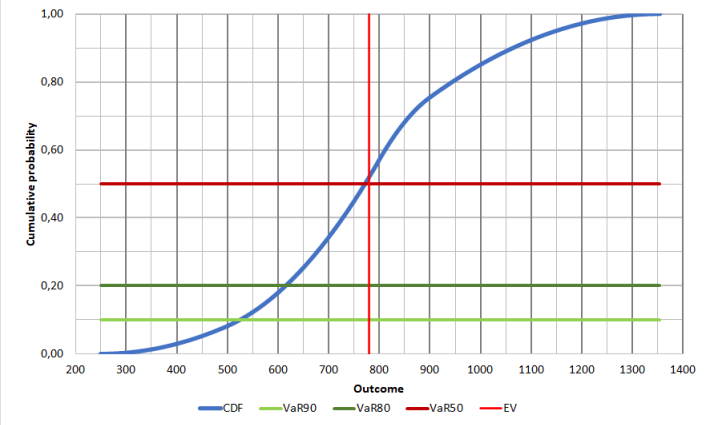

Figure no. 4 – Cumulative probability distribution (technique 2)

4. AN ATTEMPT TO DERIVE THE VALUES AT RISK FOR THE DETERMINED HISTORICAL CERTAINTY EQUIVALENT COEFFICIENTS

In order to interpret the derived certainty equivalent coefficients not only as historically observed safety margins on the expected value but also as indications of a Value at Risk, a simulation study is conducted. The study follows the rational outlined in Section 1. Under the premise that a certainty equivalent is represented by a Value at Risk with a certain confidence level, the confidence level of the value at risk for a certainty equivalent can conversely be determined from a probability distribution. In the derivation of the Values at Risk for the calculated historical certainty equivalence coefficients, it is assumed that the yields on corporate bonds are based on an investor's assessment of the company's possible income and expenses (IFRS Foundation, 2022b).

The modelling is based on the following framework conditions: (a) The median of the probability distribution has to be either identical with the expected value (a symmetrical distribution) or has to be left of the expected value (a right skewed probability distribution). The latter is because, in the case regarded, higher numerical values represent more favourable values. In a left skewed probability distribution, the median lies to the right of the expected value. This would mean the Value at Risk with the lowest confidence level (VaR50) would indicate a more favourable outcome than the expected value. From this would follow a negative cash risk premium, a situation that is incompatible with Method 1, in which the risk-adjusted expected cash flows always have a lower value than the expected cash flows (IFRS13.B25). Therefore, a right skewed probability distribution is chosen, meaning that the expected value is situated right to the median and is representing a Value at Risk with a confidence level of less (and not higher) than 50%.

(b) The probability distributions must be calibrated to the left of the expected value, as this side is decisive for deriving a Value at Risk in the case regarded (higher numerical values represent more favourable outcomes). For calibration, the recommendation of the European Central Bank from May 2015 is taken to put a valuation haircut on company bonds of 30% from the market value if these are accepted as security (European Central Bank, 2015; European Union, 2024). That safety margin is interpreted as (the Bank's) certainty equivalent

coefficient of the company's possible income and expenses, representing a VaR99 (percentile1) or a VaR95 (percentile5), following Jorion (2007, p. 119).

Based on these considerations, four distributions are modelled: (a) normal distribution with the valuation haircut (CEC= 0.7) at percentile 1 (Study 1), (b) normal distribution with the valuation haircut (CEC= 0.7) at percentile 5 (Study 2), (c) lognormal distribution with the valuation haircut (CEC= 0.7) at percentile 1 (Study 3), (d) lognormal distribution with the valuation haircut (CEC= 0.7) at percentile 5 (Study 4).

The normal distribution represents a situation that the market participants consider both a favourable and an unfavourable deviation to be equally likely. The selection of the lognormal distribution follows studies in which the variability of cost variations in major acquisition projects were modelled (Garvey *et al.*, 2012; Lee *et al.*, 2012; Kasprik, 2024). It represents a situation that the market participants consider a variability on the favourable side (higher values) as more likely than on the unfavourable side.

Regarded is a bandwidth between 0-times the expected value and 2-times the expected value with the expected value reaching the numerical value of one, so that the x-values left to the expected value represent the certainty equivalent.

The normal distribution is derived from a (0;1)-standard normal distribution, discretised in 969 equal width intervals, by varying the z-value to reach the desired percentile at the 340th interval representing the value 0.7-times the expected value when transforming the z-values between zero and two. The functional values are normalized to represent a probability distribution.

The lognormal distribution is derived from iteratively adjusting the scale parameter alpha and the shape parameter sigma after discretising the bandwidth in 1000 equal width intervals so that the input value of one is equal to the expected value as well as the cumulative probability of the input value of 0.7 is either 0.01 (Study 3) or 0.05 (Study 4). The functional values are normalized to represent a probability distribution.

The derivation of the probability distributions is done by support of Microsoft Excel Professional Plus 2021.

Annex 2 gives the distribution parameters as well as selected location parameters of the modelled distributions. The certainty equivalents for VaR50, Var60, VaR70, VaR80, and VaR90 are displayed in Table no. 2. Figure no. 5 and Figure no. 6 graphically show the modelled probability distributions.

Table no. 2 – Certainty equivalent coefficients for different Values at Risk

	Normal (Study 1) Valuation haircut (CEC= 0.7) at P1	Normal (Study 2) Valuation haircut (CEC= 0.7) at P5	Lognormal (Study 3) Valuation haircut (CEC= 0.7) at P1	Lognormal (Study 4) Valuation haircut (CEC= 0.7) at P5
CEC VaR50	1.0000	1.0000	0.9895	0.9795
CEC VaR60	0.9670	0.9546	0.9535	0.9295
CEC VaR70	0.9319	0.9051	0.9155	0.8796
CEC VaR80	0.8927	0.8473	0.8736	0.8256
CEC VaR90	0.8349	0.7668	0.8176	0.7536

5. ANALYSIS AND DISCUSSION

The analysis concentrates on the extreme classes derived in Section 4: firstly, the class with the highest certainty equivalent coefficients observed, which solely contain AAA-rated bonds (class 1), and, secondly, the three lower classes, which solely contain the certainty equivalent

coefficients of Baa-rated bonds in recession phases (class 9 to 11). The certainty equivalent coefficients of class 9 to 11 are aggregated, resulting in a weighted CEC-average of 0.9494.

Table no. 3 shows the Values at Risk for these certainty equivalent coefficients derived from the four simulations described in Section 4. Uniformly, the Values at Risk for AAA-rated bonds in class 1 lie above those of Baa-rated bonds in a recession phase. This result is explained that, in contrast to the Baa-rated bonds, in a situation where the financial stability and the market position of a company, and, further, the economic situation are assessed as favourable, a market participant sees the utility of possible outcomes as lying near the expected value (in class 1: 0.9932 times the expected value) and therefore accepts a Value at Risk with a confidence level of about 50%.

However, the derived Values at Risk for the aggregated group of Baa-rated bonds yields in a recession phase (the weighted mean of the classes 9 to 11) are also between VAR56 and VaR65 and appear to be at a rather low level (see Table no. 3), especially when taking into account that the certainty equivalents coefficients with a value of lower than 0.9661 (class 7) represent outliers (see Table no. A1 in Annex 1).

Table no. 3 – Values at Risk of the certainty equivalent coefficients derived for the outer classes of AAA- and Baa-rated corporate bonds

	Normal (Study 1) Valuation haircut (CEC= 0.7) at P1	Normal (Study 2) Valuation haircut (CEC= 0.7) at P5	Lognormal (Study 3) Valuation haircut (CEC= 0.7) at P1	Lognormal (Study 4) Valuation haircut (CEC= 0.7) at P5
Class 1 (CEC: 0.9932)	VaR52	VaR51	VaR49	VaR47
Mean of classes 9 to 11 (weighted) (CEC: 0.9494)	VaR65	VaR61	VaR61	VaR56
First Outlier (left side) (CEC: 0.9661)	VaR60	VaR57	VaR56	VaR52

To get an impression whether the Values at Risk derived for Baa-rated bond yields in a recession phase might be regarded as less representative for corporate bonds rated as riskier investment, a further estimation, then regarding U.S. high-yield bonds, is realised. Chosen is the ICE BofA index (FRED, 2024). The index gives the spreads between a computed option-adjusted spreads index of U.S. bonds that are below investment grade (rated BB or below) and a spot treasury curve on daily basis. As comparison standard, the market yields on U.S. treasury securities at 10-year constant maturity (FRED, 2025c) are chosen.

The option-adjusted spreads indicate the interest rate premium and cannot be regarded as the risk-adjusted interest rate (the sum of the interest rate premium and the risk-free interest rate), necessary for applying formula (6). Therefore, on daily basis, the corresponding market yields on U.S. treasury securities (representing risk-free interest rate) are added to the U.S. high-yield bonds option-adjusted spreads, for getting an indication of the risk-adjusted interest rate. Based on this transformation, the certainty equivalent coefficients are calculated from formula (6).

Regarded are 6,900 data points from 1996-12-31 up to 2024-08-15. The certainty equivalent coefficients gained as well as location parameters of the CEC-frequency distribution are given in Annex 3.

In contrast to the results gained by regarding AAA- and Baa-bond yields, a relationship of the certainty equivalent coefficients to a recession phase (following the definition of FRED (2025a, 2025b)) could not be observed: in the recession 2001-03-01 to 2001-11-01 the averaged CEC is 0.9258, in the recession 2007-11-30 to 2009-06-02 the averaged CEC is 0.9022, and in the recession 2020-01-31 to 2020-04-01 the averaged CEC is 0.9441.

For this reason, the Values at Risk for the first outlier on the left side as well as the second quartile of the CEC-frequency distribution are taken for checking the plausibility. The Values at Risk of the first outlier on the left side, reaches considerably higher values between 64 % (lognormal distribution with valuation haircut at P5) and 76% (normal distribution with valuation haircut at P1) (see Table no. 4) than the Values at Risk derived for Baa-rated bonds in a recession phase (mean of classes 9 to 11: VaR56 to VaR65; see Table no. 3). The Values at Risk of the second quartile (VaR54 to VaR62; see Table no. 4) are in nearly the same range of the Values at Risk derived for Baa-rated bonds in a recession phase.

The results are interpreted that they support the results gained in Study 1 to 4.

Table no. 4 – Values at Risk of the certainty equivalent coefficients derived for CEC-quartiles of U.S. high-yield bonds

	Normal (as in Study 1) Valuation haircut (CEC= 0.7) at P1	Normal (as in Study 2) Valuation haircut (CEC= 0.7) at P5	Lognormal (as in Study 3) Valuation haircut (CEC= 0.7) at P1	Lognormal (as in Study 4) Valuation haircut (CEC= 0.7) at P5
First outlier (left side) (CEC: 0.9077)	VaR76	VaR69	VaR71	VaR64
First quartile (P25) (CEC: 0.9426)	VaR67	VaR62	VaR62	VaR57
Second quartile (P50) (CEC: 0.9570)	VaR62	VaR59	VaR58	VaR54
Third quartile (P75) (CEC: 0.9658)	VaR60	VaR57	VaR56	VaR52

A second supplementary study is conducted to scrutinise the assumption in Study 1 and Study 3 that the certainty equivalent coefficient of 0.7 stands for a VaR99 and the assumption in Study 2 and Study 4 that the certainty equivalent coefficient of 0.7 stands for a VaR95. Analysed is the case that the investors have had regarded the certainty equivalent coefficient of Moody-Baa-rated bond yields in a recession phase (0.9494, the mean of classes 9 to 11; see Table no. 3) as Value at Risk with a confidence level of 80% - following the recommendation in project budgeting (see Section 1).

Therefore, the parameters of the normal (analysis 1) and lognormal (analysis 2) distribution are modelled so that the distributions' x-value of 0.9494 corresponds to percentile 20 (the VaR80). The parameters are given in Annexes.

The then derived Values at Risk for the certainty equivalent coefficients of Moody-AAA-rated bond yields (0.9932 in class 1; see in Table no. 1) are, as expected, laying above those derived in Study 1 to 4 (see Table no. 3) but still within a plausible range: In analysis 1 (normal distribution) VaR54 is gained, in analysis 2 (lognormal distribution) VaR53.

However, this possible assumption is contradicted by the extreme skewness of the probability distributions derived in analysis 1 as well as in analysis 2 (see Figure no. 5 and Figure no. 6). The probability distributions' coefficients of variation (normal distribution: 0.057, lognormal distribution: 0.058) are fare below analogues studies in which the variation

of expected and reached outcomes are analysed. There, coefficients of variation between 0.15 and 0.45 are reported and considered plausible (Thomas and Fitch, 2014). It is to mention that the coefficient of variations in Study 1 to 4 approximately lay within this range (Study 1: 0.1282, Study 2: 0.1813, Study 3: 0.1490, Study 4: 0.2053), indicating a plausible modelling.

Based on these analyses, it is concluded that a confidence level between 60% (based on the CEC of classes 9 to 11 in Study 1 to 4) and 75% (based on the CEC of the first outlier on the left side in the supplementary study; see Table no. 4) can be regarded as the upper level of the market participants' expectations with regard to the non-diversifiable risk to be compensated.

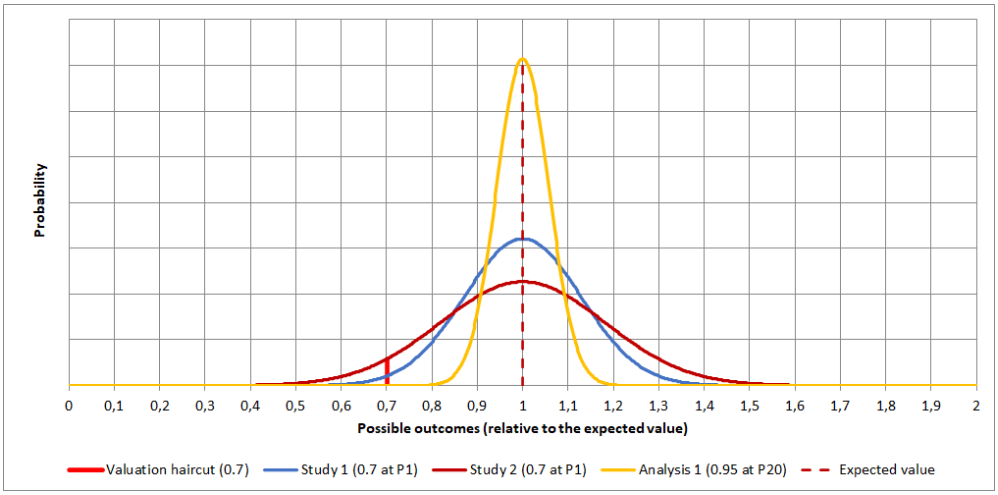

Figure no. 5 – The normal probability distributions modelled

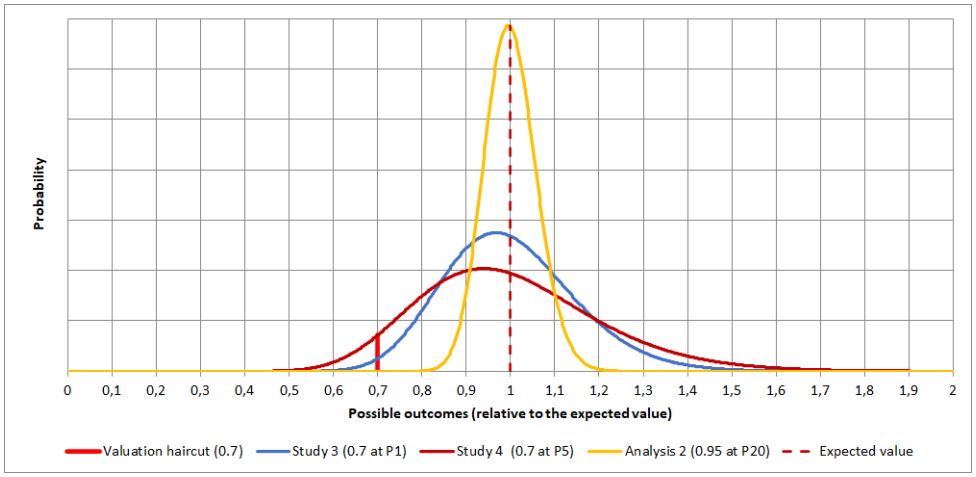

Figure no. 6 – The lognormal probability distributions modelled

It is to mention that if Values at Risk with confidence levels of above 80% might be requested or accepted then, following this analysis, relative safety margins on the expected value from 11 to 17% (VaR80; see Table no. 2) and from 17% to 25 % (VaR90; see Table no. 2) would be the consequence. In the author's view, this deviates drastically from the relative safety margin of 5% derived for Baa-rated bonds in a recessionary phase, which already are far outside the interquartile range: more than three times the interquartile range below the first quartile.

6. CONCLUDING DISCUSSION

The results suggest that a certainty equivalent which represents a confidence level between 60 and 75% should be accepted and/ or requested when deriving a fair value applying Method 1 of expected present value techniques. The certainty equivalents derivable from historic interest rate premiums of corporate bonds yields rated as AAA, Baa or below investment grade can be attributed to Values at Risk with a certainty level of 60 to 75%. This result is based on theoretical considerations, and, therefore, must be interpreted as starting point for further research interrogating the modelled probability distributions.

If one follows the opinion that the modelled probability distributions give a realistic view, then one could nevertheless take the view that the confidence levels derived in the studies are unrealistically low (in comparison to the expectations formulated in risk management practice, see Section 1).

A first explanation could be that market participants had diversified their investment, had regarded the systematic (i.e., market) risk as low and had, therefore, accepted a low confidence level.

A second explanation could be: Market participants have had derived their certainty equivalent not solely on regarding possible future income and expenses (resp. cash flows), but also on other benefits which were not incorporated in the monetary quantified possible outcomes (following Fioretti (2012)). Should this be the case, however, the income approach itself would be questionable: formally, market participants include all benefits in the possible but uncertain cash flows resp. income and expenses (IFRS Foundation, 2022b).

A third explanation could be that the observed low confidence levels would have been caused by the risk-measure Value at Risk itself. The risk-measure Value at Risk evaluates possible but uncertain outcomes by solely regarding the most unfavourable outcome of the group of outcomes which is defined by their cumulative probability of occurrence (determined by the selected confidence level), if all outcomes are considered in ascending order of advantage. No utility is ascribed to the outcomes which are more favourable and which are less favourable than the Value at Risk.

This explanation also cannot be ruled out. However, if one follows this explanation, then one has to accept a lower degree of transparency if an entity applies Method 1: neither a granular cumulative probability distribution nor the confidence level must be disclosed (see Section 3).

Based on this discussion, the author sees the need for further empirical studies analysing market expectations when investors invest in bonds of different risk classes. A frequency distribution of the belief as to whether the investor's plan will underperform, outperform or exceed the plan could help to verify the estimated probabilities for both Method 1 and Method 2. In addition, this could lead to a revision of the assumption used in this study that a confidence level of 50 % (the median) must be equal to or lower than the expected value (see Section 4).

As a side note, the author interprets the results as an indication of the question raised in the literature of how to quantify a decision that is 'more likely than not' (Bohušová *et al.*, 2014) or 'about as likely as not' (Mastrandrea *et al.*, 2010) to lead to the planned outcome or that is 'reasonably certain' to lead to the planned outcome (IFRS Foundation, 2024). He suggests that a distinction in relation to the risk measure Value at Risk is not possible if the decision is based on possible future cash flows or income and expenses. Values at risk with a confidence level of 60 to 75% describe the prevailing degree of certainty from a market perspective.

7. SUMMARY

The study raised the point to elicit thresholds for certainty equivalents when assessing the fair value with Method 1 of the present value techniques within the methodology of income approaches (the certainty equivalent method). Through applying the risk-measure Value at Risk as indicator for certainty equivalents, it is tried to utilise experience from risk management practice.

In order to come to an assessment of the expectations of market participants, the certainty equivalents of investors in corporate bonds were calculated from Moody-AAA- and of Moody-Baa-rated U.S. corporate bond yields to U.S. treasury securities at 10-year constant maturity. For scrutinising the results, an own estimation of bond yields of ICE-rated U.S. high-yield bonds to the market yield on U.S. treasury securities at 10-year constant maturity was realised.

The results show that in case of the Moody-AAA- and of Moody-Baa-rated U.S. corporate bond yields in the time span analysed (1996-2024) the lowest certainty equivalent coefficients were observed for Baa-rated bonds in a recession phase: 0.9459 (weighted average). This corresponds to a rounded relative safety margin of 5% on the expected value. In case of the ICE-rated U.S. high-yield bonds regarded (1997-2024) the certainty equivalent coefficient of the second quartile reaches a similar magnitude: 0.9570, a remarkable difference is observable at the first outlier (minus 1.5-times the interquartile change from the first quartile): CEC: 0.9077 (a relative safety margin of 9% on the expected value).

The author attempted to interpret the observed certainty equivalent coefficients as Value at Risk with a confidence level corresponding to the certainty equivalent coefficients observed. Four studies und two supplementary analyses led to the result that a confidence level between 60% (Baa-rated bonds in a recession phase between 1996-2024) and 75% (first outlier-observation in ICE-rated U.S. high-yield bonds between 1997-2024) can be regarded as the upper level for the expectations of market participants with regard to the non-diversifiable risk to be compensated.

The proposition in risk management practice, to utilize a confidence level of 80% or higher when evaluating possible but uncertain outcomes, is not supported by this study and cannot be assessed as the market participants' confidence level.

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ANNEX 1
MOODY-AAA- AND MOODY-BAA-RATED BOND YIELDS

Table no. A1 – Location parameters of the CEC-frequency distribution

	CEC
Percentile1	0.9641
First outlier (-1.5 times the IQR from P25)	0.9661
First quartile (P25)	0.9792
Median (P50)	0.9837
Third quartile (P75)	0.9879
Percentile99	0.9940
"Outlier" (Percentile100; +1.068 times the IQR from P75)	0.9972
Average	0.9830

IQR: Interquartile range

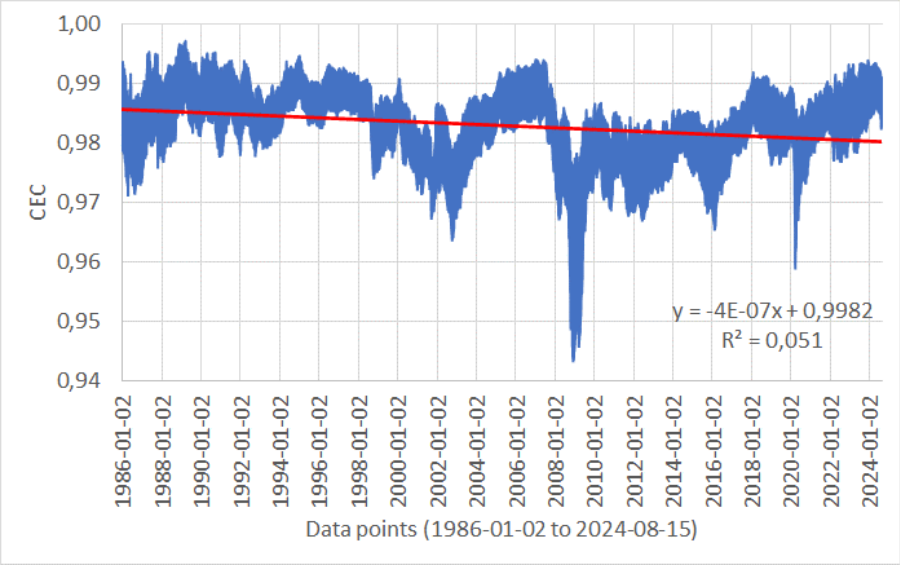

Figure no. A1-1 – Certainty equivalent coefficients of AAA- (upper limit) and Baa-rated (lower limit) U.S. corporate bond yields from 1986-01-02 to 2024-08-15

Table no. A2 – Distribution parameters of the normal probability distributions

	Study 1: Valuation haircut (CEC= 0.7) at percentile1	Study 2: Valuation haircut (CEC= 0.7) at percentile5
z-value (+ / -)	7.8001	5.5151
Mode	1.0000	1.0000
Median (P50)	1.0000	1.0000
Expected value	1.0000	1.0000
Coefficient of Variation	0.1282	0.1813
Yules Coefficient of Skewness	0.0000	0.0000

Table no. A3 – Location parameters of the normal probability distributions

	Study 1: Valuation haircut (CEC= 0.7) at percentile1	Study 2: Valuation haircut (CEC= 0.7) at percentile5
Percentile1	0.7007	0.5789
First quartile (P25)	0.9133	0.8782
Median (P50)	1.0000	1.0000
Third quartile (P75)	1.0867	1.1218
Percentile99	1.2972	1.4211

Table no. A4 – Distribution parameters of the lognormal probability distributions

	Study 3: Valuation haircut (CEC= 0.7) at percentile1	Study 4: Valuation haircut (CEC= 0.7) at percentile5
Scale parameter alpha	0.9891	0.9797
Shape parameter sigma	1.1597	1.2261
Mode	0.9675	0.9395
Median (P50)	0.9895	0.9795
Expected value	1.0000	1.0000
Coefficient of Variation	0.1490	0.2053
Yules Coefficient of Skewness	0.0505	0.0667

Table no. A5 – Location parameters of the lognormal probability distributions

	Study 3: Valuation haircut (CEC= 0.7) at percentile1	Study 3: Valuation haircut (CEC= 0.7) at percentile5
Percentile1	0.7017	0.6097
First quartile (P25)	0.8956	0.8536
Median (P50)	0.9895	0.9795
Third quartile (P75)	1.0935	1.1234
Percentile99	1.3953	1.5712

ANNEX 2
U.S. HIGH-YIELD-RATED BONDS

Table no. A6 – Certainty equivalent coefficients for yields of U.S. high-yield bonds to the market yield on U.S. treasury securities at 10-year constant maturity (1986-01-02 to 2024-08-15)

	CEC (group average)	Relative frequency
Class 1	0.9691	0.3267
Class 2	0.9574	0.3236
Class 3	0.9433	0.1722
Class 4	0.9297	0.1113
Class 5	0.9163	0.0357
Class 6	0.9044	0.0080
Class 7	0.8887	0.0029
Class 8	0.8710	0.0029
Class 9	0.8606	0.0107
Class 10	0.8461	0.0033
Class 11	0.8327	0.0028

Table no. A7 – Location parameters of the CEC-frequency distribution

	CEC
Percentile1	0.8596
First outlier (-1.5 times the IQR from P25)	0.9077
First quartile (P25)	0.9426
Median (P50)	0.9570
Third quartile (P75)	0.9658
Percentile99	0.9762
"Outlier" (Percentile100; +0.5036 times the IQR from P75)	0.9776
Average	0.9516

IQR: Interquartile range

ANNEX 3
COUNTER-CHECK OF THE STUDY'S PROBABILITY DISTRIBUTIONS

Table no. A8 – Distribution parameters of the probability distributions under the condition that the CEC of Baa-rated bonds (0.9494) corresponds with VaR80

	Analysis 1: Normal distribution	Analysis 2: Lognormal distribution
Scale parameter alpha		0.9983
Shape parameter z resp. sigma	17.3517	1.0600
Mode	1.0000	0.9955
Median (P50)	1.0000	0.9975
Expected value	1.0000	1.0000
Coefficient of Variation	0.0576	0.0583
Yules Coefficient of Skewness	0.0000	0.0256

Table no. A9 – Location parameters of the probability distributions under the condition that the CEC of Baa-rated bonds (0.9494) corresponds with VaR80

	Analysis 1: Normal distribution	Analysis 2: Lognormal distribution
Percentile1	0.8658	0.8716
First quartile (P25)	0.9608	0.9595
Median (P50)	1.0000	0.9975
Third quartile (P75)	1.0392	1.0375
Percentile99	1.1342	1.1434

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Testing Semi-Strong Market Efficiency for Leading Altcoins

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Abstract: This study probes semi-strong market efficiency in leading altcoins by examining how various regulatory and international events impact the daily returns of altcoins. We aspire to contribute valuable insights into the behavior of altcoins market in response to external stimuli, highlighting the implications for investors and market analysts in the rapidly evolving landscape of digital currencies. Several events over the period of 2018 to 2024 are considered categorized in two distinct groups namely, crypto-regulatory events and international events, ranging from outbreak of global pandemics, geo-political events and wars, including COVID-19 waves, vaccines authorizations, imposition of lockdowns, BREXIT post 2018, US withdrawal from Afghanistan, Russia-Ukraine war and Israel-Palestine conflict. Subsequently the impact of these events on the daily returns of five leading altcoins is assessed using the Auto-Regressive Component GARCH-Mean model. Altcoins have been responding to both positive and negative regulatory as well as international events. However, the significance of cumulative abnormal returns in the event window indicates signs of semi-strong market inefficiency. The findings provide new insights into the response of cryptocurrencies to various events at a global level, contributing to the understanding of market behavior and market efficiency, particularly, in the leading crypto-assets other than bitcoin. The findings can help altcoin investors devise trading strategies and build investment portfolios in an optimal manner, thereby minimizing the risks involved.

Keywords: altcoins; event study; semi-strong market efficiency; regulatory and international events.

JEL classification: G14; G15; E44.

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1. INTRODUCTION

Warren Buffet, CEO of Berkshire Hathaway, commented in 2014: "Stay away from bitcoin since it is a mirage. The idea that it has some huge intrinsic value is just a joke in my view" (Crippen, 2014). Nakamoto (2008) suggested a peer-to-peer payments system using blockchain technology that triggered a revolution in the field of digital currencies and paved way for an eccentric mode of investment later known to be as cryptocurrencies. Cryptocurrency is a very unique type of digital currency that functions without the monitoring of any central bank and uses encryption techniques to control creation of units of money and verify movement of funds (Kramer, 2019). The upsurge of the first ever cryptocurrency, bitcoin, has remained controversial since its inception. Bitcoin's startling price rise in late 2017 and the following collapse in the early 2018 demonstrated its extraordinary volatility and raised serious concerns among the investors about its utility as a store of value. Amidst all the apprehensions surrounding bitcoin volatility, there are over 13000 different cryptocurrencies listed on Coinmarketcap.com as of December 2024 (CoinMarketCap, 2024) showing a significant boom in this market since 2008. With all the abrupt swings in the cryptocurrency market, a strong debate concerning the market efficiency of cryptocurrencies and its susceptibility to form financial bubbles has erupted in the academia and the investment industry around the world. Hence, the question arises whether the cryptocurrency market can be deemed efficient and to what degree.

Fama (1970) asserted that markets follow a random walk model and are fully efficient, meaning that the current prices fully reflect all available information about a security which follows that the future returns cannot be predicted based on the past returns; Hence, the return series follows a random walk. According to Fama (1970), there are three levels of market efficiency: weak, semi-strong, and strong. In the weak form efficiency, past data on financial assets cannot be used to forecast future asset prices, therefore, technical analysis is useless for forecasting the prices of an asset in the future; Publicly available information, according to semi-strong efficiency, is immediately reflected to the present price and is therefore useless for projecting future prices. According to strong form efficiency, market price adjustment is incredibly frictionless and responsive to any type of information, therefore, even private information like insider information has no relevance in forecasting the future price.

Lengyel-Almos and Demmler (2021) systematically reviewed and analyzed 25 highly ranked journal articles to determine whether bitcoin market meets the prerequisites of an efficient market as per Eugene Fama's ground breaking Efficient Market Hypothesis (EMH) and concluded that academicians and financial professionals have not been able to come to an agreement on the market efficiency of bitcoin; However, a significant number of papers refute the EMH, also leading to the conclusion that speculative bubbles are likely to be formed in the bitcoin market.

Bitcoin values are so volatile that using them as a unit of account is impractical and worthless for communicating pricing, which is typically a basic characteristic of any type of money (Lengyel-Almos and Demmler, 2021). The extreme volatility in cryptocurrency can be witnessed by looking at its eccentric swings in the last few years. For example, bitcoin's price went from around 800 USD in early 2017 to over 19,000 USD by the end of the year before falling to 6,300 USD in February 2018. Prices again rose dramatically in the second half of 2020, from around 5,000 USD in March to over 40,000 USD by February 2021, and then reach an all-time high of around 49,000 USD by the end of February 2021. As of December 31, 2023, the bitcoin price plummeted to 42,265 USD whereas as of December

31st, 2024, bitcoin was worth over 93,000 USD making a significant milestone in its history (CoinDesk, 2024). Such price swings are indeed unprecedented for any financial asset.

Investors are still split on whether cryptocurrencies are financially sound investments or merely speculative assets, thereby necessitating further academic study on this topic. Despite the fact that the impact of cryptocurrencies on the world economy has been instrumental, there is a dearth of conclusive empirical studies on the topic. Cryptocurrencies are considered to be a controversial investment avenue, particularly in a developing country, like Pakistan, where it has not been yet accepted as one of the legal tenders by the regulators or even a viable investment avenue by the masses. According to The Federation of Pakistan Chambers of Commerce & Industries (2021), the use of cryptocurrencies in Pakistan has accelerated in recent years, and the nation is currently ranked third in the Global Crypto Adoption Index for 2020–21. Pakistan recorded a value of cryptocurrencies of roughly $20 billion, a 711 percent extraordinary rise in 2020-21. Nevertheless, the State Bank of Pakistan in 2018 urged the general public to avoid investing in cryptocurrencies because of its abnormally high price volatility.

Determining as to what extent cryptocurrency markets are efficient could help investors devise their trading strategies and build investment portfolios in an optimal manner. In order to achieve the aforesaid objective, this study attempts to test the market efficiency of cryptocurrencies. However, majority of the studies relating to market efficiency of cryptocurrencies in the last few years have centered around the weak form of efficiency and the results have been of varying nature. Moreover, majority of the market efficiency research on cryptocurrency has focused on bitcoin. Other cryptocurrency coins, referred to as altcoins, have been scarcely studied in this context. Altcoins have grown significantly in size and volume in the last few years with the market capitalization of almost half of the entire global crypto market (see Table no. 1). We aim to test market efficiency (other than weak-form) in the leading altcoins. We select five leading altcoins by market capitalization including, Ethereum, XRP, BNB, Cardano and Dogecoin over the period of 2018 to 2024 whereas the same time period has been marred by significant events, such as Covid-19, whereby the whole world witnessed a standstill of unprecedented nature. Other than that, the US exit from Afghanistan, Brexit, Russia-Ukraine war, Israel-Palestine conflict along with various crypto-regulatory events, warrant that altcoins shall be tested for market efficiency with regards to both positive and negative news surrounding the aforesaid events.

Therefore, this study aims to bridge this research gap in the existing body of knowledge on cryptocurrencies by investigating the semi-strong market efficiency in altcoins while focusing on the most recent significant global events which have transformed the world we live in and impacted almost every sphere of our lives. The set of events have been systematically chosen for this study keeping in mind their presumed colossal impact on the digital currencies as per the media reporting and the fact that these specific set of events have not been examined by past studies in the context of crypto assets. Only those momentous events have been finely selected which have been comprehensively reported by almost all major news streams across the globe since 2018 (see Annexe for Table no. A1 and no. A2), thus further contributing effectively to the resolution of the identified research gap.

The rest of this paper is organized as such that Section 2 presents a brief literature review followed by methodology in Section 3 whereas Section 4 presents the findings and Section 5 concludes.

2. LITERATURE REVIEW, THEORETICAL UNDERPINNINGS AND HYPOTHESES DEVELOPMENT

It is hardly surprising that there have been an overwhelming number of articles written about EMH because it is one of the fundamental tenets of finance. The main outcome of the seminal theory of (Fama, 1970) is straightforward: Asset prices promptly take all new information into account and there is absence of any information asymmetries thus investors cannot expect to earn abnormal profits. However, empirical findings suggest that financial markets cannot be relied upon to act completely rationally; Instead, bubbles are likely to form under specific circumstances, which foster a climate conducive to reckless investing.

Multiple factors causing financial bubbles include, lower interest rates prevailing for a prolonged period of time, emergence of new technologies creating overly optimistic sentiments among investors, behavioral biases and an overall irrational exuberance manifested by investors (Dhar and Goetzmann, 2006; Shiller, 2015). Presence of speculative financial bubbles is one of the characteristics of market inefficiencies. Cryptocurrency markets have been showing similar characteristics of market inefficiencies for the last many years, including, excessive volatility, presence of financial bubbles, repetitive events of boom and bust (Lengyel-Almos and Demmler, 2021). The overall rise in the speculative activity in cryptocurrencies weakens the effectiveness of the portfolio diversification methods and increases the sensitivity of cryptocurrency markets to abrupt price changes (Katsiampa, 2017).

Bitcoin prices, according to Bartos (2015), react quickly to the release of public information. Additionally, it asserts that Bitcoin can be viewed as a typical economic asset whose price is determined by the interaction of market supply and demand and denies that exogenous macroeconomic factors affect Bitcoin's price. Cheah *et al.* (2018) conducted different rigorous statistical tests to gauge market efficiency of Bitcoin market and concluded that markets are "moderate to highly inefficient", consequently rejects the EMH. Investors can, therefore, take advantage of the predicted long-term memory in pricing and profit from speculation. Urquhart (2016) examined the market efficiency of Bitcoin using a number of credible tests, such as the VAR test, Ljung-Box test, Bartel's test, AVR test, BDS test, and Hurst exponent (R/S Hurst), and came to the conclusion that bitcoin returns are significantly inefficient across the entire sample. However, when the sample is divided into two subsample periods, some tests show that bitcoin is efficient between 2013 and 2016; It was, therefore, concluded that the Bitcoin market may be on its way to becoming efficient. Subsequently, using eight distinct tests, Nadarajah and Chu (2017) demonstrated that a straightforward power transformation of the bitcoin returns does indeed satisfy the weak form of EMH hypothesis. Only the tests for independence yield negative results, indicating moderately efficient markets; all other tests yield positive results.

In the absence of exogenous stimuli, Garcia *et al.* (2014) discovered two positive feedback loops in the bitcoin market: one driven by word of mouth and the other by new bitcoin adopters. It was determined that EMH is not applicable in bitcoin market because of positive feedback loops and asset bubble development. Cheung *et al.* (2015) examined whether bitcoin exhibits bubbles and busts using the PSY approach. It was identified that three significant and several minor bubbles occurred between 2010 and 2014, including the crash of the Mt Gox exchange. Hence, it is inferred that bitcoin cannot be regarded as an efficient market. By using econometric modelling to analyze bitcoin prices, Cheah and Fry (2015) came to the conclusion that the cryptocurrency displays speculative bubbles. The EMH

is therefore disproved. The writers also provided empirical support that bitcoin's intrinsic price is zero. Using the Detrended Fluctuation Analysis (DFA) test, Alvarez-Ramirez *et al.* (2018) examined long-range correlations and the informational efficiency of the Bitcoin market. They came to the conclusion that the market is not consistently efficient because anti-persistence of price returns appeared cyclically.

Using PWY and PSY models, Agosto and Cafferata (2020) looked into co-explosivity in crypto assets meaning whether the explosive behavior of one cryptocurrency causes the explosive behavior of other cryptocurrencies. They discovered significant relationships between the explosive behaviors of cryptocurrencies and discovered that the price dynamics of cryptocurrencies are highly interdependent among cryptocurrencies. Through these results, they essentially rejected the presence of EMH in five largest cryptocurrencies. Using the LPPL model, the VAR test, and the Granger causality test, Xiong *et al.* (2020) examined Bitcoin price cycles over a two-year period between 2017 and 2018 to examine the validity of the bubble theory. They used VAR and LPPL models to demonstrate that the Bitcoin bubble is dependent on production costs, and found that this approach had a high level of forecasting accuracy. They even predicted that the following Bitcoin bubble would occur at the end of 2020.

In the instance of the four biggest cryptocurrencies, Caporale and Plastun (2019) investigated price overreactions and the day of the week effect using a trading robot technique. They verified the existence of price trends following overreactions by using a number of parametric and nonparametric tests. The overreactions observed in the bitcoin market, however, do not present prospects for speculative profit-making. Hence, there was insufficient evidence to refute the existence of EMH. In their study of Bitcoin's semi-strong efficiency in the Bitstamp and Mt. Gox markets, Vidal-Tomás and Ibañez (2018) demonstrated how bitcoin responds to changes in monetary policy and other market-related events from 2011 to 2017. They employed GARCH-type models and came to the conclusion that bitcoin has become more responsive to its own market events over time. The semi-strong variant of EMH gets approved as a result. The results of this investigation also revealed that bitcoin is not impacted by news regarding monetary policy.

Comparable crypto-assets that are conditional on benchmarks and market segmentation were found to violate the weak-form market efficiency hypothesis of Koutsoupakis (2022). While the majority of market cap benchmark indices show positive excess returns at the end of the week, particularly on Friday and throughout the weekend, the majority of crypto-assets defy the Monday effect hypothesis. Using variance ratios, Nimalendran *et al.* (2025) evaluated the effects of liquidity and regulation on the efficiency of the cryptocurrency market, concentrating on crypto-assets with differing levels of control. The findings show that efficiency is increased and investor risks in crypto-assets are decreased when current regulatory standards are followed. Additionally, assets that voluntarily follow regulations can achieve the same level of efficiency as assets that are subject to government regulation.

With an emphasis on Bitcoin (BTC), Ethereum (ETH), Tether (USDT), and Binance Coin (BNB-USD), Mallesha and Archana (2024) examined the cryptocurrency market's efficiency. They employed the rolling window technique to determine if market efficiency is constant over time or fluctuates. The findings showed that, with the exception of USDT, the efficiency of the cryptocurrency market stays constant over time. The random walk hypothesis is supported by the results, which show that historical price fluctuations do not provide any indication of future prices. Hassanzadeh Tavakkol (2022) tested weak form of market efficiency on 8 altcoins by replicating previous studies while using new data set and concluded

that weak form of market efficiency mainly holds in the altcoin market and the results form the previous studies stand verified for different time-spans and assets.

Hypotheses

Based on the existing literature reviewed on the market efficiency of cryptocurrencies, it can be inferred that there is a lack of consensus amongst researchers as to whether cryptocurrency markets are efficient and to what extent. Moreover, the semi-strong efficiency in crypto-assets clearly seems to be much less explored than weak form of efficiency. There are a greater number of studies, however, that refute the existence of EMH in bitcoin. Studies relating to testing of market efficiency in altcoins are meagre despite the fact that the altcoins represent around half of the global crypto-market as per CoinMarketCap (2024). In order to achieve the aforesaid research objectives and based on the existing literature, this study, therefore, hypothesizes as follows:

H1*: The prices of the leading altcoins fully and fairly reflect all publicly available significant information relating to cryptocurrency regulatory events and, therefore, are semi-strong efficient.*

H2*: The prices of the leading altcoins fully and fairly reflect all publicly available significant information relating to international events and, therefore, are semi-strong efficient.*

3. METHODOLOGY

Semi-strong market efficiency can be typically tested using an event study since it is deemed to be an appropriate method to gauge how an asset returns are impacted by publicly available news (Abraham, 2021; Kang *et al.*, 2022; Krishnan and Periasamy, 2022). This study employs event study methodology, adapted from Vidal-Tomás and Ibañez (2018) and Feng *et al.* (2018), as the method to examine semi-strong form of efficiency in the altcoin market. We select publicly available significant events in the global economy from the time period 2018 to 2024 (See Table no. A1 and no. A2) and assess their impact on the altcoin returns using the aforesaid event study in order to determine whether crypto markets in altcoins are semi-strong efficient.

The most well-known cryptocurrency globally is indeed bitcoin and has the largest market capitalization of approximately 1.85 trillion USD as of December 31st, 2024 as per CoinMarketCap (2024). Nonetheless, bitcoin always makes the news but cryptocurrency alternatives to bitcoin known as "altcoins" have gained popularity in the last few years and there are hundreds of different choices available. In order to account for the potential variance in the semi-strong market efficiency of different cryptocurrencies, this study does not investigate bitcoin, like most studies in the past, but rather uses data of the 5 leading altcoins by market capitalization including, Ethereum, XRP, BNB, Cardano and Dogecoin. All these coins vary in their characteristics in terms of when they were created and who created them, therefore, it can be reasonably presumed that the dynamics of semi-strong market efficiency may be different in these coins and hence this study would also allow for comparative examination of semi-strong market efficiency of various altcoins. As of December 31, 2024, the total market capitalization of the selected altcoins as a % of all altcoins is 84% whereas the total market capitalization of the selected altcoins as a % of global crypto market is 40%; Hence, the sample of the five leading altcoins selected for this study, based on market

capitalization, is significantly a representative one. Market capitalization of the global crypto-market is further mentioned below in Table no. 1 as sourced from Coinmarketcap.com.

Table no. 1 – Approximate Market Capitalization of the Crypto-Market

Cryptocurrencies Market Cap in US$ as on December 31, 2024	
Global Crypto Market	3.5 trillion (100%)
Bitcoin	1.85 trillion (50.78%)
All Altcoins	1.65 trillion (49.22%)
Market Cap of the Sample of Selected Leading Altcoins in US$ as on December 31, 2024	
1. Ethereum	401 billion
2. BNB	101 billion
3. XRP	119 billion
4. Cardano	29.65 billion
5. Dogecoin	46.54 billion

We specifically use the global events of the last few years which were prima facie very significant ones considering the impact they have left on the global economy, including COVID-19 waves, Russia-Ukraine war, Brexit, US withdrawal from Afghanistan, Israel- Palestine war and cryptocurrency regulations around the world to carry out the event study which would help validate the hypothesis of semi-strong efficiency in altcoins. The database of events includes a total of 49 events: There are 19 events relating to cryptocurrency regulations and 30 events covering global affairs ranging from outbreak of global pandemics, geo-political events and wars. The international events have been taken from various sources as reported in the media while the crypto-regulation events have been sourced from coindesk.com (see appendix 1A & 1B). Events have been categorized as either positive or negative depending on the intrinsic nature of the events and their presumed impact on the asset prices.

The specific criteria for the selection of events are as follows: The events database composition method primarily follows the past studies that have employed event study in examining semi-strong market efficiency in crypto-assets (Feng *et al.*, 2018; Vidal-Tomás and Ibañez, 2018; Abraham, 2021). However, the specific events used in this study are unique per se, to the best of our knowledge. Since cryptocurrencies are considered to be global digital currencies as they are not regulated by the central bank of any country, the selection criterion mainly hinged upon the global impact of the events and is not confined to any specific country. The severity of the global impact was, therefore, determined by analyzing the news content as reported in the media. While the possibility of researcher bias in events selection cannot be entirely ruled out, efforts were made to ensure that the selection of events remained free from bias.

With the event study methodology employed in this research, it is assessed as to how the altcoins market reacts to certain events, characterized as either positive or negative, by quantifying their impact on the returns of the chosen currencies. Daily returns on the selective cryptocurrencies are used while applying natural log on prices at time t and $t-1$. Data of prices is extracted from Coinmarketcap.com, one of the most referenced price websites for crypto-assets. The dynamic behavior of the returns of the selected altcoins is modelled using Auto Regressive-Component Generalized Auto Regressive Conditional heteroskedasticity (AR-CGARCH) model while using the parallel events as independent variables.

The GARCH model is typically used when financial time-series data is heteroskedastic, which is usually the case, meaning the error term does not have a constant variance and zero mean (Engle, 2001). The component GARCH model is used in line with the recommendations

by Katsiampa (2017) who examined various GARCH models to determine the goodness-of-fit for volatility in bitcoin prices and proposed AR-CGARCH as the most suitable one. According to the standard GARCH model, conditional variance of the financial time series is determined by its own historical values and the previous squared residuals. On the other hand, financial time series frequently display more intricate patterns and can be impacted by other elements, including market trends, macroeconomic data, and other external factors. In order to better represent the underlying dynamics of the volatility, the Component GARCH model introduces extra components in order to overcome this restriction. Component GARCH model is, therefore, an extension of the traditional GARCH that is more suitable for capturing the time-varying volatility in financial time series data by breaking it down into different components (Katsiampa, 2017). The behavior of altcoins returns in this study is modeled using the equation given below:

Equation 1: Baseline Model

$$r_t = c + \beta_1 r_{t-1} + \beta_2 ne_t + \beta_3 pe_t + u_t ; \quad u_t = h_t z_t , \quad z_t \sim i.i.d\ (0, 1)$$
$$h^2_t = q_t + \alpha\ (u^2_{t-1} - q_{t-1}) + \gamma\ (u^2_{t-1} - q_{t-1})\ d_{t-1} + \varphi(h^2_{t-1} - q_{t-1}) \quad (1)$$
$$q_t = \omega + \rho\ (q_{t-1} - \omega) + \theta\ (u^2_{t-1} - h^2_{t-1})$$

where: r_t represents return on day t

ne_t represents the negative events on day t

pe_t represents the positive events on day t

u_t represents the error term

z_t represents white noise process

h^2_t represents conditional variance modelled through CGARCH equation

In the conditional variance, q_t represents the time-varying long-run volatility, γ represents the transitory leverage effects whereas d is the dummy variable that indicates the presence of negative shocks.

In CAR (-1,1), ne_t and pe_t are equal to 1/3 on days $t - 1$, t, and $t + 1$ respectively, and 0 for the remaining days, using AR_0, ne_t and pe_t are equal to 1 on the day of the event t and 0 for the remaining days. By examining the abnormal returns (AR) on the day of the event and the cumulative abnormal returns (CAR) across a 1-day timeframe, this study investigates the impact of each event. $AR_0/CAR_{(-1,1)}$ for negative events is represented by β_2, whereas $AR_0/CAR_{(-1,1)}$ for positive events is represented by β_3. Employing a larger event window could potentially make the results more robust (Hashemi Joo *et al.*, 2020; Abraham, 2021); However, due to the fact that a few events were overlapping, using an event window longer than three days has not been feasible in this study. Subsequently, the AR-CGARCH-M model is used in this study, and given its significance in each regression, the standard deviation of residuals $\sigma\ (u_t)$ with its associated coefficient (β_4) is added in the r_t equation.

3.1 Robustness checks

The findings are made more stringent by examining two specific scenarios, in line with Vidal-Tomás and Ibañez (2018) and using the baseline model (equation 1): In the first scenario (equation 2) the impact of each event is assessed on the time-varying long-run volatility, q_t, and in the second scenario, equation 3, the impact of each event is assessed on the transitory/short-run component, $h^2_t - q_t$. These additional statistical assessments should ensure the results are robust when subject to the evaluation on long-run and short-run volatility measures.

$$q_t = \omega + \rho\,(q_t - 1 - \omega) + \theta\,(u^2_{t-1} - h^2_{t-1}) + \beta_5\, ne_t + \beta_5\, pe_t \quad (2)$$

$$h^2_t - q_t = \alpha\,(u^2_{t-1} - q_{t-1}) + \gamma\,(u^2_{t-1} - q_{t-1})\, d_{t-1} + \varphi\,(h^2_{t-1} - q_{t-1}) + \beta_7\, ne_t + \beta\, pe_t \quad (3)$$

3.2 Calculation of abnormal returns

For the calculation of abnormal returns (AR_0), this study followed the market risk-adjusted returns model as prescribed by . This model is considered to be a superior one as compared to other simpler models, such as mean-adjusted returns model or market adjusted returns model, as it regresses assets returns (r_i) with the returns on the market index (r_m) as follows: $r_t = \alpha + \beta\, r_m$. The abnormal returns were then calculated using the equation, $AR_t = r_t - (\hat{\alpha} + \hat{\beta}\, r_{mt})$. For the market returns, this study uniquely used CRYPTO20 index returns.

Launched in December 2017, CRYPTO20 is the first tokenized cryptocurrency index fund in the world that tracks the performance of the top 20 crypto-assets by market capitalization (CoinMarketCap, 2024).

4. EMPIRICAL RESULTS AND DISCUSSION

4.1 Descriptive statistics

Table no. 2 reports the descriptive statistics of the daily log returns of the five leading altcoins. It can be observed that Dogecoin is the most volatile (largest Std. Dev.) as compared to other altcoins coins despite having the least market capitalization amongst the five selected coins. The least volatile amongst the five coins is Ethereum while having relatively the largest market capitalization. Kurtosis is significantly higher for all currencies indicating tendencies of leptokurtic distribution because of the volatility clustering that causes periods of high volatility followed by periods of low volatility as this can lead to a higher peak (more data around the mean) and fatter tails (more extreme deviations). Vidal-Tomás and Ibañez (2018) obtained similar results for kurtosis in bitcoin.

Table no. 2 – Summary Statistics of the Selected Alt Coins

	Ethereum	XRP	BNB	Cardano	Dogecoin
Mean	0.0005	-0.0004	0.0016	-0.0001	0.0014
Median	0.0005	-0.0008	0.0010	0.0000	-0.0008
Min	-0.5507	-0.5504	-0.5428	-0.5037	-0.5149
Max	0.2307	0.5486	0.5292	0.2794	1.5162
Std. Dev.	0.0465	0.0548	0.0497	0.0540	0.0701
Skewness	-1.0383	0.5053	-0.1589	-0.1309	5.3973
Kurtosis	11.7283	17.7666	16.9584	5.8028	107.6123

4.2 Model diagnostics

Table no. 3 below reports results of various statistical tests to determine the suitability of the data. Augmented Dickey-Fuller (ADF) test is performed on the daily returns to ascertain whether the data has a unit root. P-values of all five altcoins are significant, therefore, the data of the daily returns are stationary and devoid of a unit root; Hence the data is suitable for reliable modeling and predictions.

In order to determine whether the data of daily returns have ARCH effects present, Engle ARCH test was applied at five lagged values in line with . The significant p-values indicate that the financial time series exhibit ARCH effects and hence the data suffers from conditional heteroskedasticity at the pre-estimation phase as expected. The ARCH effect indicates volatility clustering since it amply demonstrates that there are times of low volatility followed by times of high volatility. At the post-estimation stage, in order to assess the adequacy of the estimated models of AR-CGRACH and AR-CGRACH-M on the data, ARCH (5) test is again applied and the goodness-of-fit of the chosen models is found to be appropriate and hence the white noise is established after fitting the model for all five alt coins.

Table no. 3 – ADF and Engle ARCH Tests:

Currency	ADF Test		ARCH(5) Test (Pre-estimation)		ARCH (5) Test (Post-estimation) AR-CGRACH		ARCH (5) Test (Post-estimation) AR-CGRACH-M	
	Test	p-value	Test	p-value	Test	p-value	Test	p-value
Ethereum	-12.144	0.01	55.211	0.000	6.626	0.107	5.839	0.127
XRP	-13.278	0.01	78.753	0.000	4.630	0.657	3.370	0.721
BNB	-12.306	0.01	130.21	0.000	7.289	0.070	7.037	0.080
Cardano	-11.890	0.01	80.274	0.000	7.290	0.218	4.559	0.211
Dogecoin	-12.472	0.01	46.021	0.000	1.610	0.791	1.145	0.701

4.3 Main results

During the estimation of the parameters for the base line equation, different ARMA(p,q) specifications were used but the best results were obtained from ARMA(1,0) or simply AR(1) process. Tables no. 4 and no. 5 below present this study's principal findings. The beta coefficients in Table no. 4 denote the effects of events on the returns as extracted from AR-CGARCH model for all five altcoins whereas Table no. 5 reports beta coefficients for the effects of events on the returns as extracted from AR-CGARCH-M model. In the AR-CGARCH-M model, the standard deviations of residuals are added $\sigma(u_t)$ with its corresponding coefficient (β_4) in the r_t equation. Although, this study aims mainly at testing semi-strong market efficiency by evaluating effects of several events on the altcoins returns, there are other related findings as well that Tables no. 4 and no. 5 indicate: β_1 coefficients for r_{t-1} in both Tables no. 4 and no. 5 are always significant and mostly at 1 percent significance level which in fact alludes to the weak form of inefficiency in altcoins which are similar to the findings of Palamalai *et al.* (2021). The significant β_1 values for the autoregressive returns of order 1 shows that the present returns are dependent on the past returns; Hence the weak form of market efficiency cannot be established as it is characterized by independence in returns as per Fama (1970).

This study evaluates the effects of events in two different categories, i.e., crypto-regulation events and international events. For all five altcoins investigated in this study, the beta coefficients are significant in Tables no. 4 and no. 5 for both on the day of the events (AR_0) and in the event window ($CAR_{(-1,1)}$), except for a few instances in table 4 only where the coefficients for positive news are insignificant. This may be due to the fact that an overwhelming number of events are indeed negative. Moreover, the coefficients are significant for both international and regulatory events. Therefore, it can be inferred from the

results of Tables no. 4 and no. 5 that all five altcoins have been responding to the events taking place on a global scale and in the regulatory domain.

Table no. 4 – AR-CGARCH Model: AR_0 and $CAR_{(-1,1)}$ Estimations

Currency	Crypto-Regulation Events			International Events	
	Variables	AR_0	$CAR_{(-1,1)}$	AR_0	$CAR_{(-1,1)}$
Ethereum	r_{t-1} , (β_1)	-0.501***	0.514***	-0.501***	0.513***
	n_{et} , (β_2)	0.403***	0.245*	0.309***	0.291***
	p_{et} , (β_3)	1.071	0.336	0.147***	0.088
XRP	r_{t-1} , (β_1)	-0.551***	0.554***	-0.549***	0.553***
	n_{et} , (β_2)	0.285**	0.210***	0.291**	0.286***
	p_{et} , (β_3)	-1.215	0.329*	0.096	0.355**
BNB	r_{t-1} , (β_1)	-0.493***	0.510***	-0.497***	0.513***
	n_{et} , (β_2)	0.497***	0.322***	0.200*	0.261***
	p_{et} , (β_3)	0.395**	-0.878**	0.118	0.142
Cardano	r_{t-1} , (β_1)	-0.499***	0.518***	-0.494***	0.514***
	n_{et} , (β_2)	0.369***	0.375**	0.329***	0.274***
	p_{et} , (β_3)	-0.237	0.218	0.112	0.214
Dogecoin	r_{t-1} , (β_1)	-0.544***	0.553***	-0.543***	0.551***
	n_{et} , (β_2)	0.500***	0.275**	0.264***	0.259***
	p_{et} , (β_3)	-0.569	0.368	0.160	0.137

Note: *** Significance at the 1% level; ** significance at 5% level; * significance at 10% level.

Table no. 5 – AR-CGARCH-Mean Model: AR_0 and $CAR_{(-1,1)}$ Estimations

Currency	Crypto-Regulation Events			International Events	
	Variables	AR_0	$CAR_{(-1,1)}$	AR_0	$CAR_{(-1,1)}$
Ethereum	r_{t-1} , (β_1)	-0.525***	0.522***	-0.530***	0.523***
	n_{et} , (β_2)	0.364***	0.224***	0.309***	0.290***
	p_{et} , (β_3)	2.067***	0.140***	0.146***	0.088***
	$\sigma(u_t)$, (β_4)	1.032***	-0.030***	1.023***	-0.023***
XRP	r_{t-1} , (β_1)	-0.571***	0.544***	-0.565***	0.548***
	n_{et} , (β_2)	0.288***	0.215***	0.292***	0.297***
	p_{et} , (β_3)	-1.149***	0.335***	0.096***	0.367***
	$\sigma(u_t)$, (β_4)	1.023***	-0.022***	1.025***	-0.024***
BNB	r_{t-1} , (β_1)	-0.508***	0.515***	-0.509***	0.515***
	n_{et} , (β_2)	0.495***	0.320***	0.200***	0.264***
	p_{et} , (β_3)	0.413***	-0.838***	0.115***	0.147***
	$\sigma(u_t)$, (β_4)	1.013***	-0.014***	1.010***	-0.010***
Cardano	r_{t-1} , (β_1)	-0.540***	0.531***	-0.505***	0.513***
	n_{et} , (β_2)	0.367***	0.374***	0.329***	0.278***
	p_{et} , (β_3)	-0.228***	0.216***	0.108***	0.221***
	$\sigma(u_t)$, (β_4)	1.015***	-0.015***	1.013***	-0.013***
Dogecoin	r_{t-1} , (β_1)	-0.597***	0.570***	-0.565***	0.542***
	n_{et} , (β_2)	0.498***	0.272***	0.264***	0.267***
	p_{et} , (β_3)	-0.562***	0.356***	0.161***	0.143***
	$\sigma(u_t)$, (β_4)	1.019***	-0.021***	1.025***	-0.024***

Note: *** Significance at the 1% level; ** significance at 5% level; * significance at 10% level.

Table no. 6 – AR-CGARCH Model: AR0 and CAR(-1,1) Estimations: Long Run Volatility

Currency	Crypto-Regulation Events			International Events	
	Variables	AR_0	$CAR_{(-1,1)}$	AR_0	$CAR_{(-1,1)}$
Ethereum	r_{t-1} , (β_1)	0.000***	0.000	0.000*	0.000**
	n_{et} , (β_2)	0.000***	0.000	0.000	0.000
	p_{et} , (β_3)	0.096***	0.001***	0.000***	0.000***
	n_{et} , (β_5)	0	0	0	0
	p_{et} , (β_6)	0	0	0	0
XRP	r_{t-1} , (β_1)	0.000	-0.001***	0.000	-0.001***
	n_{et} , (β_2)	0.000	-0.001	0.001**	0.000
	p_{et} , (β_3)	0.048***	0.000	0.001***	-0.002
	n_{et} , (β_5)	0***	0***	0***	0
	p_{et} , (β_6)	0	0	0	0
BNB	r_{t-1} , (β_1)	0.000***	0.000	0.000***	0.000***
	n_{et} , (β_2)	0.000	0.000**	0.000	0.000*
	p_{et} , (β_3)	0.004***	-0.006***	0.001***	-0.001***
	n_{et} , (β_5)	0	0	0	0
	p_{et} , (β_6)	0	0	0	0
Cardano	r_{t-1} , (β_1)	0.000	0.000	0.000**	0.000**
	n_{et} , (β_2)	0.000	0.000	0.000	0.000***
	p_{et} , (β_3)	0.018***	0.006***	0.001***	-0.001**
	n_{et} , (β_5)	0	0	0	0
	p_{et} , (β_6)	0	0	0	0
Dogecoin	r_{t-1} , (β_1)	0.000	-0.002***	0.000	-0.002***
	n_{et} , (β_2)	0.001**	-0.001	0.000	-0.002***
	p_{et} , (β_3)	0.011***	-0.002	0.004***	-0.003***
	n_{et} , (β_5)	0***	0***	0***	0***
	p_{et} , (β_6)	0	0	0	0***

Note: *** Significance at the 1% level; ** significance at 5% level; * significance at 10% level.

Table no. 7 – AR-CGARCH-Mean Model: AR0 and CAR(-1,1) Estimations: Long Run Volatility

Currency	Crypto-Regulation Events			International Events	
	Variables	AR_0	$CAR_{(-1,1)}$	AR_0	$CAR_{(-1,1)}$
Ethereum	r_{t-1} , (β_1)	0.000***	0.000***	0.000**	0.000***
	n_{et} , (β_2)	0.000*	0.000***	0.000	0.000
	p_{et} , (β_3)	0.036***	-0.001***	0.000***	0.000***
	$\sigma(u_t)$, (β_4)	0.000***	0.000	0.000*	0.000
	n_{et} , (β_5)	0.000	0.000	0.000	0.000
	p_{et} , (β_6)	0.000	0.000	0	0
XRP	r_{t-1} , (β_1)	0.000	0.000***	0.000	0.001***
	n_{et} , (β_2)	0.003*	0.002	0.001*	0.002***
	p_{et} , (β_3)	-0.004	0.001	0.001***	0.000
	$\sigma(u_t)$, (β_4)	0.002***	0.000	0.002***	-0.001***
	n_{et} , (β_5)	0.000	0.000	0.000	0.000
	p_{et} , (β_6)	0.000	0.000	0	0***
BNB	r_{t-1} , (β_1)	0.000**	0.000	0.000	0.000***
	n_{et} , (β_2)	0.000	0.001***	0.000	0.000**
	p_{et} , (β_3)	0.000	-0.001	0.001***	-0.001***
	$\sigma(u_t)$, (β_4)	0.000*	0.000***	0.000	0.000
	n_{et} , (β_5)	0.000	0.000	0.000	0.000

	p_{et} , (β_6)	0.000	0.000	0	0
Cardano	r_{t-1} , (β_1)	0.000	0.000***	0.000	0.000
	n_{et} , (β_2)	0.000	0.000	0.000	0.000***
	p_{et} , (β_3)	0.017***	-0.006***	0.001***	-0.001**
	$\sigma(u_t)$, (β_4)	0.000	0.000	0.000	0.000
	n_{et} , (β_5)	0.000	0.000	0.000	0.000
	p_{et} , (β_6)	0.000	0.000	0	0
Dogecoin	r_{t-1} , (β_1)	0.000	0.002***	0.000	0.001***
	n_{et} , (β_2)	0.000	0.002**	0.002***	0.003***
	p_{et} , (β_3)	-0.003	0.004	0.001**	0.002*
	$\sigma(u_t)$, (β_4)	0.003***	-0.001***	0.003***	-0.001***
	n_{et} , (β_5)	0.000***	0.000***	0.000	0.000***
	p_{et} , (β_6)	0.000	0.000	0	0***

Note: *** Significance at the 1% level; ** significance at 5% level; * significance at 10% level.

Table no. 8 – AR-CGARCH Model: AR0 and CAR(-1,1) Estimations: Short Run Volatility

Currency	**Crypto-Regulation Events**			**International Events**	
	Variables	**AR_0**	**$CAR_{(-1,1)}$**	**AR_0**	**$CAR_{(-1,1)}$**
Ethereum	r_{t-1} , (β_1)	0.001	0.004	0.000	0.004*
	n_{et} , (β_2)	0.020*	0.036***	-0.002***	0.023
	p_{et} , (β_3)	1.155***	0.117***	0.030***	0.023
	n_{et} , (β_7)	0*	0***	0.000***	0.000***
	p_{et} , (β_8)	0	0	0.000	0.000
XRP	r_{t-1} , (β_1)	0.003	-0.046***	0.000	-0.049***
	n_{et} , (β_2)	0.026	-0.033*	0.049**	-0.033**
	p_{et} , (β_3)	0.849***	-0.048	0.023*	-0.035
	n_{et} , (β_7)	0	0	0.000	0.000
	p_{et} , (β_8)	0	0	0.000	0.000
BNB	r_{t-1} , (β_1)	-0.010***	0.000***	-0.011***	0.003
	n_{et} , (β_2)	-0.005	-0.011	-0.008	0.011
	p_{et} , (β_3)	0.007	-0.007	0.029**	-0.029
	n_{et} , (β_7)	0	0***	0.000	0.000
	p_{et} , (β_8)	0***	0***	0.000*	0.000
Cardano	r_{t-1} , (β_1)	0.003	-0.006**	0.001	0.013***
	n_{et} , (β_2)	0.031**	0.004	0.009	0.019***
	p_{et} , (β_3)	1.016***	-0.011	0.012	0.003
	n_{et} , (β_7)	0	0	0.000	0.000
	p_{et} , (β_8)	0	0	0.000	0.000
Dogecoin	r_{t-1} , (β_1)	0.006	-0.042	0.006	-0.042***
	n_{et} , (β_2)	0.019	-0.049	0.019	-0.049***
	p_{et} , (β_3)	0.011	-0.041	0.011	-0.041*
	n_{et} , (β_7)	0	0	0.000	0.000
	p_{et} , (β_8)	0***	0	0.000***	0.000

Note: *** Significance at the 1% level; ** significance at 5% level; * significance at 10% level.

Table no. 9 – AR-CGARCH-Mean Model: AR0 and CAR(-1,1) Estimations: Short Run Volatility

Currency	Crypto-Regulation Events			International Events	
	Variables	AR_0	$CAR_{(-1,1)}$	AR_0	$CAR_{(-1,1)}$
Ethereum	r_{t-1} , (β_1)	0.016***	0.020***	0.016***	0.019***
	n_{et} , (β_2)	0.011	0.006	0.005	0.019***
	p_{et} , (β_3)	-2.540***	0.013	-0.001	-0.007
	$\sigma(u_t)$, (β_4)	0.035***	0.007***	0.037***	0.005***
	n_{et} , (β_7)	0	0	0.000	0.000
	p_{et} , (β_8)	0	0	0.000**	0.000
XRP	r_{t-1} , (β_1)	0.025***	0.026***	0.026***	0.025***
	n_{et} , (β_2)	0.005	0.099***	0.045**	0.047***
	p_{et} , (β_3)	-0.282	0.011	0.018	0.010
	$\sigma(u_t)$, (β_4)	0.097***	-0.032***	0.097***	-0.029***
	n_{et} , (β_7)	0	0	0.000	0.000
	p_{et} , (β_8)	0	0	0.000	0.000
BNB	r_{t-1} , (β_1)	0.020***	0.025***	0.019***	0.024***
	n_{et} , (β_2)	-0.003	0.036***	0.011	0.023***
	p_{et} , (β_3)	0.002	-0.004	-0.002	-0.007
	$\sigma(u_t)$, (β_4)	0.048***	0.006*	0.047***	0.003
	n_{et} , (β_7)	0	0	0.000	0.000
	p_{et} , (β_8)	0	0	0.000	0.000
Cardano	r_{t-1} , (β_1)	-0.011***	-0.019***	0.007***	0.015***
	n_{et} , (β_2)	0.023*	0.003	0.026	0.035***
	p_{et} , (β_3)	-0.050	-0.001	0.000	0.005
	$\sigma(u_t)$, (β_4)	-0.049***	0.005*	0.042***	-0.014***
	n_{et} , (β_7)	0	0	0.000	0.000
	p_{et} , (β_8)	0	0	0.000***	0.000
Dogecoin	r_{t-1} , (β_1)	-0.022***	-0.033***	-0.015***	-0.032***
	n_{et} , (β_2)	-0.020	-0.038***	0.025	-0.060***
	p_{et} , (β_3)	0.033	-0.026	0.009	-0.035*
	$\sigma(u_t)$, (β_4)	-0.043***	-0.029***	-0.062***	0.012***
	n_{et} , (β_7)	0	0	0.000	0.000
	p_{et} , (β_8)	0	0	0.000	0.000

Note: *** Significance at the 1% level; ** significance at 5% level; * significance at 10% level.

If abnormal returns for the event day AR_0 and cumulative abnormal returns for the event window $CAR_{(-1,1)}$ for each altcoins are examined separately, the validity of semi-strong hypotheses can be tested. Significance of AR_0 shows that the altcoins is responding to the events on the day of the events occurring and the coin has generated abnormally high returns as compared to the risk-adjusted benchmark returns whereas significance of cumulative abnormal returns in the event window (-1, 1) shows that the effect of the event has lingered on throughout the event window and therefore the market has not absorbed the information relating to the event instantaneously; If it had, the cumulative abnormal returns would not have been significant (Benninga, 2014). Hence the presence of significant cumulative abnormal returns indicates semi-strong market inefficiency. As illustrated in Tables no. 4 and no. 5, all five altcoins can be said to have semi-strong market inefficiency with respect to the crypto-regulation events and international events. Therefore, the results do not support the hypothesized statements (see Table no. 10).

Furthermore, Table no. 6 to Table no. 9 state results for coefficients for events in terms of their long-term and transitory/short-term components as extracted from the component GARCH model employed in this study in line with Katsiampa (2017) and Vidal-Tomás and Ibañez (2018). The beta coefficients in these cases produce overall mixed results with some significant and some insignificant values. The size of the coefficients has also been reduced because of controlling for the effect of each event on the long-term and short-term components.

Table no. 10 – Results of Hypothesized Statements

Hypotheses	Supported / Not Supported
H1: The prices of the leading altcoins significantly reflect publicly available information relating to regulatory events and, therefore, are semi-strong efficient.	*Not Supported*
H2: The prices of the leading altcoins significantly reflect publicly available information relating to international events and, therefore, are semi-strong efficient.	*Not Supported*

5. CONCLUSION AND RECOMMENDATIONS

There has been a plethora of studies examining market efficiency of bitcoin in the last few years since cryptocurrencies have emerged as an alternate avenue for investors worldwide, however, whether it is a viable investment choice is a controversial matter. As cited in the literature review, majority of the studies have focused on testing weak form of efficiency in bitcoin using various statistical tests. However, bitcoin has become too expensive and almost out of reach for a regular investor and nevertheless its volatility has been unprecedented. A new range of different cryptocurrencies have therefore emerged on various platforms as an alternate to bitcoin, i.e., altcoins. There is a dearth of studies in the existing literature examining market efficiency of altcoins. This study contributes to the existing literature by evaluating semi-strong market efficiency of altcoins using event study methodology and taking post 2018 events in two unique segments. Moreover, Component GARCH model was used to assess the effect of events on altcoin returns since it was proven to be the best GARCH model in modelling volatility of cryptocurrencies as corroborated by Katsiampa (2017) and Vidal-Tomás and Ibañez (2018).

Five major altcoins were chosen for this study, considering their large market capitalizations. Results have revealed that all five altcoins have been responding to both crypto-regulation and international events. Significant cumulative abnormal returns in the selected event window of three-days show that the semi-strong market efficiency in altcoins overall cannot be validated. However, certain events chosen for this study were of unusual nature, such as outbreak of COVID-19 waves, therefore, one could argue that these events were so significant that the resulting abnormal returns could be prolonged and hence the persistence of abnormal returns even in the event window may not indicate semi-strong market inefficiency but rather a natural response to the nature of the events itself. Nevertheless, it is difficult to infer the same for all the events, as a result, this study concludes that semi-strong market efficiency is not prevalent in the altcoins market.

This study uniquely contributes to the existing literature on the market efficiency of altcoins, such as Abraham (2021); Abreu *et al.* (2022); Koutsoupakis (2022) taking a comprehensive set of recent global events in two distinct categories to probe the semi-strong

market efficiency. By exposing such a thorough spectrum of events to robust statistical tests, we provide an insight into the behavior of altcoin market in response to external stimuli and the ensuing results for market efficiency in the rapidly evolving landscape of digital currencies.

Furthermore, based on the results it is recommended that altcoin investors should diligently analyze the events occurring on a global scale and in the regulatory domain in order to earn extraordinary returns as these events appear to have a significant impact on the altcoin returns and the same is not instantaneously reflected in the prices. Since r_{t-1}, (β_1) coefficients were also significant, indicating weak-form market inefficiency, altcoin investors can also analyze past returns to beat the market. Therefore, engaging in fundamental as well as technical analysis is not going to be a futile exercise for altcoin investors. Furthermore, the policymakers should remain wary of their actions with respect to the imposed regulations since crypto-regulation events have a significant bearing on the altcoin returns and this market has not achieved sufficient semi-strong or even weak market efficiency thus far.

Based on the empirical results, following policy implications are further suggested: There is a space for further improvement with regard to transparency in the altcoin market to ensure that any pertinent information is disclosed uniformly and promptly. Some mechanism relating to market surveillance could be put into place to prevent market manipulation. Government and regulators should develop educational programs to guide retail investors on how to perform a risk assessment while investing in cryptocurrencies so as to help them make informed and prudent investment decisions.

This research used an event window of (-1, +1), however, this should have been extended given the unusual nature of the events, such as COVID-19 waves but because of the overlapping of multiple events scenarios, the window could not be expanded any further. Future research could employ an extended event window to enhance robustness of the event study methodology. Future studies could take a wide range of other altcoins and examine their semi-strong market efficiency for more generalizable results. More rigorous methodologies could also be identified to further test the strong form of market efficiency in altcoins to fill this dearth in the existing literature. Additionally, further research opportunities in testing market efficiency in altcoin market could include the use of machine learning and artificial intelligence-based methodologies in order to capture complex, non-linear dependencies in the time series data of altcoin returns.

The selection criteria for the events were derived mainly from the past studies and the presumed global impact of the events as reported in the media, however, the possibility of researcher bias cannot be entirely dismissed despite making the due efforts to remain value-free.

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ANNEX

Table no. A1 – Crypto-Regulatory Events as Reported in the Media

No.	Date	Effect	Country	Event News	Source
1	2-Jan-18	Negative	European Union (EU):	"The EU implemented the Fifth Anti-Money Laundering Directive (5AMLD), which brought cryptocurrency exchanges and wallet providers within the scope of anti-money laundering (AML) and know-your-customer (KYC) regulations."	https://www.coindesk.com/
2	1-Jul-18	Negative	USA	"The U.S. Securities and Exchange Commission (SEC) clarified its stance that some cryptocurrencies and initial coin offerings (ICOs) may be considered securities and subject to federal securities laws."	https://www.coindesk.com/
3	1-May-19	Negative	Japan	"Japan introduced new regulations requiring cryptocurrency exchanges to comply with more stringent AML and KYC requirements."	https://www.coindesk.com/
4	1-Jun-19	Negative	USA	"The Financial Action Task Force (FATF), an intergovernmental organization, released guidance recommending that its member countries implement AML regulations for cryptocurrencies."	https://www.coindesk.com/
5	1-Mar-20	Positive	India	"The Supreme Court of India lifted a banking ban that the Reserve Bank of India (RBI) had imposed on cryptocurrency transactions, allowing for greater cryptocurrency trading in the country."	https://www.coindesk.com/
6	1-Dec-20	Negative	USA	"The U.S. Department of the Treasury proposed new regulations requiring cryptocurrency exchanges and wallet providers to collect and report customer information."	https://www.coindesk.com/
7	22-Apr-21	Negative	USA	"The U.S. Treasury Department unveiled a proposal for requiring cryptocurrency transfers worth $10,000 or more to be reported to the Internal Revenue Service (IRS), in an effort to crack down on tax evasion."	https://www.coindesk.com/
8	18-May-21	Negative	China	"The People's Bank of China (PBOC) issued a notice directing financial institutions to refrain from providing cryptocurrency-related services, including trading, clearing, and settling transactions involving cryptocurrencies."	https://www.coindesk.com/
9	9-Jun-21	Negative	China	"Three key industry associations in China issued a joint statement reiterating the PBOC's warning and further emphasizing that financial institutions should not engage in cryptocurrency-related businesses."	https://www.coindesk.com/
10	18-Jun-21	Negative	China	"Chinese authorities in Sichuan, a major hub for Bitcoin mining, ordered the shutdown of cryptocurrency mining operations in the region. This action significantly impacted the mining industry,	https://www.coindesk.com/

No.	Date	Effect	Country	Event News	Source
				especially Bitcoin miners who operated in the area."	
11	1-Jul-21	Negative	European Union (EU):	"The EU proposed the Markets in Crypto-Assets (MiCA) regulation, aiming to create a regulatory framework for cryptocurrencies and crypto-assets in the EU."	https://www.coindesk.com/
12	28-Jul-21	Negative	USA	"The U.S. Senate passed the Infrastructure Investment and Jobs Act, which included provisions related to cryptocurrency tax reporting. It proposed that cryptocurrency exchanges and brokers would need to report transactions to the IRS, similar to traditional financial institutions."	https://www.coindesk.com/
13	1-Sep-21	Negative	USA	"U.S. regulators, including the Securities and Exchange Commission (SEC) and the Commodity Futures Trading Commission (CFTC), increased their scrutiny of the cryptocurrency industry and discussed potential regulations for stablecoins, which are digital currencies designed to maintain a stable value."	https://www.coindesk.com/
14	1-Jan-22	Negative	UK	"The UK Financial Conduct Authority (FCA) announced its intention to regulate some stablecoins as e-money, which involves oversight and compliance with financial regulations."	https://www.coindesk.com/
15	21-Apr-22	Negative	Australia	"Australia's Financial Regulator (The Australian Prudential Regulation Authority - APRA) aims to implement Crypto Regulation by 2025."	https://www.coindesk.com/
16	5-Jun-23	Negative	USA	"The U.S. Securities and Exchange Commission (SEC) Sues Crypto Exchange Binance and CEO Changpeng Zhao, Alleging Multiple Securities Violations."	https://www.coindesk.com/
17	7-Sep-23	Negative	European Union (EU)	"The European Union's Markets in Crypto Assets regulation, MiCA, is due to take effect in 2024, making it the first major jurisdiction in the world to introduce comprehensive, tailored rules for the sector."	https://www.coindesk.com/
18	13-Mar-24	Positive	-	"Ethereum Finalizes 'Dencun' Upgrade, in Landmark Move to Reduce Data Fees."	https://www.coindesk.com/
19	20-Mar-24	Negative	-	"Ethereum Exchange Traded Funds Hopes Dim Amid Regulatory Probe Reports."	https://www.coindesk.com/

Table no. A2 – International Events as Reported in the Media

No.	Date	Effect	Event News	Source
1	18-Jan-18	Negative	"The European Union (Withdrawal) Bill has its First Reading in the House of Lords."	https://researchbriefings.files.parliament.uk/documents/CBP-7960/CBP-7960.pdf
2	26-Jun-18	Negative	"The European Union (Withdrawal) Bill receives Royal Assent and becomes an Act of Parliament: the European Union (Withdrawal) Act."	https://researchbriefings.files.parliament.uk/documents/CBP-7960/CBP-7960.pdf
3	25-Nov-18	Negative	"The UK and the EU agreed to the terms of the Withdrawal Agreement, which included provisions for a transition period."	https://researchbriefings.files.parliament.uk/documents/CBP-7960/CBP-7960.pdf
4	15-Jan-19	Negative	"The UK Parliament rejected the Withdrawal Agreement negotiated by Theresa May in a historic defeat."	https://researchbriefings.files.parliament.uk/documents/CBP-7960/CBP-7960.pdf
5	17-Oct-19	Negative	"The UK and the EU agreed on a revised Withdrawal Agreement and Political Declaration."	https://researchbriefings.files.parliament.uk/documents/CBP-7960/CBP-7960.pdf
6	19-Oct-19	Positive	"The UK Parliament voted to delay Brexit, requesting an extension beyond the initial deadline of October 31, 2019."	https://researchbriefings.files.parliament.uk/documents/CBP-7960/CBP-7960.pdf
7	31-Dec-19	Negative	"The first cases of a novel coronavirus are reported in Wuhan, China."	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!
8	30-Jan-20	Negative	"The World Health Organization (WHO) declares the outbreak a Public Health Emergency of International Concern."	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!
9	31-Jan-20	Negative	"The UK formally left the EU at 11:00 pm GMT, marking the end of its EU membership. This date is commonly referred to as "Brexit Day."	https://researchbriefings.files.parliament.uk/documents/CBP-7960/CBP-7960.pdf
10	11-Mar-20	Negative	"The WHO officially declares the outbreak a global pandemic. Many countries around the world implement lockdowns and travel restrictions."	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!
11	13-Mar-20	Positive	"COVID-19 Solidarity Response Fund launched to receive donations from private individuals, corporations and institutions."	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!
12	18-Mar-20	Positive	"WHO and partners launch the Solidarity Trial, an international clinical trial that aims to generate robust data from around the world to find the most effective treatments for COVID-19. "	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!
13	19-May-20	Positive	"The 73rd World Health Assembly, the first ever to be held virtually, adopted a landmark resolution to bring the world together to fight the COVID-19."	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!
14	11-Aug-20	Positive	"Sputnik vaccine authorized for use against COVID-19."	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!
15	28-Sep-20	Positive	"WHO joined with partners to make 120 million affordable, quality COVID-19 rapid tests available for low- and middle-income countries."	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!
16	2-Dec-20	Positive	"The Pfizer-BioNTech vaccine received emergency use authorization (EUA) against COVID19."	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!

No.	Date	Effect	Event News	Source
17	18-Dec-20	Positive	"The Moderna vaccine received emergency use authorization (EUA)."	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!
18	30-Dec-20	Positive	"AstraZeneca vaccine authorized for use in various countries."	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!
19	1-Jan-21	Negative	"The UK fully left the EU's Single Market and Customs Union, marking the complete implementation of Brexit."	https://researchbriefings.files.parliament.uk/documents/CBP-7960/CBP-7960.pdf
20	1-May-21	Negative	"The United States initiated its withdrawal from Afghanistan as part of an agreement reached in 2020 between the U.S. and the Taliban during the Trump administration."	https://www.bbc.com/news
21	30-Aug-21	Negative	"The final withdrawal of U.S. troops was completed on August 30, 2021, ahead of the initially announced deadline."	https://www.bbc.com/news
22	26-Nov-21	Negative	"WHO designated the variant B.1.1.529 a variant of concern, named Omicron, on the advice of WHO's Technical Advisory Group on Virus Evolution."	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!
23	24-Feb-22	Negative	"Russia invaded its neighboring country, Ukraine."	https://www.usnews.com/news/best-countries/slideshows/a-timeline-of-the-russia-ukraine-conflict?onepage
24	11-Sep-22	Negative	"Ukraine Forces Russian Retreat."	https://www.usnews.com/news/best-countries/slideshows/a-timeline-of-the-russia-ukraine-conflict?onepage
25	5-Oct-22	Negative	"Russia Annexes Four Ukrainian Regions."	https://www.usnews.com/news/best-countries/slideshows/a-timeline-of-the-russia-ukraine-conflict?onepage
26	1-Feb-23	Negative	"Russia Appears to Launch New Offensive in Ukraine."	https://www.usnews.com/news/best-countries/slideshows/a-timeline-of-the-russia-ukraine-conflict?onepage
27	5-May-23	Positive	"The World Health Organisation (WHO) declared the end of the global emergency status for COVID-19 on May 5, over three years since its initial declaration."	https://www.business-standard.com/world-news
28	7-Oct-23	Negative	"The Israel-Hamas conflict in Gaza broke out when Hamas launched a surprise attack on Israel on October 7 and the retaliatory assault on Gaza by Israel ensued."	https://www.business-standard.com/world-news
29	1-Apr-24	Negative	"Strike on an Iranian consular building that is widely blamed on Israel. Iran promises revenge."	https://www.pbs.org/newshour/world/a-timeline-of-recent-events-that-led-to-irans-assault-on-israel
30	14-Apr-24	Negative	"Iran launches major aerial assault on Israel".	https://www.pbs.org/newshour/world/a-timeline-of-recent-events-that-led-to-irans-assault-on-israel

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Assessing Operational and Investment Efficiency in the Greek Dairy Industry: A DEA-Based Composite Model

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Abstract: This study evaluates the efficiency of Greek dairy industry enterprises using a two-stage approach with Data Envelopment Analysis (DEA). The production model analyzes inputs such as personnel, net fixed assets, and operating expenses in relation to outputs like revenues and gross profits, while the investment model examines capital and investment management, assessing inputs such as depreciation and investment expenses against investment returns and EBITDA. The results reveal significant efficiency differences among the enterprises, with a small percentage achieving full efficiency and serving as benchmarks, while many firms display considerable room for improvement, particularly in resource management and investment strategies. Slack analysis identifies areas where excessive inputs can be reduced without affecting output, while the integration of the production and investment models highlights the need for better alignment between these two aspects of efficiency. The findings highlight opportunities for improvement through targeted resource management, sustainable practices, and collaboration within the sector. Policymakers are encouraged to support these efforts through incentives, funding tools, and the promotion of clusters. These insights provide actionable recommendations to enhance competitiveness, foster innovation, and ensure the sustainable development of the Greek dairy industry.

Keywords: two-stage DEA; operational efficiency; investment efficiency; dairy industry; Greece.

JEL classification: C23; Q12; Q14.

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1. INTRODUCTION

The dairy industry is one of the most dynamic and strategically important sectors of the agri-food sector, making a substantial contribution to the global economy, human nutrition and sustainable development. According to Fao (2023), global milk production exceeds 900 million tons per year, with India, the United States and the European Union being the main producers. The growing demand for dairy products with high nutritional value and innovation in production are leading to steady growth in the sector (Hill, 2024).

In Europe, the dairy industry represents around 15% of total agricultural production, with countries such as Germany, France and the Netherlands playing a leading role. At the same time, strict quality regulations and a shift towards sustainable practices are strengthening the international competitiveness of European dairy products (Bórawski *et al.*, 2020; Eurostat, 2023).

The Greek dairy industry, with deep roots in tradition, develops by combining small-scale local production with large-scale industrial activity (Ghadge *et al.*, 2017). At the same time, industry faces challenges, such as increasing production costs due to inflationary pressures, changes in consumer preferences and the need to adapt to modern sustainability requirements. However, Greek dairy industries are investing in innovation, introducing new production technologies and diversifying their products to respond to international market trends (Koutouzidou *et al.*, 2022). Large companies control approximately 90% of the market, while smaller units serve local needs and maintain cultural tradition (Icap. CRIF, 2023). Basic products, such as strained yogurt, occupy a dominant position in exports, representing 73.8% of the sector's total exports.

Figure no. 1 shows the changes in the consumption of different categories of milk in Greece for the year 2023. We observe that fresh pasteurized milk recorded a decrease of 9.7%, while categories such as highly pasteurized milk and milk drinks recorded increases. This reflects the changing consumer trends in the Greek market.

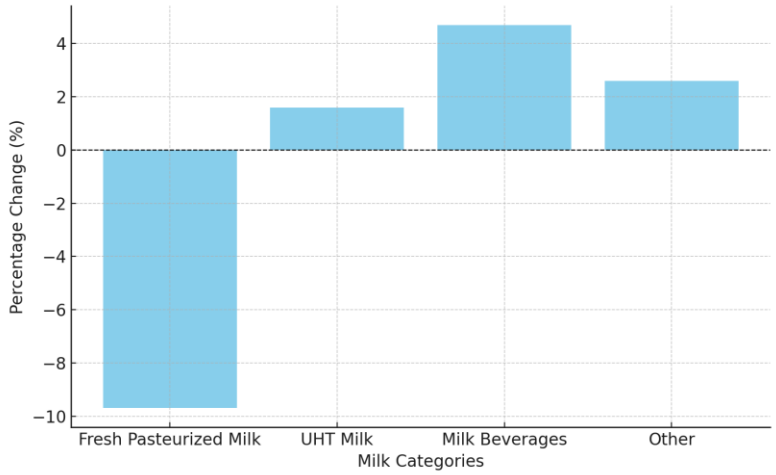

Figure no. 1 – Changes in Milk consumption in Greece (2023)

Source: *Icap. CRIF (2023)*

Figure no. 2 shows the evolution of Greek yogurt exports during the period 2018-2023. Greek yogurt exports remain at high levels, recording a slight increase from 2018 to 2023. Yogurt continues to be a key export product of the Greek dairy industry, strengthening its international competitiveness. The decline in Greek yogurt exports in 2022 is mainly due to the increase in production costs due to inflation and the energy crisis, intense competition from other countries, and supply chain disruptions following the pandemic. At the same time, changes in consumer preferences towards plant-based yogurts and the strengthening of local production in importing countries have affected demand.

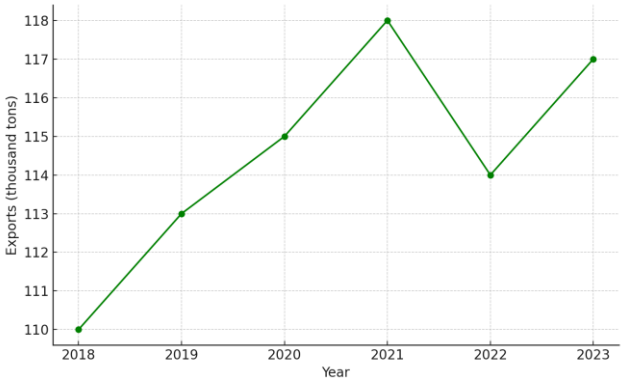

Figure no. 2 – Greek yogurt exports (2018-2023)

Source: *Icap. CRIF (2023)*

Figure no. 3 shows the evolution of milk production in Greece from 2013 to 2023. Milk production in Greece has shown a steady decline over the period 2013-2023, mainly due to structural changes in the sector and reduced demand. This trend reflects the challenges facing the sector, such as increasing production costs and changing consumer preferences.

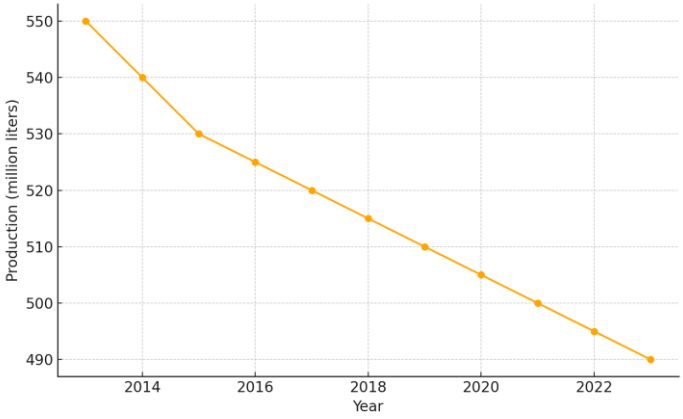

Figure no. 3 – Milk production in Greece (2018-2023)

Source: *Icap. CRIF (2023)*

The decline in milk production in Greece in recent years is due to factors such as the increase in production costs, the decrease in the number of livestock units, the aging of the population involved in livestock farming, climate change and changes in consumer habits, such as the shift to plant-based beverages. At the same time, the lack of strategic support for the sector and structural difficulties intensifies the problem. These conditions make it necessary to analyze the financial data of companies in the sector, to evaluate the productivity of their investments and enhance the efficiency of their operation. Such an approach can provide valuable guidance for improving the competitiveness and sustainability of the sector.

The challenges faced by the Greek dairy industry highlight the critical need for targeted strategic adjustments that will enhance its competitiveness in an ever-changing international environment. The necessity of investments in advanced technologies is of vital importance, as these can contribute to increasing productivity and effectively managing available resources (Koutouzidou *et al.*, 2022). At the same time, the adoption of sustainable practices aligned with global sustainability trends, such as reducing the environmental footprint and implementing circular production models, is essential for maintaining international competitiveness (Bórawski *et al.*, 2020; Pliakoura *et al.*, 2024b).

Furthermore, the cultural value of Greek dairy products, which combine the uniqueness of local raw materials with centuries-old tradition and expertise, can be leveraged as a strategic advantage for international differentiation (Ghadge *et al.*, 2017). Harnessing this identity offers opportunities for penetration into new markets, particularly among consumers seeking high-quality products with an authentic character.

Simultaneously, the analysis of the sector's efficiency assumes a pivotal role, as it enables a scientific understanding of resource utilization, production operations, and investment profitability. Through tools such as Data Envelopment Analysis (DEA), the quantitative evaluation of efficiency is possible at various levels, from operational to regional. Such analyses provide valuable data for policymaking and strategic decisions, ensuring a balance between tradition and innovation while laying the groundwork for the sector's long-term sustainable development (Gardijan and Lukać, 2018; Mavrommati *et al.*, 2024).

While previous studies have examined either production or investment efficiency in agrifood sectors using DEA, the integration of both dimensions into a unified efficiency assessment remains limited, especially in the context of the dairy industry. This paper addresses this gap by applying two DEA models to separately evaluate operational and investment efficiency and then combining their outputs into a composite model that reflects overall performance. In doing so, the study contributes to the literature by offering a comprehensive approach to efficiency analysis and providing practical insights for both policymakers and business decision-makers in the Greek dairy sector.

The remainder of this paper is organized as follows: Section 2 presents the relevant literature on the application of DEA analysis in the food and dairy industries. Section 3 describes the methodology and data used for the analysis, while Section 4 presents and analyzes the results. Finally, Section 5 discusses the findings, and Section 6 provides conclusions and policy recommendations.

2. LITERATURE REVIEW

Data Envelopment Analysis (DEA) is one of the most widely used efficiency assessment tools, introduced by Charnes *et al.* (1978). This method allows simultaneous analysis of

multiple inputs and outputs, facilitating the evaluation of the efficiency of decision-making units (DMUs). The flexibility of DEA makes it ideal for the food and dairy industry, and it can be adapted to incorporate external factors, such as environmental indicators and regulatory requirements, providing a more multidimensional picture of efficiency (Halkos and Petrou, 2019; Hermoso-Orzáez *et al.*, 2020).

This method has become much more common, with 82% of the relevant publications recorded in the period 2013–2019. This reflects the growing acceptance and adoption of the method in new areas, such as environmental efficiency and sustainability analysis (Emrouznejad and Yang, 2018). Although DEA is widely applied in industries such as tourism, financial services, and healthcare, its use in the food industry remains relatively limited (Karakitsiou *et al.*, 2007; Lukač and Gardijan, 2017; Mavrommati *et al.*, 2022; Chrysanthopoulou *et al.*, 2023; Mavrommati *et al.*, 2024). This can be attributed to factors such as the lack of specialized data and tools, as well as the reduced adoption of the method by small and medium-sized enterprises that often dominate the agri-food sector (Liu *et al.*, 2013). Despite these challenges, DEA remains a flexible and powerful tool for analyzing multidimensional data, making it ideal for improving efficiency and sustainability in this field (Halkos and Petrou, 2019; Mavrommati *et al.*, 2021).

In literature, the "Food and Beverage" sector attracts great interest, as it is a crucial pillar of the global economy (Karakitsiou *et al.*, 2004; Mavrommati and Migdalas, 2005; Mavrommati and Papadopoulos, 2005; Assaf and Matawie, 2009; Karakitsiou and Mavrommati, 2009; Chatzitheodoridis *et al.*, 2013; Kapelko and Oude Lansink, 2022; Pliakoura *et al.*, 2024a). The use of DEA in this sector has proven to be particularly effective for analyzing efficiency at various levels, such as production, distribution and sustainability. For example, Assaf and Matawie (2009) developed a two-stage approach to assess operational and financial efficiency in the food industry in Australia, offering valuable suggestions for improvement. Similarly, Liu *et al.* (2022) used Two-Stage DEA to analyze environmental efficiency in the Chinese industrial sector, focusing on the interaction of inputs and environmental parameters. Furthermore, Yang and Ma (2019) examined efficiency in vegetable agricultural production, demonstrating the multidimensional application of DEA in agricultural and industrial production. Although the method is widely used, more research is needed in specific sectors and markets with high demands for sustainability and efficiency (Chatzitheodoridis *et al.*, 2016; Kalfas *et al.*, 2024; Kalogiannidis *et al.*, 2024).

The dairy industry is one of the most interesting areas of application of DEA, even though it has been less studied compared to other categories of the food industry. Theodoridis and Psychoudakis (2008) used DEA and Stochastic Frontier Analysis (SFA) to evaluate 165 Greek dairy farms, identifying significant room for improvement through better resource management. Vlontzos and Theodoridis (2013) investigated the efficiency and productivity change in the Greek dairy industry, identifying fluctuations that affect efficiency. At the international level, Jaforullah and Whiteman (1999) analyzed the scale efficiency of the New Zealand dairy industry, while Krause and Nowoświat (2019) assessed the energy efficiency of dairy production systems in the same country, identifying best practices for sustainable production. Furthermore, Aldeseit (2013) used DEA to measure scale efficiencies in Jordanian dairy farms, while Lima *et al.* (2018) analyzed efficiency levels in the Brazilian dairy industry, focusing on improvement strategies. Furthermore, Ruales-Guzmán *et al.* (2021) analyzed the efficiency of 19 dairy companies in Colombia, identifying efficient and inefficient businesses using the VRS model. Mo *et al.* (2014) applied various DEA models to

measure efficiency in the dairy industry, providing practical suggestions for improving productivity. A more advanced approach is presented by Khalili-Damghani *et al.* (2011), who applied a hybrid combination of DEA and fuzzy logic to measure efficiency in the flexibility of supply chains in the dairy sector. The improvement strategies proposed by these studies highlight the value of DEA as a tool to support sustainable practices, enhance competitiveness, and increase efficiency in the dairy sector.

The food industry in general benefits from the application of DEA, as it offers a robust framework for assessing efficiency in multidimensional operations. Ghadge *et al.* (2017) analyzed the efficiency of small and medium-sized enterprises in the food industry, incorporating parameters such as environmental investments and regulatory requirements, demonstrating the flexibility of DEA in measuring complex systems. Similarly, Saha (2020) used a Two-Stage DEA approach to analyze efficiency in the food processing industry in India, providing a separation between market and technical efficiency.

The variables used in DEA analyses are numerous and tailored to the requirements of each sector. Inputs traditionally include raw material costs, energy consumption, labor use, technological investments and infrastructure among others. On the output side, variables such as the quantity of products produced, net profit, product quality and environmental efficiency are measured. In the context of Two-Stage DEA, external factors such as geographical location, climatic conditions, regulatory requirements and social responsibility indicators are incorporated to provide a more comprehensive picture of efficiency. In conclusion, DEA and Two-Stage DEA offer powerful tools for understanding efficiency and sustainability in the food and dairy industry. Despite existing studies, there is a need for further research, especially in regions and sectors with limited application of the method.

The two-stage DEA approach is applied for the multidimensional evaluation of efficiency, enabling analysis in two interconnected stages. The first stage may focus on operational or financial aspects, as in the studies by Yang (2006) and Assaf and Matawie (2009), while the second stage incorporates external factors or undesirable outcomes, such as pollutant emissions (Aminuddin *et al.*, 2017). Studies like those by Gutiérrez *et al.* (2017) utilized the first stage to identify sources of inefficiency and the second to analyze exogenous factors. Hanoum *et al.* (2020) highlighted the application of the approach in the creative industry sector, while Liu *et al.* (2022) confirmed its ability to capture multidimensional interactions in complex sectors, such as the dairy industry. This methodology has proven to be flexible and useful for understanding and improving efficiency across various industries.

Despite the increasing use of DEA in agrifood efficiency analysis, most existing studies tend to focus on either production or investment aspects separately. Composite models integrate both remain uncommon, particularly in the dairy sector. This study seeks to fill this gap by applying a combined DEA approach tailored to the structure of the Greek dairy industry.

3. DATA AND METHODOLOGY

This study develops a comprehensive two-stage Data Envelopment Analysis (DEA) model to evaluate the overall efficiency of the Greek dairy industry, using data for the year 2023 obtained from ICAP. The analysis focuses on a sample of 33 enterprises, integrating production and investment perspectives to provide a systematic assessment of efficiency. An input-oriented DEA model was selected, as it reflects the strategic goal of minimizing resource usage—a key concern in a sector facing rising production costs and input

inefficiencies. The model aims to minimize inputs in the production stage and maximize outputs in the investment stage, aligning with the specific objectives of dairy enterprises.

Production Approach

The production approach treats firms as units that produce products through the utilization of human, capital and other resources. Inputs include personnel, fixed assets, facilities, working capital and operating expenses, while outputs include sales revenue and gross profit. This approach assesses the ability of firms to achieve efficient production and cost control, supported by the existing literature on efficiency in the food industry.

Investment Approach

In the investment approach, firms are treated as financial intermediaries that invest capital to maximize return and value. Inputs include depreciation, investment expenses and total investment capital, while outputs include investment profits and EBITDA. This approach aims to measure the efficiency of investment strategies, considering the desire of businesses to maximize profits.

Integration of Stages

In the second stage, the efficiency results of production and investment are integrated into a single DEA model to generate a composite efficiency score. A dummy variable (with a constant value across all DMUs) is used as the sole input, while the outputs are the production efficiency and the inverse of the investment efficiency obtained from the first-stage models. This formulation ensures that both aspects contribute to the overall score, with greater weight assigned to the dimension in which each firm performs relatively better. The model is specified under the CCR (Constant Returns to Scale) assumption to ensure comparability across units. The practical objective of this step is to evaluate the overall managerial effectiveness of each enterprise by assessing its ability to balance productive operations and investment performance in an integrated and interpretable framework.

The data used in this study concern the Greek dairy industry for the year 2023. The information was collected from Icap. CRIF (2023), a reliable source of economic and business data, ensuring the accuracy and timeliness of the analysis. The analysis utilizes both the BCC and CCR models to comprehensively examine scale efficiency issues, providing valuable information for improving the operational and investment strategy of Greek dairy businesses. The DEA models were implemented using the R software environment, which supports robust linear programming techniques suitable for efficiency analysis.

Data Envelopment Analysis (DEA) is a mathematical programming approach for evaluating the relative efficiency of decision-making units (DMUs) that utilize multiple inputs to produce multiple outputs. DEA identifies a set of efficient DMUs that define the best practice frontier and evaluates other units against this benchmark. This section presents the two primary models used in DEA: the CCR model (Charnes *et al.*, 1978), which assumes Constant Returns to Scale, and the BCC model (Banker *et al.*, 1984), which assumes Variable Returns to Scale. These foundational models form the basis for evaluating technical and scale efficiency within DEA.

The BCC model assumes variable returns to scale and is formulated as follows. For each DMU_0 under evaluation, the input-oriented model is defined as a linear programming problem:

$$\min(\theta, \lambda_j)$$

$$subject\ to: \sum_{\{j=1\}}^{\{n\}\lambda_j} \lambda j y_{\{rj\}} \geq y_{\{ro\}} \qquad for\ r = 1, 2, \ldots, s$$

$$\sum_{\{j=1\}}^{\{n\}\lambda_j} \lambda j x_{\{ij\}} \leq \theta\, x_{\{io\}} \qquad for\ i = 1, 2, \ldots, m$$

$$\lambda_j \geq 0 \qquad for\ j = 1, 2, \ldots, n$$

In the BCC model, the following convexity constraint is also added: $\sum_k \lambda_k = 1$, where:

θ: Efficiency score of the DMU under evaluation

x_{ij}: Input i for DMU j

y_{rj}: Output r for DMU j

λ_j: Intensity variable for DMU j

n: Number of DMUs

m: Number of inputs

s: Number of outputs

The solution yields the efficiency score θ\thetaθ for the DMU under evaluation, along with the λ\lambdaλ-weights that form the convex combination of peer units comprising its reference set.

The BCC model evaluates the pure technical efficiency (PTE) of DMUs by excluding scale effects, offering a measure of managerial performance. In contrast, removing the convexity constraint, as in the CCR model, expands the feasible region and may reduce the number of units classified as efficient.

The CCR model assumes constant returns to scale (CRS) and provides a measure of overall technical efficiency. Unlike the BCC model, it does not include the convexity constraint $\sum \lambda_k = 1$, and thus assumes that all DMUs operate at an optimal scale. This model is useful for identifying both technical and scale inefficiencies simultaneously.

A DMU is considered strongly efficient if it lies on the efficient frontier and all input and output slacks are zero. In contrast, weak efficiency is observed when a DMU obtains an efficiency score of 1 but retains positive slacks in some dimensions. This distinction is important for understanding the full potential for improvement (Cooper *et al.*, 2004; Soltani *et al.*, 2021; Oukil, 2024).

Selecting appropriate inputs and outputs is critical for accurate measurement of efficiency. In this study, the selected variables reflect key aspects of the operation of businesses in the Greek dairy industry.

Production model

Outputs

Revenue - Sales: Represents the total income derived from the sale of products or services. This variable provides an indication of the business's commercial performance and position in the market. Coelli *et al.* (2005) highlighted revenue as a central measure in efficiency analyses, particularly in competitive markets. Sellers-Rubio (2010) demonstrated its use in assessing wineries' performance, emphasizing its critical role in financial evaluation.

Gross Profit: Defined as the difference between revenue and cost of goods sold. Gross profit reflects the efficiency of the production model and the ability to control costs. Kaplan and Norton (1996) described gross profit as a foundational indicator of operational efficiency, central to strategic business planning. Färe *et al.* (1994) linked gross profit with technical efficiency in evaluating production models.

Inputs

Personnel: Refers to the total number of employees involved in the operations of the business. Human resources are a critical factor in the production capacity and quality of the products produced. Becker and Huselid (1998) underscored the critical role of effective human resource management in boosting operational efficiency. Voulgaris *et al.* (2013) emphasized personnel's influence on productivity and firm performance in labor-intensive industries.

Net Fixed Assets: Represent the financial value of long-term tangible investments such as buildings, machinery, and equipment, as recorded in company balance sheets. This variable reflects the capital invested in the production capacity of the firm, encompassing both movable and immovable assets that are expected to contribute to productivity over time. Greene (2008) incorporated fixed assets as key inputs in efficiency analyses, emphasizing their role in operational capacity. Karakitsiou *et al.* (2020) examined how the scale of such capital investments affects performance in the hospitality and food sectors using DEA.

Facilities: Denote the physical operating space and structural layout of the business, such as production plants, warehouses, and administrative offices. While these may be part of the assets included under Net Fixed Assets, they are considered here in terms of their spatial-functional role—affecting logistics, capacity utilization, and workflow efficiency. Ray (2004) highlighted the contribution of facility layout to technical efficiency in agricultural enterprises. Seiford and Zhu (1999) also assessed how infrastructure characteristics directly impact production performance.

Working Capital: Defined as the difference between current assets and short-term liabilities. It reflects the liquidity of the business and its ability to meet daily operational needs. Hill *et al.* (2013) highlighted the importance of working capital management for maintaining operational stability. Reddy *et al.* (2019) reviewed the role of working capital in financial and operational efficiency across industries.

Operational Expenses: These include the costs associated with the daily operation of the business, such as salaries, energy and raw materials. Managing operating expenses is critical to maintaining profitability and competitiveness. Kaplan and Norton (1996) emphasized the role of operational cost management in improving efficiency. Dobos and Vörösmarty (2019) analyzed operational expenses in supply chain performance, linking cost management with competitiveness.

Investment model

Outputs

Investment Gains in Equities and Real Estate: The total profits arising from investments in financial and real estate assets. Evaluates the effectiveness of the company in managing high-risk and high-return investments. Banker *et al.* (1984) incorporated investment gains in efficiency models, showcasing their role in financial stability. Additionally, Karagiannis and Sarris (2005) analyzed the efficiency of Greek tobacco growers, highlighting the significance of scale efficiency and strategic resource allocation in promoting sustainable agricultural performance.

Earnings Before Interest, Taxes, and Depreciation (EBITDA): The company's operating profits before interest, taxes, depreciation, and impairments are deducted. Measures the profitability of the company from its core operations, regardless of financing or accounting policies. Damodaran (2001) advocated EBITDA as a key metric for operational performance and valuation. Latruffe *et al.* (2008) used EBITDA in multi-criteria efficiency evaluations, emphasizing its relevance across sectors.

Inputs

Total Depreciation: The cost of wear and tear and the reduction in value of fixed assets. Demonstrates the efficiency of the use of fixed assets in operation and investment. Penman (2010) and Battese and Coelli (1995) analyzed depreciation's role in operational efficiency and financial planning.

Investment Expenses: Expenditures incurred to acquire or upgrade assets and investments. Evaluates the effectiveness of investments in relation to their performance. Assaf and Matawie (2009) studied investment expenses in cost efficiency analyses of Australian wine companies. Jensen (1999) explored their impact on firm growth and strategy execution.

Total Investments: The total capital committed to investment activities. Purpose: Reflects the scale and effectiveness of the investment strategy. Färe *et al.* (1994) and Greene (2008) analyzed total investments in efficiency models to assess their impact on long-term growth. Voulgaris *et al.* (2013) linked investment levels to competitiveness and financial stability in volatile markets.

Figure no. 4 illustrates the structure and methodology used to evaluate the efficiency of businesses. In the first stage, two separate processes are analyzed: the production model and the investment model. In the second stage, the efficiencies from the two initial models are integrated into a single index, which assesses the overall efficiency of each business unit.

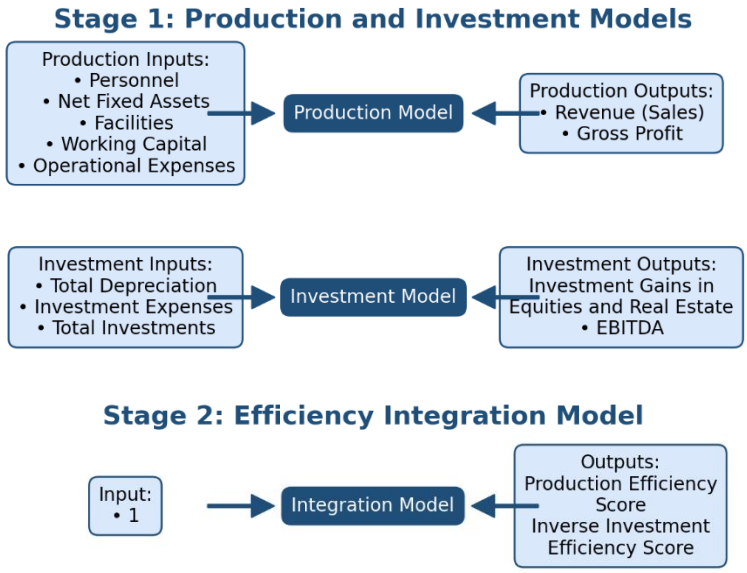

Figure no. 4 – Structure and Methodology of Efficiency Evaluation in Two Stages

The second stage of the analysis serves a critical practical purpose: it enables the integration of two distinct efficiency dimensions – operational and investment – into a single composite indicator that captures the overall performance of each enterprise. While the first-stage models evaluate production and investment efficiency separately, real-world business performance depends on the interplay and alignment between these two domains. The second stage thus reflects the ability of a firm to balance productive operations with sound investment strategies. This composite efficiency score provides actionable insights for both managers and policymakers by identifying firms that excel in both areas, highlighting those with mismatches, and guiding targeted interventions. For example, an enterprise that performs well in production but poorly in investment may need to revise its capital allocation policies. Conversely, high performance in both stages indicates a sustainable and balanced business model that can serve as a benchmark for others in the sector.

4. RESULTS

The results section begins with a statistical overview of the sample firms, which provides context for the efficiency evaluation that follows.

Table no. 1 – Descriptive statistics of outputs and inputs in production model

	Max	Median	Min	Average	Standard Deviation
Outputs					
Revenue (Sales)	328197728	31422000	1117938	67208893.61	82382872.33
Gross Profit	64135000	4550000	358437	13327460.73	17272875.25
Inputs					
Personnel	1025	125	14	250.36	277.64
Net Fixed Assets	254627824	8236059	34294	31730442.27	58798886.14
Facilities	114647263	7087410	95870	17427980.64	25410650.96
Working Capital	181636058	7251000	99929	23004334.88	36789549.26
Operational Expenses	71234000	4214580	438167	11315733.52	16170588.8

Table no. 1 presents the summary statistics for outputs and inputs in the production model of the dairy industry. The analysis of these statistics reveals that, for outputs, revenue (sales) has a significant range, with a maximum value of €328197728, a median of €31422000, and a minimum of €1117938, resulting in an average of €67208893.61 with a standard deviation of €82382872.33. Gross profit exhibits similar variability, with an average of €13327460.73 and a standard deviation of €17272875.25, suggesting disparities in profitability. Personnel size ranges from 14 to 1025 employees, with a median of 125, reflecting diverse workforce sizes.

For inputs, net fixed assets exhibit the largest variability, with a maximum of €254627824 and a minimum of €34294, averaging €31730442.27 with a standard deviation of €58798886.14. Facilities, working capital, and operational expenses follow similar patterns of high variability, with average values of €17427980.64, €23004334.88, and €11315733.52, respectively. The high standard deviations across inputs underscore significant differences in resource utilization among dairy enterprises, highlighting the potential for operational improvements to align performance with industry leaders.

Table no. 2 – Descriptive statistics of outputs and inputs in investment model

	Max	Median	Min	Average	Standard Deviation
Outputs					
Investment Gains in Equities and Real Estate	2943002.8	162361	3247.7	521314.68	695046.76
EBITDA	29410028	912800	32477	5494725.24	8311436.09
Inputs					
Total Depreciation	45114000	2497799	26895	8664110.12	12251936.86
Investments Expenses	7259000	70736	1639	634626.97	1460578.61
Total Investments	54828000	4897085	80061	13403835.5	15332986.3

Table no. 2 presents descriptive statistics for the investment model inputs and outputs. The results indicate high variability across all variables, with significant differences between maximum and minimum values, suggesting the presence of outliers and a wide range of practices. For example, investment gains in equities and real estate range from a minimum of 3247.7 to a maximum of 2943002.8, with an average of 521314.68 and a standard deviation of 695046.76, highlighting substantial dispersion. Similarly, total depreciation varies from 26895 to 45114000, with an average of 8664110.12 and a standard deviation of 12251936.86. These large discrepancies, along with high standard deviations, reflect diverse business profiles and the influence of extreme values.

Table no. 3 – DEA Results for Production and Investment Models

	Production		Investment	
	CCR	BCC	CCR	BCC
Average Score	0.59	0.76	0.40	0.56
Standard Deviation	0.23	0.22	0.36	0.35
Maximum Efficiency Score	1	1	1	1
Minimum Efficiency Score	0.33	0.38	0.02	0.06
Number (and %) of Efficient DMUs	6 (18.18%)	11 (33.33%)	5 (15.15%)	11 (33.33%)
Strongly Efficient DMUs (n, %)	4 (12.12%)	8 (24.24%)	4 (12.12%)	7 (21.21%)
Weakly Efficient DMUs (n, %)	2 (6.06%)	3 (9.09%)	1 (3.03%)	4 (12.12%)
DMUs with Increasing Returns	19	-	4	-
DMUs with Constant Returns	1	3	2	5
DMUs with Decreasing Returns	13	-	27	-
Benchmark DMUs	1, 4, 6, 11	2, 3, 5, 8	1, 5, 9	2, 5, 11

Note: Benchmark DMUs are those used as reference units (with $\lambda > 0$) in at least one other DMU. These units are efficient and form the best-practice frontier under each model.

Table no. 3 presents the DEA-based efficiency scores of Greek dairy enterprises, evaluating both production and investment activities under Constant Returns to Scale (CCR) and Variable Returns to Scale (BCC) assumptions. The comparison across the four models highlights notable differences in performance and inefficiency patterns among firms.

The average efficiency scores indicate better performance under BCC assumptions. In the production model, the average score is 0.76 under BCC and 0.59 under CCR. Similarly, for the investment model, the average score reaches 0.56 under BCC, compared to 0.40 under CCR. These results reflect the ability of the BCC model to account for scale inefficiencies, offering a more flexible representation of firm-level efficiency.

The standard deviation values are relatively similar across models, indicating comparable dispersion. In production, the CCR and BCC models report standard deviations of 0.23 and 0.22, respectively. For the investment model, variability is slightly higher (0.36 CCR, 0.35 BCC), suggesting greater heterogeneity in capital allocation and investment outcomes.

All models include fully efficient firms, as denoted by the maximum score of 1. However, the minimum efficiency scores reveal significant inefficiencies – particularly in investment. While the production model reports minimum scores of 0.33 (CCR) and 0.38 (BCC), the investment model scores drop to 0.02 (CCR) and 0.06 (BCC), indicating major performance gaps in investment efficiency.

The number of efficient firms differs by model. In the production model, 11 firms (33.33%) are efficient under BCC – of which 8 are strongly and 3 weakly efficient – while 6 (18.18%) are efficient under CCR (4 strongly, 2 weakly). In investment, 11 firms (33.33%) are efficient under BCC (7 strongly, 4 weakly), and only 5 (15.15%) under CCR (4 strongly, 1 weakly). These differences illustrate the broader frontier defined by the BCC model.

Returns to scale, identifiable only under BCC, provides further insight into performance dynamics. In production, 19 firms operate under Increasing Returns to Scale (IRS), suggesting potential efficiency gains through expansion, while 13 firms exhibit Decreasing Returns to Scale (DRS), reflecting inefficiencies from over-sizing. Only one firm operates at Constant Returns to Scale (CRS). In investment, most firms (27) are under DRS, with only 4 under IRS and 2 at CRS—highlighting widespread inefficiencies in capital deployment.

Benchmark DMUs—those serving as reference points with strictly positive λ-values—are also identified. For production, BCC models select DMUs 1, 4, 6, and 11, while CCR models identify DMUs 2, 3, 5, and 8. In investment, the benchmarks under BCC are DMUs 1, 5, and 9, and under CCR, DMUs 2, 5, and 11. These units form the efficiency frontier and can serve as practical examples of best performance within the sector.

In summary, production activities show more favorable efficiency patterns than investment. The BCC models uncover a broader set of efficient firms and richer insights into scale characteristics, while CCR models define a stricter efficiency frontier. The results highlight the need for performance improvements, particularly in investment strategy and scale adjustment, and point to specific firms that can serve as role models within the industry.

Beyond the numerical results, the DEA findings offer deeper insights into the structural and strategic conditions prevailing in the Greek dairy industry. The significant gaps in efficiency – particularly within the investment dimension – highlight challenges in capital deployment, financial planning, and long-term strategic orientation. The widespread presence of decreasing returns to scale in the investment model suggests over-investment or suboptimal resource utilization, indicating the need for more targeted and sustainable growth strategies.

In contrast, the prevalence of increasing returns to scale among several enterprises in the production model points to unrealized efficiency potential, especially for firms operating below optimal scale. Strategic expansion or improved resource management could help these enterprises move closer to the production frontier.

Benchmark units identified in all four models act as reference points and illustrate best-practice operations in both production and investment contexts. Their role is critical, as they offer evidence of managerial effectiveness and coherent operational strategies. Promoting the practices of these efficient units could foster learning and drive convergence across the sector.

Furthermore, the divergence in efficiency performance between production and investment activities in some enterprises suggests a lack of integrated management. Firms

with strong production capabilities but weak investment efficiency may jeopardize long-term competitiveness if they fail to align operational success with strategic financial planning. This underlines the importance of two-stage DEA models as tools for diagnosing multi-dimensional inefficiencies and supporting comprehensive, evidence-based decision-making.

Table no. 4 presents the second-stage DEA efficiency scores, which integrate production and investment performance for each DMU. The results show that the mean efficiency score is 0.402, indicating that, on average, the DMUs achieve 40.2% of the ideal efficiency, with significant variability as reflected in a standard deviation of 0.348. Only 5 DMUs (15.15%) are fully efficient (score = 1.0), while the minimum score of 0.023 underscores substantial inefficiencies. These findings highlight the need for many DMUs to improve both operational and investment strategies to enhance overall performance.

Table no. 4 – Overall Efficiency (Based on CCR Analysis)

Efficiency Metric	Results
Mean Efficiency Score	0.402
Variation (Standard Deviation)	0.348
Top Efficiency Achieved	1.0
Lowest Efficiency Score	0.023
Number of Efficient DMUs	5
Percentage of Efficient DMU	15.15%

Table no. 5 presents the efficiency scores of Decision-Making Units (DMUs) at two levels: Average First-Stage Efficiency and Overall Efficiency (Second Stage). The first-stage scores reflect the average CCR-based efficiency results from the separate production and investment DEA models. These scores indicate how well each enterprise performs in each dimension individually. The second-stage score represents the integrated efficiency score obtained from the CCR-based composite DEA model, where a dummy input and the first-stage outputs (production efficiency and inverse investment efficiency) are used. This comparison enables the identification of firms with consistent performance across both stages, as well as those showing a mismatch between operational and investment efficiency. The practical objective of this step is to assess the overall strategic alignment of each enterprise by measuring its ability to effectively manage both resource use and capital deployment within a unified framework.

A notable finding is the presence of fully efficient DMUs in both stages. In the first stage, DMUs 1, 2, 3, 10, 20, and 22 achieve a perfect efficiency score of 1.0, reflecting their ability to optimize both production and investment operations. In the second stage, DMUs 1, 2, 3, 10, 13, 20, and 22 maintain their efficiency, demonstrating robust integration of production and investment efficiencies. These DMUs serve as benchmarks for best practices within the dataset.

Several DMUs exhibit high efficiency across both stages, with scores close to 1.0. For instance, DMUs 25, 21, and 29 show consistently strong performance, indicating effective operations and minimal inefficiencies during the integration phase. However, some DMUs experience significant drops in efficiency between the stages. DMU 7, for example, drops from 0.66 in the first stage to 0.37 in the second stage, while DMU 24 decreases from 0.69 to 0.40. These declines suggest challenges in harmonizing production and investment model.

Table no. 5 – DMU-Level Efficiency Comparison

DMU	*Average First Stage Efficiency*	*Overall Efficiency (Second Stage)*
1	1.00	1.00
2	1.00	1.00
3	1.00	1.00
4	0.77	0.68
5	0.76	0.60
6	0.71	0.55
7	0.66	0.37
8	0.69	0.41
9	0.83	0.68
10	1.00	1.00
11	0.73	0.56
12	0.74	0.48
13	0.69	1.00
14	0.75	0.50
15	0.68	0.48
16	0.77	0.56
17	0.75	0.52
18	0.75	0.51
19	0.69	0.49
20	1.00	1.00
21	0.85	0.70
22	1.00	1.00
23	0.85	0.69
24	0.69	0.40
25	0.93	0.91
26	0.69	0.41
27	0.73	0.49
28	0.67	0.50
29	0.85	0.70
30	0.71	0.46
31	0.81	0.74
32	0.74	0.59
33	0.82	0.64

Moderately efficient DMUs, such as 4, 5, and 9, maintain efficiency scores between 0.55 and 0.83 across both stages. These units demonstrate potential for improvement but also highlight the need for targeted interventions to optimize their operations further. On the other hand, DMU 13 shows an improvement in the second stage, reaching a score of 1.0 despite a first-stage score of 0.69. This indicates that the integration analysis benefits certain DMUs, likely due to better alignment of production and investment activities.

The efficiency scores across the DMUs display a broad range, with second-stage scores spanning from 0.37 to 1.0. Similarly, first-stage scores range from 0.66 to 1.0, reflecting varying levels of baseline efficiency. The variation suggests opportunities to analyze underperforming DMUs and identify the factors contributing to inefficiencies.

In summary, while some DMUs consistently excel across both stages, others face integration challenges or underperformance. The analysis highlights fully efficient DMUs as benchmarks, identifies areas for improvement for moderate performers, and emphasizes the

need for strategic interventions to align production and investment efficiencies effectively. These findings provide actionable insights for enhancing overall operational performance within the dairy industry.

The analysis focused on the slacks of the production model, as these provide direct insights into the management of key resources such as personnel and fixed assets. This choice was made because improvements in productive efficiency are more immediate and actionable, whereas addressing slacks in the investment model often requires long-term planning and capital strategies. Additionally, the available data for the inputs of the production model were more detailed, enabling a more precise analysis.

Table no. 6 – Slacks for CCR Production Models

DMU	Personnel	Net Fixed Assets	Facilities	Operational Expenses	Working Capital
1	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00
4	-30.60	-2857695.61	-3190110.74	0.00	0.00
5	-23.72	-2263970.46	-1681872.15	0.00	15854955.10
6	-5.09	-1189571.38	-642489.99	0.00	3826609.08
7	-15.15	-3039307.65	-1683792.68	0.00	18028793.16
8	-26.89	-2242743.09	-2834184.07	0.00	30494574.23
9	-65.43	-527155.04	-639370.24	0.00	9574292.72
10	0.00	0.00	0.00	0.00	0.00
11	0.00	-101792533.70	-26682792.38	0.00	315417301.2
12	-16.46	-17218483.73	-2267626.35	0.00	110274112.3
13	-6.45	-7852218.913	-6641702.99	0.00	16262604.84
14	0.00	-122166286.1	-46188767.04	0.00	174896858.70
15	-15.27	-2728434.288	-2046931.09	0.00	12760248.70
16	-90.46	-17345582.91	-16625422.80	0.00	9599318.42
17	-6.42	-3506242.43	-2452293.02	0.00	8728612.64
18	-73.00	-35577003.45	-10889047.08	0.00	81659406.17
19	-4.18	-2535309.96	-2673525.82	0.00	5340302.67
20	0.00	0.00	0.00	0.00	0.00
21	0.00	-45389813.55	-9483749.61	0.00	254740660.40
22	0.00	0.00	0.00	0.00	0.00
23	-33.45	-800926.44	0.00	0.00	11245124.94
24	-5.22	-3062916.82	-1130403.21	0.00	17444220.27
25	-269.30	-26284230.98	-23817828.80	0.00	42587518.64
26	-0.05	-18355090.74	-2138103.45	0.00	75966312.74
27	-10.55	-2766958.06	-2759233.76	0.00	11343859.81
28	-1.57	-45816.43	-404679.06	0.00	2532310.68
29	-533.02	-5687288.81	0.00	0.00	77120180.67
30	-14.61	-890358.10	-1071963.16	0.00	15082984.69
31	-116.94	-9025289.21	-4653474.17	0.00	33817534.22
32	0.00	-31420197.97	-20022387.02	0.00	117786020.10
33	0.00	-8907076.52	-4637880.69	0.00	62789692.07

Slacks for CCR Production Models (Table no. 6) highlights critical inefficiencies in the utilization of inputs across dairy industry enterprises (DMUs). This table provides valuable

insights into areas where input reductions are possible without compromising production levels, revealing significant opportunities for optimization.

Several DMUs, such as 1, 2, 3, 10, 20, and 22, exhibit zero slacks across all input categories. These DMUs are fully efficient under the CCR model and can serve as benchmarks for others. Their effective resource utilization offers valuable lessons in workforce management, asset optimization, and cost efficiency. These efficient DMUs demonstrate the potential for balancing input utilization with production output, setting the standard for less efficient enterprises.

However, other DMUs show substantial inefficiencies, with notable overuse of inputs. For instance, DMU 25 displays the largest slack in both Personnel (-269.30) and Net Fixed Assets (-26284231), signaling significant overstaffing and underutilization of fixed assets. Similarly, DMU 29 has the highest inefficiency in Personnel (-533.02), suggesting opportunities to reduce staffing levels without affecting production. These inefficiencies highlight the need for targeted cost optimization strategies, including workforce restructuring and better asset allocation.

The slacks in Facilities and Working Capital also present important findings. DMUs such as 16, 18, and 25 show considerable inefficiencies in facilities management, indicating potential misallocation or underutilization of physical resources. On the other hand, DMUs like 8 and 25 exhibit significant slacks in working capital, pointing to inefficiencies in cash flow or inventory management. Addressing these issues could unlock financial and operational improvements.

Interestingly, Operational Expenses exhibit zero slack across all DMUs. This suggests that operational costs are being allocated efficiently across the industry, providing a strong foundation for further optimization efforts. This insight underscores the importance of focusing on other input categories, such as personnel and fixed assets, for greater impact.

In conclusion, the CCR production model slacks reveal a clear dichotomy between efficient and inefficient DMUs in the dairy industry. Enterprises with significant slacks should prioritize targeted interventions in workforce management, capital utilization, and facilities optimization. By benchmarking against fully efficient DMUs, less efficient enterprises can identify best practices and move closer to the efficient frontier. This analysis underscores the potential for improved resource allocation and productivity, driving the overall competitiveness of the sector.

5. DISCUSSION

The efficiency analysis of Greek dairy industry enterprises through the two steps DEA model revealed significant findings that can guide improvement strategies. The production and investment models provided a comprehensive view of efficiency, while the integration of the two models highlighted notable differences in enterprise performance.

The production model showed that some enterprises are fully efficient, while others have significant room for improvement. The observed slacks in inputs such as personnel and fixed assets indicate that many enterprises manage resources inefficiently. The large efficiency discrepancies among the DMUs underline the need to adopt best practices employed by the most efficient units. Specifically, operational cost management appears generally efficient, as most DMUs showed no slack in this area. This suggests a focus on cost control, although improvements in other inputs are needed to fully unlock their potential.

The investment model revealed poor performance for most enterprises, with results indicating ineffective investment strategies. Enterprises need to focus on optimizing capital utilization and increasing profitability through more efficient investments.

The integration of the two models in the second stage exposed inconsistencies between productive and investment efficiency. Only a small percentage of enterprises were fully efficient, highlighting the need for better alignment of productive and investment activities. The analysis showed that enterprises performing well in the production model are not necessarily equally efficient in the investment model, and vice versa. This mismatch underscores the need for a comprehensive strategy that integrates both domains.

The analysis provides critical insights for improving efficiency in the dairy industry, laying the groundwork for strategic adjustments and sustainable development. Enterprises must reduce excessive input usage, such as personnel and fixed assets, through optimal resource management, adapting their processes to increase productivity and reduce operating costs. Simultaneously, revising investment policies is crucial, with an emphasis on innovation, profit growth, and sustainability. Innovation involves adopting technologies that enhance production and reduce environmental impact, while profit growth can be achieved through targeted investments in high value-added products that meet market demands. For sustainability, ensuring long-term economic robustness requires green practices and responsible strategies that maintain environmental balance.

Furthermore, efficient enterprises can serve as benchmarks for less efficient ones, sharing expertise and best practices to align strategies and achieve overall sector improvement. By implementing these strategies, the dairy industry can enhance its efficiency, achieve greater economic robustness, and create a sustainable future for the sector.

6. CONCLUSIONS AND IMPLICATIONS

Conclusions

The efficiency analysis of Greek dairy industry enterprises using the composite DEA approach highlights critical strategic implications for both businesses and policymakers seeking sustainable development and enhanced competitiveness. Greek dairy firms can capitalize on global trends in sustainability and innovation. The rising demand for high-nutritional-value products, such as strained yogurt and functional foods (e.g., probiotics), creates opportunities for differentiation in international markets. At the same time, the integration of advanced technologies, such as automation in production processes, can help reduce costs and improve product quality. The analysis also reveals considerable room for improvement in investment strategies. With average investment efficiency (0.40) significantly lower than production efficiency, there is a clear need to revise capital allocation practices. Enterprises should focus on enhancing profitability through targeted investments in high value-added products and more efficient management of working capital.

Strategic implications

Policymakers can play a critical role in supporting the sector by:

- Providing tax incentives for investments in sustainable practices, such as the use of renewable energy sources and waste reduction.
- Offering financial tools to support small producers in improving their efficiency.

- Promoting clusters and collaborations to disseminate best practices and reduce costs through shared infrastructure.

Collaboration among enterprises can act as a catalyst for achieving better efficiency. The creation of sectoral clusters and the exchange of expertise can enhance the dissemination of advanced technologies and reduce costs. Efficiency improvement, especially among businesses operating near the efficient frontier, can enhance the competitiveness of Greek products in international markets. The exports of strained yogurt, already a cornerstone of the sector's global presence, can be strengthened through product diversification and quality improvement. Transitioning to sustainable practices, such as reducing the environmental footprint, can provide a competitive advantage, particularly in environmentally conscious markets. The adoption of green technologies and compliance with international standards (e.g., ISO 14001) enhance product credibility and market penetration in demanding markets. Enterprises in the sector must adopt a comprehensive strategy that combines optimizing efficiency in production and investments, aligning with international trends, and integrating sustainable practices. Fully efficient enterprises can serve as benchmarks, helping disseminate best practices across the sector. Collaboration with policymakers to implement the above recommendations can strengthen the Greek dairy sector's position in global markets.

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eWOM vs. aWOM: AI Powered Word of Mouth and its Impact on Consumer Decision Making in Tourism

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Abstract: This paper explores the impact of artificial intelligence (AI) on consumer behaviour in the online tourism industry, focusing on two types of Word of Mouth (WOM): electronic Word of Mouth (eWOM) and Algorithmic Word of Mouth (aWOM). While eWOM, driven by consumer-generated content on platforms like TripAdvisor, influences travel decisions, aWOM uses AI to provide personalized recommendations based on data analysis. Despite its potential for greater personalization, aWOM raises concerns about transparency and authenticity. The study, using in-depth interviews and a focus group, reveals a general preference for eWOM due to its perceived authenticity, with participants valuing credible, detailed reviews. The findings suggest that aWOM can complement eWOM but should be used cautiously in the tourism industry to maintain trust and transparency.

Keywords: eWOM; aWOM; AI generated content; trust; credibility; consumer reviews.

JEL classification: M31; M37.

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1. INTRODUCTION

In the digital era, the way consumers make decisions about products and services is increasingly influenced by online conversations, particularly through electronic word-of-mouth (eWOM). As the digital interactions grow, eWOM has emerged as a significant factor in shaping consumer behaviour, particularly within the tourism industry. However, with the rise of artificial intelligence (AI), a new form of word-of-mouth, algorithmic word-of-mouth (aWOM), has begun to take shape. Unlike traditional eWOM, which is generated by human users, aWOM is powered by algorithms that analyse vast amounts of data to provide personalized recommendations. This shift introduces a new layer of complexity to online reviews and consumer decision-making.

The novelty of this topic lies in the relatively unexplored territory of aWOM and its potential to transform consumer decision-making processes in the tourism industry. While eWOM has been widely studied, the application of AI to generate personalized recommendations – through aWOM – is an emerging area of research. This introduces important questions about the effectiveness, trustworthiness, and personalization of algorithmically generated content compared to user-generated reviews. This study seeks to bridge this gap by exploring how aWOM influences consumer perceptions and behaviours in ways that differ from traditional eWOM.

This study investigates the impact of aWOM on consumer purchase intentions, particularly in the context of travel services, and compares the perceived credibility of eWOM and aWOM. It also explores the factors that influence consumer decision-making, focusing on how consumers evaluate and trust these different forms of word-of-mouth when choosing travel-related services. By examining these aspects, the research aims to provide insights into how aWOM could complement or even replace eWOM in the future, offering businesses in the tourism industry guidance on adapting their marketing strategies in response to this shift.

The research gap identified in this study lies in the limited exploration of aWOM within existing literature. While eWOM is well-researched and its impact on consumer decision-making is well understood, the effect of AI-driven recommendations – aWOM – on consumer behaviour remains underexplored, particularly in terms of trust, credibility, and personalization. This gap presents a unique opportunity for this study to contribute new insights into how aWOM could complement or even replace traditional eWOM in the future, particularly in the context of online travel services. Understanding how consumers respond to aWOM versus eWOM can help businesses in the tourism industry adapt to evolving consumer expectations and enhance their digital marketing strategies.

The main objectives of the research are to assess the impact of aWOM on consumer purchase intention, compare the perceived credibility of eWOM and aWOM, and explore the factors that influence consumer decision-making in the context of online travel services. By examining the similarities and differences between these two types of word-of-mouth, the study aims to inform businesses in the tourism industry on how to best utilize both forms to enhance customer engagement and decision-making. Additionally, the study seeks to provide insights into the future potential of aWOM in shaping consumer behaviour in an increasingly digital world.

This article, through its comprehensive methodology and research objectives, provides valuable insights into the evolving role of digital word-of-mouth in influencing consumer decisions and lays the foundation for future studies exploring the ethical and practical applications of AI.

2. LITERATURE REVIEW

In today's digital age, where conversations about products and services happen mostly online, electronic word of mouth (eWOM) is becoming an essential element in purchasing decisions. In parallel, algorithmic word of mouth (aWOM), eWOM generated by artificial intelligence (AI), implicitly by algorithms, adds a new and interesting perspective to the way consumers interact and perceive online recommendations.

2.1 Electronic Word of Mouth (eWOM): Definition and Scope

Word-of-mouth (WOM), which can be loosely defined as personal recommendation or person-to-person recommendation, is the initial connections between customers about a brand (Abbas *et al.*, 2020). In this paper, we use the term eWOM to describe "any positive or negative statement made by potential, current or former customers about a product or company that is made available to a wide range of people and institutions through the Internet" (Hennig-Thurau *et al.*, 2004). Therefore, eWOM occurs when consumers exchange information online and can be observed in various forms, such as user-generated content, online reviews of products or services, personal emails and social media posts.

The study by Babić Rosario *et al.* (2020) addresses the lack of clarity in defining the concept of eWOM. It is emphasized that any content generated by online consumers about products, even if it is not a recommendation directed to other consumers, should be recognized as eWOM. To understand the phenomenon holistically, it is proposed that the term 'eWOM' should serve as an umbrella term for online consumer-generated content. However, it is necessary to clarify the concept of eWOM by distinguishing its essential properties from those of related concepts such as: general information sharing, offline WOM, critic reviews, advertising, consumer-generated content, electronic recommender systems, online search rankings and observational learning. For example, unlike UGC, which refers to any content created by users and distributed primarily online, eWOM is necessarily and clearly related to consumption.

To facilitate the consistent use of the eWOM concept and the progressive building of knowledge on the subject, the authors offer the following revised definition: eWOM is consumer-generated, consumer-related communication that uses digital tools and is mainly directed to other consumers. This proposed definition succinctly addresses the prevailing confusion about the concept and allows the delineation of key competencies for theory development:

- source (i.e. consumers as eWOM emitters);
- the message (consumer-related content);
- the channel (digital conversation tools).

eWOM has been shaped by the growth of Internet use and shows significant differences from traditional word of mouth in two key aspects: the first relates to the number of people participating in the conversation (eWOM involves communication between a large number of users) (Gretzel and Yoo, 2008), and the second to the speed of communication (eWOM is faster than WOM) (Akbari *et al.*, 2022). On the Internet, not only can firms build relationships with their customers, but also customers can share their opinions, ideas, experiences, and information with a vast community of other customers (Akbari *et al.*, 2022).

eWOM represents unpaid communication by online users and is accessible to a wider audience, including both direct and indirect customers, as it can be distributed in online spaces. eWOM plays a crucial role in influencing the decision-making process of tourists and can take various forms such as reviews, recommendations, social media posts and blogs. In addition, it operates through a variety of modes, facilitating one-to-one or one-to-many interactions, and can occur in real time (synchronous) or with time delays (asynchronous) (Williams *et al.*, 2020).

Consumers rely on eWOM to assess the quality of services, and it is becoming a key factor in the decision-making process. eWOM also shapes expectations and customer satisfaction levels by providing information about the experiences of others (Chen and Law, 2016). eWOM plays a vital role in the consumer's decision-making process from initial consideration stage to post-purchase behaviour.

Verma and Dewani (2021) present nine variables associated with the sender that have a significant impact on the credibility of eWOM. These variables are as follows: source credibility which refers to how the receivers perceive the information source, homophily and strength of connection which focuses on the similarity between the information source and the receiver and the level of connection and influence it has with the receivers, source expertise which reflects the level of knowledge of the source, source trust which implies the degree of trust placed in the source, source attractiveness which relates to the physical attractiveness or personality of the source, source identity which refers to how the source is perceived and recognized, sponsorship disclosure which involves disclosing any sponsorship relationships. Previous studies have established that sponsorship disclosure significantly influences source credibility and changes attitudes towards the eWOM message. When consumers know that the reviews are written for personal benefit, it reduces the perceived quality of the information provided. Therefore, when the issuer receives financial incentives for providing online reviews, this negatively affects the credibility of eWOM. This complex relationship between sponsorship disclosure, source credibility and perceived information quality emphasizes the importance of transparency in online reviews. The last variable is social capital which represents the resources and benefits that people gain through social interactions. This social capital can be divided into two types: bridging and bonding. The former refers to weak ties and provides useful information to connections a distance, while bonding refers to strong ties and is linked to social and emotional support.

2.2 Algorithmic Word-of-Mouth (aWOM): Definition & Scope

The recent spread of artificial intelligence (AI) raises questions about how consumers react to these innovative technologies. In addition, the global accessibility of AI plays a key role in adoption and adaptation to these technologies. This global expansion opens new possibilities for improved interactions between services and consumers. As the study by Williams *et al.* (2020) indicates, aWOM represents algorithmically created and distributed content from non-human sources, media digital or eWOM, using artificial intelligence (AI) algorithms. This form of communication is designed to support customer decision-making about destinations, activities and more. AI-driven recommendations are powered by algorithms that analyse huge amounts of beats to predict user preferences and suggest options relevant to the consumer (Brooks, 2022).

Continuing the discussion of the innovative aspects of aWOM, it is important to recognize its ability to leverage technology in a way that far exceeds the capabilities of eWOM. A key example of this relates to the use of AI assistants on mobile devices. In such scenarios, aWOM can integrate additional contextual information gleaned from previous user interactions. Here we include details such as travel patterns, sensor data from personal devices and social media. This exhaustive data integration allows aWOM to personalize content to a significantly greater extent than is possible through eWOM (Williams *et al.*, 2020).

A relevant example of this is how a software robot can use location sensors and eWOM reviews. Based on the user's current location, the robot can analyse the sensor data together with existing eWOM recalls creating a text or voice message. This message could describe the current state of nearby attractions, for example their degree of crowding (Williams *et al.*, 2020).

This example highlights the unique potential of aWOM to improve the personalization and relevance of information for users, especially in the context of online travel services. Such advanced personalization gives aWOM a special status as a transformative tool in online consumer behaviour. In this context, artificial intelligence is a valuable tool for improving customer experience.

Another concrete example of the use of AI is its application in analysing and managing guest reviews. Guest reviews are a treasure trove of information for hotels, providing insights into guest satisfaction levels and potential improvements needed in service. Another benefit of AI in this context is its ability to automatically generate responses to different reviews. This facilitates communication and building a strong relationship with customers (Candela, 2023).

Another study by Longoni and Cian (2022) introduces a concept called word of machine. This effect is based on the belief that AI is more competent at evaluating utilitarian attributes (such as practicality and functionality), but less competent at hedonic attributes (such as enjoyment and satisfaction). aWOM and word of machine reflect the same fundamental idea, in that aWOM can be considered a specific application of the broader concept of word of machine.

In tourism, this can manifest itself through AI systems that provide personalized travel recommendations based on utilitarian data (such as location and travel patterns), while attempting to enhance the hedonic experience by considering individual preferences and past consumer behaviours. This highlights the potential of aWOM to revolutionize decision making in the tourism industry through a balanced approach of utilitarian and hedonic aspects.

What is interesting to note is that the success of AI in influencing consumer decisions seems to be more pronounced when AI does not completely replace human recommendations but works together with humans. When AI assists a human recommender and supports them in the process of providing information or options, consumers appear to be more likely to receive and trust those recommendations (Longoni and Cian, 2022).

In this way, AI does not take over the role of final decision-maker but becomes a key tool that helps amplify the experience. This collaboration between technology and human intelligence represents a promising outlook for the future, where the benefits of both sides can be brought to the forefront to deliver better and personalized experiences to consumers.

According to the study conducted by Huang and Philp (2021), it is observed how consumers are more reluctant to share negative opinions after a failure of a service using AI compared to a human one. This difference is due to the perceived link between consumers and AI, which uses previously analysed data to predict future preferences. The study emphasizes the importance of understanding the interactions between consumers and AI and

suggests that firms should carefully implement AI in their services, taking these dynamics into account.

In this way, in the context of AI and eWOM-based recommendations, we can summarize the synergy between these two elements enriches the shopping experience of the modern traveller, giving them the tools to guide them towards a more informed decision. While AI-based recommendations offer high personalization, eWOM adds a layer of social proof and credibility by reflecting the experiences and opinions of real users (Longoni and Cian, 2022).

Table no. 1 – Differences between eWOM vs aWOM

Feature	eWOM	aWOM
Source of Content	**Consumer-generated content**	**AI-driven content**
Personalization	Based on individual experiences	Based on algorithmic predictions of user preferences
Transparency	Transparent, source identifiable	Potential lack of transparency regarding AI influence
Credibility	Perceived as authentic, human-driven	May lack authenticity, seen as less human
Speed of Communication	Slower, time-dependent	Faster, real-time updates
Ethical Concerns	Minimal, but can be biased in some cases	Algorithmic bias, privacy concerns, manipulation potential
Privacy Issues	Limited to shared personal experiences	Rely on extensive data mining, including personal data without explicit consent
Trust	High trust in user-generated reviews	Lower trust, especially when AI involvement is unclear
Impact on Consumer Behaviour	Influences based on social proof	Highly influences through personalized suggestions

Source: own processing

2.3 Tourist Experience in the Context of eWOM and aWOM

The effects of eWOM on consumer behaviour in the context of hospitality and tourism management are complex and significant. eWOM influences consumers' attitudes towards products and services, leading them to make purchasing decisions and express their intentions.

The tourist experience comprises several distinct but interconnected stages. It is not just limited to the moment you arrive at the destination but begins with the planning and preparation phase (anticipation), continues during the trip when tourists are physically present at the location, and extends beyond the trip by capturing memorable moments and retrospection of the trip (reflection) (Miao and Yang, 2023). In other words, the tourist experience is influenced by the entire process planning to subsequent memories and reflections.

First, the more informative the reviews a hotel accumulates, the more likely subsequent users are to post informative reviews, and these reviews are more likely to receive peer recognition ('helpful votes'). Second, reviews that give low ratings are more likely to create 'hot topics' for users, motivating them to contribute more informative and helpful reviews. Other studies have observed that, compared positive reviews, negative reviews attract more attention from readers and are more likely to be considered useful (Boo and Busser, 2018), while another study finds that negative reviews (mainly low-rated reviews with no other

comments) can motivate subsequent consumers to post higher quality reviews. Third, reviews posted by reviewers with a high reputation on the platform may prompt subsequent users to contribute their own high-quality reviews about the same hotel.

This feedback amplification effect can occur for two ulterior motives: (1) based on the above reasons, people want to conform to an established social norm in that they post high-quality reviews like others; (2) more high-quality reviews or reviewers with a high reputation willing to post reviews can increase the popularity of the hotel.

Based on the study conducted by Majeed *et al.* (2020), it is observed that there are other incentives for posting eWOMs, influenced by the quality of online information and the ease of accessing it. The results of the study conducted by Majeed *et al.* (2020) emphasize that there are other incentives that contribute to the increased tendency of tourists to distribute eWOMs, these are the high quality of information available online, along with an accessible and easy to navigate platform.

According to another study, conducted by Moliner-Velázquez *et al.* (2023), we can state that motivations for consulting eWOMs play a key role in shaping attitudes towards eWOMs in the online tourism industry. Of the two eWOM characteristics proposed as antecedents of motivations (credibility and volume), only perceived credibility was found to have a significant effect. This emphasizes the need for companies in the tourism industry to develop and maintain a solid reputation to gain consumer trust and ensure that eWOM remains positive.

This trend of increasing online booking has changed the way the tourism industry operates, with the focus largely on online presence and digital reputation management. This emphasizes the importance of technology and digital platforms in the contemporary tourism industry (Elsaid and Sayed, 2022).

A consumer's decision to purchase tourist accommodation is influenced by a number of criteria, including the reviews left by previous customers. It is important to note that a significant majority of consumers, around 60%, rely on customer comments and reviews in their decision-making process when making a purchase. Furthermore, an impressive 90% of consumers recognize that these reviews have a significant impact on their decision to make a purchase (Garcia *et al.*, 2022).

Customer satisfaction is determined by a wide range of characteristics, both tangible (such as room decor, design and cleanliness) and intangible (service quality) (Sparks and Browning, 2011).

According to Rize Reviews, hotels are the second industry most impacted by reviews, surpassed only by restaurants, which ranks first (Serrano, 2020). 96% of travellers consider reviews important in the research phase of planning a vacation, and 83% say reviews play a key role in their final booking decision. Furthermore, 52% of people would never book a hotel that has no reviews (Elphick, 2023).

To conduct a comprehensive analysis of consumer behaviour regarding online tourism services, it is essential to highlight the most extensively used platforms in the context of reviews. While general review platforms, such as Facebook, may provide a wider audience, hotel review websites bring in a higher percentage of potential customers. According to the article by Lyman (2023) for Podium, these platforms are:

– TripAdvisor - The world's largest travel platform gathers a staggering 490 million monthly users and hosts around one billion reviews (Tripadvisor - Statistics & Facts, 2024). 72% of consumers consult reviews before booking (Campbell, 2023).

– Booking.com is known as one of the world's top choices for booking travel, especially in Europe. The site currently has nearly 30 million listings in the hotel sector and collects over 240 million reviews. Booking.com's algorithm takes hundreds of factors into account to personalize recommendations for each individual user. It analyses individual booking history and preferences, ensuring that users are presented with options that are folded on previous bookings. Although review scores play a role in the algorithm, they are not the main ranking criteria. However, many users use the review score filter to quickly find high-quality options, typically looking for hotels with scores above 8 (Report Recap: The Hotelier's Guide to Booking.com, 2023).

– Google - Although Google is not specific to tourism reviews, it is worth adding because of its general importance. Customers often use the Google search engine to compare properties based on location, prices and, of course, reviews. This feature gives users a simple and convenient way to evaluate and choose accommodations that meet their needs. Google reviews have become increasingly popular and have become a favourite mobile search platform, impacting hotels and other businesses. Google offers reviews integrated into Google searches and Google Maps, making it easy for users to access reviews and other information. Simplicity of use, integration, and authentic user reviews have contributed to its popularity, while other platforms such as TripAdvisor have faced challenges with advertising and user trust (Filieri *et al.*, 2020).

2.4 Trust and credibility in aWOM

An important aspect in evaluating aWOM is the perceived credibility of users. Studies show that although AI-generated reviews can be highly personalized and relevant, users may be sceptical about the transparency of the generation process and the lack of an authentic, human voice (Al-Hyari *et al.*, 2023). However, aWOM has the potential to influence purchase decisions through highly accurate recommendations based on extensive data and predictive analytics.

AI-based systems are used in offering suggestions for hotels, flights and other ancillary travel services based on user preferences, behaviour and budget. By meticulously analysing customer data, these systems look for patterns and trends in past trips, enabling the delivery of highly personalized recommendations. This personalized approach enhances user satisfaction by aligning with current individual preferences, as well as the revenue the company generates. The continuous learning capabilities of AI algorithms help to constantly refine recommendations, ensuring that they remain in line with changing customer preferences and market dynamics.

A relevant example for aWOM is TripAdvisor, which uses artificial intelligence to synthesize and present the most relevant information from many reviews. For example, a travelled looking for a clean and quiet hotel room can quickly access a summary that highlights these attributes, along with direct quotes from the original reviews. This simplifies the decision-making process, allowing users to make informed choices without having to wade through numerous individual reviews. This presentation is built on the summaries assigned to each qualitative attribute within the reviews, reflecting users' overall unbiased opinions according to the aspects they value most. The summaries are designed to be easy to read, are of optimal length, and are strictly based on quotes from the reviews. This process ensures the unbiasedness and authenticity of the experiences reflected, thus enhancing credibility and trust in the information presented (Gang and Raja, 2024).

However, the emergence of these summaries highlights weaknesses of generative artificial intelligence: inaccuracy and misleading information (Mauran, 2024).

In addition, the ethical implications of AI, including aWOM, are a topic of current concern, bringing into question privacy, surveillance, algorithmic discrimination, and the potential for AI to manipulate and spread misinformation. These developments emphasize high influence and ethical considerations related to aWOM, highlighting the importance of rigorous regulations and practices ensure a trustworthy and transparent environment for users (Akdim, 2021).

According to Palmer (2023) some Amazon reviews are created by robots, by AI. This practice raises serious concerns about the authenticity and credibility of reviews. Fake reviews can influence consumers' purchasing decisions by presenting products in a more favourable light than they would be or, conversely, unduly denigrating them. This manipulation can undermine consumer trust in platforms and the online shopping process in general. Although this example comes from Amazon, an e-commerce platform, this is also relevant for us.

If inaccuracies and misinterpretations go unnoticed, these summaries - presented authoritative - could damage the reputations of the products and, by extension, aWOM. This could lead to a loss of trust in the algorithms that govern aWOM and, ultimately, to a decrease in the credibility of the whole recommendation process. Thus, it is important to have filtering and verification systems in place that in an efficient way ensure the authenticity and accuracy of the information presented to consumers, thus protecting the integrity and reputation of aWOM (Mauran, 2024).

The impact of fake reviews is particularly relevant in aWOM because it relies on reviews and ratings already existing online to guide consumers' purchasing decisions, and fake reviews can distort these automatic recommendations. The importance of reviews in booking phase is particularly pronounced, with an overwhelming majority of travellers assigning them increased importance. Specifically, (Meng, 2024) indicates that 82% of travellers emphasize the relevance of reviews when selecting accommodation, while 77% consider them crucial in evaluating attractions. This underlines the considerable influence exerted by reviews in guiding travel-related choices, earning their role as indispensable sources of information for discerning consumers. If the reviews are not authentic, trust in aWOM may be significantly affected and consumers may be less willing to rely on these automated recommendations in the future.

Declining trust is also a challenge for platforms that rely on user-generated content. Users experienced a 2% increase in fake reviews on TripAdvisor in 2022 (Meng, 2024). This trend is worrying and highlights the importance of countering the phenomenon of fake reviews. It is essential that platforms invest in technological solutions and more rigorous verification processes to ensure that the reviews submitted are authentic and trustworthy, thereby strengthening credibility and trust online.

aWOM tools could generate content using information collected from the sensors of personal smart devices, thus raising privacy and information security concerns, especially for users who have not consented to such activities (Williams *et al.*, 2020).

Finally, aWOM's trust and credibility play a key role in shaping consumer perceptions and decisions in its eventual use. Highlighting these factors allows us to more deeply understand the impact of technology on consumer behaviour. In doing so, companies and marketers need to highlight their efforts towards a transparent policy towards the use of AI. Going forward, the balance between ethics and innovation will determine the success of aWOM.

2.5 Ethical Concerns of aWOM

Despite the advantages of aWOM, several ethical concerns need to be addressed, particularly around algorithmic bias, privacy, and transparency. Algorithmic bias refers to the potential for AI systems to perpetuate biases present in the data they are trained on. If the training data includes biased or unrepresentative information, the AI could generate skewed recommendations that favour certain groups, products, or services. For example, an AI system might prioritize luxury hotels over budget-friendly options, even when the latter might better suit a user's preferences or needs. This bias can lead to an unfair distribution of recommendations, undermining the trust consumers place in AI-driven systems and reinforcing existing inequalities (Akdim, 2021).

Privacy concerns are another significant ethical issue with aWOM. AI-driven systems rely on extensive data collection, including browsing history, preferences, and even location data, to make personalized recommendations. While this allows for a more tailored user experience, it raises questions about the extent to which consumers are aware of and consent to the data being collected. In many cases, users may not fully understand how much personal data is being gathered, nor how it is being used by the platforms they interact with. This lack of awareness can lead to privacy violations, as well as concerns about data security. Moreover, AI systems are often vulnerable to data breaches, which could expose sensitive consumer information and lead to a loss of trust in the system (Brooks, 2022).

The lack of transparency in aWOM is another critical ethical concern. Since AI algorithms often function as "black boxes," consumers are typically unaware of how their data is being used to generate recommendations. This lack of transparency makes it difficult for users to understand the rationale behind the suggestions they receive, potentially leading to feelings of manipulation. Without clear disclosure of how AI influences the recommendation process, consumers may question the authenticity and fairness of the content they encounter, further diminishing trust in aWOM (Longoni and Cian, 2022). Transparency is essential not only to maintain consumer trust but also to ensure that AI systems are being used ethically and responsibly.

While eWOM remains a powerful tool in influencing consumer decisions, aWOM offers unparalleled personalization that could reshape the tourism industry. The potential for aWOM to replace or complement traditional eWOM depends on how companies navigate the ethical implications of AI. For example, AI-generated content could be more effective when it works alongside human recommendations rather than replacing them entirely. Studies suggest that consumers are more likely to trust recommendations when AI assists human reviewers rather than fully automating the process (Longoni and Cian, 2022). This collaboration between human intelligence and AI-driven algorithms may lead to more effective and trustworthy recommendations, offering a balanced approach that combines the strengths of both systems.

The ethical concerns surrounding aWOM necessitate careful consideration of how AI is integrated into the consumer decision-making process. As the tourism industry increasingly embraces aWOM, it will be essential to address issues of algorithmic bias, privacy, and transparency to ensure that these technologies enhance rather than undermine consumer trust. The balance between innovation and ethics will ultimately determine the success of aWOM as a tool for influencing travel-related decisions.

aWOM represents a transformative force in the tourism industry, offering highly personalized recommendations that improve consumer decision-making. However, to fully realize its potential, it is essential to address the ethical challenges associated with its use. By

ensuring transparency, minimizing bias, and protecting user privacy, businesses can foster trust in aWOM while enhancing the customer experience. As AI continues to evolve, the future of aWOM will depend on how well the industry balances innovation with ethical responsibility.

3. RESEARCH METHODOLOGY

The aim of this research is to analyse and compare the impact of these two forms of WOM on online travel consumer behaviour. Objectives include understanding consumer preferences, the average budgets allocated to online bookings, the decision makers involved, as well as information on the online travel service platforms used. It will also explore the potential impact of aWOM implementation and how it could influence purchasing decisions. Thus, this paper aims to contribute to better, more effective and user-oriented marketing strategies in the online tourism industry.

The purpose of this research is to find out how companies in the tourism industry can successfully use eWOM and aWOM to increase their visibility and attract more tourists, taking into account the differences in credibility, persuasiveness and impact on purchase intention. This leads to the research problem, which is framed as follows: to determine the optimal strategies for using eWOM and aWOM to increase visibility and attract more tourists in the tourism industry, taking into account the differences between the two types of information in terms of credibility, persuasiveness and impact on purchase intention.

The objectives set for this research are the following:

O1. To assess the impact of aWOM on consumers' purchase intention of online tourism services.

O2. To evaluate the perceived difference between aWOM and eWOM among consumers.

O3. To compare consumers' level of trust in aWOM versus eWOM.

O4. To explore the link between purchase intention and eWOM and aWOM.

Therefore, O1 and O2 will be followed up through the interview, and O3 and O4 through the focus group.

In the present study, research on online tourism consumer behaviour will be conducted using qualitative methods. Qualitative research is conducted in an objective way, and the combination of using several methods, such as interview and focus group, allows us to get a deeper and more complete understanding of the reality.

In this case, to achieve a rigorous qualitative research, two techniques were used: the interview and a focus group. The approach was sequential, using several qualitative methods to assess participants' perceptions. The research period was between May-June of 2024, both interviews and the focus group have been conducted online, with the use of virtual meeting platforms.

To gain an initial understanding of participants' level of knowledge on the topic, the research began with an in-depth interview. This interview was designed to explore participants' previous experiences of eWOM and aWOM. The interview included open-ended questions designed to reveal participants' perceptions and behavioural attitudes (Annex 1). In this part of the study, 12 participants were chosen based on their frequency of travel, with all participants traveling approximately 3-4 times per year. The sample was diverse, consisting of individuals from various professional backgrounds: 3 doctors, 3 assistant managers, 2 in finance, 1 in construction, 1 in teaching, and 1 in IT. This diverse sample ensures a variety of

perspectives, as it captures differences in the budget allocated to traveling and a broad range of opinions. The diversity of the participants is relevant, as it provides insights into how different professional backgrounds may influence perceptions of eWOM and aWOM in the context of tourism services, thus offering a well-rounded view on consumer behaviour.

A focus group was organized in which, 7 participants were selected from the ones which participated in the first part of this study – the interview, and they were presented with different examples and forms of eWOM and aWOM (Annex 2). The aim of this focus group was to facilitate an interactive discussion, allowing participants to express their ideas and interact with other opinions. Focus group discussions were carefully moderated and recorded for analysis. The target audience for the focus group as well for the interviews consisted of:

– People who frequently book travel and accommodation online.

– Users of online review platforms for tourism services.

– People who used Booking before.

To conduct the focus group experiment we generated reviews using an artificial intelligence system, specifically ChatGPT-4o. These reviews were created in support of our experiment to reflect the diversity and variety found in the online environment, on Booking platform. Each of the reviews was designed to simulate the authenticity offered by a human reviewer but also included different styles and tones of expression (these reviews can be found in Annex 2).

To support the reviews in photographic form, different elements were also added to enhance their credibility, these were:

– Perceived usefulness indicator displayed by the number of people who found the review useful.

– New accommodation on Booking that reflects the timelines and relevance of the user experience.

– Some reviews are marked with "most liked review", indicating a high number of votes and likes.

– AI-generated content warning providing transparency for users.

– Overall score provided by the reviewer to give an overview of the quality of the stay.

Another element found in booking reviews is structuring them by highlighting their strengths and weaknesses, highlighted by happy emoji and sad emoji.

By introducing these elements, we wanted to instil credibility and transparency to participants, thus contributing to an improved user experience and trust in review platforms and AI.

TripAdvisor and Booking.com were chosen for this study due to their significant popularity and wide usage in the travel and tourism industry. TripAdvisor, as one of the largest travel platforms globally, hosts millions of user-generated reviews, ratings, and recommendations, making it an essential source for studying eWOM. Its focus on destinations, attractions, and services adds depth to understanding how consumers make decisions based on shared experiences. Booking.com, on the other hand, is a key player in online hotel bookings, where user reviews directly influence purchasing decisions. This platform is especially relevant because its reviews are tied directly to bookings, providing insights into consumer behaviour during the decision-making process. We chose to focus on TripAdvisor and Booking not only because they are among the most popular travel review platforms, but also because, at the time we started documenting the topic of artificial intelligence in tourism, they were already among the few platforms that had already integrated

some AI-based functionalities directly into the user experience. Another reason for choosing these platforms is the fact that they appear frequently in both interviews and the focus group. At that time, in 2024, TripAdvisor used AI technologies to personalize recommendations, aggregate relevant reviews, or highlight the most useful information from user feedback.

4. RESULTS

4.1 Interview results

In this sub-chapter, we present the themes identified from analysing the interviews that support our research objectives.

The first theme identified was *Online Channels and Resources for Travel Planning*, which resulted from grouping the questions *Do you often travel within a year? Tell me about your approach to planning a holiday*, *Which online platforms do you frequently consult for information about travel destinations, accommodation, flights or other travel services?* and *How much do online reviews influence your travel booking decisions*. These questions were posed at the beginning to introduce participants to the topic of the discussion and guide them through the steps involved in planning a vacation.

Table no. 2 provides a detailed analysis of consumer preferences and travel planning behaviour. This information is relevant for understanding how consumers interact with the online environment in the context of travel services.

Table no. 2 – Online channels and resources for travel planning

Category	Item	Frequency
Platforms Used	Booking.com	12
	AirBnb	5
	Airlines websites	5
	TripAdvisor	4
	Facebook groups	4
	Skyscanner	3
	Momondo	2
	Google Flights	1
Inspiration	TikTok	4
	Pinterest	1
Platform Choice Factors	Quality of reviews	8
	Number of reviews	8
	Platform reputation	7
	Details of the information	3
	Specific functionalities (filters)	1

Source: own processing

When it comes to travel frequency and organizing vacations, most participants report traveling at least once or twice a year. Some, like for example, respondent 1, travels more frequently but prefers short trips relatively close to home. The planning process generally starts with determining the destination, securing transportation, and checking accommodation prices. For example, respondent 5 said, “Several times a year. If traveling by air, I choose my flight tickets from the airline's website and then purchase accommodations from sites like

Booking/AirBnb.". Respondent 6 also noted, "I think about where I'd like to go, look for tickets to see the best price, and then I look for accommodation sometime after the vacation."

The data analysis revealed a predominant preference for using popular booking sites such as Booking, which were mentioned most often 12 times. Opinions were also split between AirBnb and airline websites such as WizzAir or RyanAir, each being mentioned 5 times. This preference can be attributed to the high level of trust that consumers have in these platforms, as well as the ease of use and variety of options on offer. It is also important to consider platforms that facilitate price comparisons, such as Momondo, mentioned by 4 respondents. Respondent 3 stated they use "Booking, TikTok, Google Flights, Skyscanner" while respondent 9 prefers "Facebook groups dedicated to people who have been/will go on vacation." Respondent 12 added, "I mainly use Booking and sometimes AirBnb, depending on what prices I find on accommodations. For flights, I use company websites but also Momondo."

In terms of their main source of travel **inspiration**, TikTok plays a significant role for a significant number of respondents (4 out of 12), thanks to its engaging and easy-to-view content. Content creators promote destinations and travel experiences that are affordable for any budget. Pinterest is also mentioned as a main source by only one respondent.

When it comes to factors influencing **the choice of a platform**, respondents attach equal importance to both the quality and quantity of reviews. Reputation is also an important factor, with frequency of 7 out of 12. For instance, respondent 7 noted, "I choose a platform by the number of reviews, user trust scores, and honest reviews." Respondent 12 agreed, emphasizing the importance of a "significant user base" and "verified reviews," while Interview 2's respondent mentioned the importance of the "length of comments/reviews" as a key indicator of reliability.

The types of information that travellers seek out in eWOM sources often vary. Many look for detailed descriptions, real photos, and videos of destinations, accommodations, and experiences. As respondent 4 explained, "I look for detailed descriptions, photos, and prices," while respondent 10 added, "It helps me most if I have real photos and videos. From there I can draw conclusions and form my own opinion." Many also seek out practical advice, such as "how quiet is the area" or "how comfortable is the bed," as respondent 11 said when selecting accommodations.

One objective we set out to achieve is related to the level of trust in eWOM. Therefore, based on two questions, *What types of information do you specifically look for in eWOM sources?* and *How do you assess the usefulness and trustworthiness of information found in eWOM sources?*, we have identified the theme *eWOM Preferences* (see Table no. 3).

The analysis also reveals that respondents attach considerable importance to the information available online. Specifically, user reviews are a decisive factor in the choice of destinations, accommodation or other tourism-related activities, with every respondent having the answer. They consistently emphasized the value of reviews in forming a realistic picture. One respondent stated that "*In general reviews are a good factor to determine the quality of a service/offer"*.

In addition to reviews, photos or videos, i.e. visual content, also play an important role in the planning process. 7 out of 7 respondents felt that they value the possibility to visualize destinations or facilities before making a booking. One respondent says: "*It helps me most if I have real photos and videos. From this I can draw conclusions and form an opinion*". Tips or tips and tricks are also actively sought by participants, who are interested in practical or personalized information to transform their experience.

Table no. 3 – eWOM preferences

Category	Item	Frequency
Types of Information Sought	Reviews	12
	Photos and videos	7
	Tips & tricks	6
Specific Details Sought in Reviews	Cleaning	5
	Comfort	3
	Negative sides	3
	Quiet	1
	Positive sides	1
	Specific experiences	1
Rating Reviews	Number of similar reviews	7
	Writing style and tone	6
	Source check	2

Source: own processing

When it comes to specific elements sought in the reviews, cleanliness (5 responses), comfort (3 responses) and negatives (3 responses) are key aspects. This reflects the need for a pleasant but carefree experience.

In evaluating online information, respondents consider it important to evaluate a review in the context of its veracity. Specifically, respondents pay attention to the number of reviews written in a similar way (7 answers), the writing style and tone of the review (6 answers), but also to checking the source of the information (2 respondents). Respondent 5 stated, "I check more reviews." while respondent 10 said "I usually look at multiple reviews and on different platforms to make sure the reviews are truthful.". These factors are pillars in determining credibility but also relevance. These factors help form a clear perception, which facilitates a user's satisfaction.

These observations bring to the forefront the behaviour of users as active and critical in evaluating online information, seeking to ensure its veracity and personal relevance before deciding.

The theme below we can say that it is a mixed theme, containing elements related to the participants' preferences as well as the behaviours exhibited during travel. So, its name is *Travel Preferences and Behaviours* (see Table no. 4).

Table no. 4 – Travel preferences and behaviours

Category	Item	Frequency
Frequency of Travel	2-3 times a year	6
	From	5
	Once a year	1
Type of Trip	Long vacation	4
	City break	3
	Exotic destinations	1
	Exploring Romania	1
Travel Planning	Planned	7
	Spontaneous	5
Travel Companions	Alone	3
	Group of friends	2
	Family	1

Source: own processing

Respondents' frequency of travel is varied, with most opting for 2-3 trips per year or frequent trips. This diversity reflects differences between respondents in terms of priorities, but also in their pace of life. In terms of type of travel, preferences tend towards long vacations (4 answers) and city breaks (3 answers).

Travel planning is split between spontaneity and careful planning. Some prefer to enjoy surprise trips (5 responses), while others appreciate details and careful organization (7 respondents). One respondent state "*I often find myself looking for new vacation locations, so I can say that with me everything is more spontaneous*".

In the case of travel companions, most respondents prefer to travel alone, motivated by a desire for freedom in exploring destinations. Travel with a group of friends (2 responses) is also popular, which may reflect a desire to socialize. Although only one respondent mentioned traveling with family, these trips are important for spending quality time together as well as for memories.

These preferences may vary depending on different factors (type of trip, destination, budget, etc.). One respondent mentioned that they prefer to organize their holidays *"together with someone to be more manageable"* and another that *"I choose the destination, I decide the group of friends I go with"*, suggesting that they choose the company according to ease of organization or social preferences.

Table no. 5 offers details of previous experiences with AI, if any, views on the credibility and usefulness of AI-generated recommendations, and future willingness to use such tools. In this case information was extracted from questions *12. Have you interacted with chatbots, virtual assistants or other AI systems that provide travel recommendations or tourist information, 13. To what extent do you consider AI-generated reviews to be objective and trustworthy compared to those of real users?* and *14. How much do you think AWOM recommendations would influence your travel booking decisions.* This information is relevant to the research as it indicates an opportunity to introduce and promote these tools. Moreover, it helps to tailor the way of communication to build trust.

Table no. 5 – Attitudes and perceptions towards AI

Category	Item	Frequency
Interaction with AI	Mistrust	11
	No	10
Perception of AWOM	Limit	3
	Yes	2
	Small	5
	General	3
	Openness	2
Influence	Repetitive	1
	Source of inspiration	7
AWOM predictions	Increased adoption	5
	Limitations and scepticism	4
	Improved personalization	3
	Replacing human experience	2

Source: own processing

The majority, 10 out of 12 respondents, have not interacted with artificial intelligence systems, preferring human interaction or being unfamiliar with such technologies. But there is an openness towards AI adoption, with 2 respondents reporting interactions.

In terms of perceptions of AWOM recommendations, there is significant distrust among respondents due to concerns about potential conflicts of interest or ethical issues. Respondents consider AWOMs to be repetitive (1 response), general (3 responses) and limited (3 responses), and there are also concerns about commercial interests in them.

In terms of AWOM's influence on travel decisions, many respondents (7 out of 12) consider that it would have little influence, preferring to use the recommendations as a source of inspiration and to compare them with other sources of information, stating that "*both types of reviews have complementary roles in forming an informed opinion*". Respondent 6 shared, "I couldn't compare these 2 types, I would only trust real users for that because they have lived the human and real experience." Likewise, respondent 7 felt that "AWOM recommendations don't influence me," as they "prefer to take the opinion of people rather than algorithms." Despite this, some participants acknowledged that AI could be useful for providing initial inspiration or for offering generalized information. Respondent 2 suggested, "It would influence the decision quite a bit, as I would spend time looking for information from various sources, not just AI."

In terms of the future of aWOM, respondents are split between optimism about increased adoption and improved personalization (8 out of 14) and scepticism about the limitations of the technology (4 out of 14). Some respondents emphasize the importance of direct experience and reviews from other real users, while others see the potential for AI to provide more personalized and relevant recommendations as technology advances.

Table no. 6 presents the theme of *the Impact of eWOM on travel decisions and experiences*. This theme explores the mechanisms by which online reviews shape online travel consumer behaviour, highlighting the importance of perceptions and feedback in the digital environment. eWOM not only informs potential travellers but also shapes their expectations at all stages of the planning process.

Table no. 6 – Impact of eWOM on travel decisions and experiences

Category	Item	Frequency
The influence of reviews	Very big	7
	Confirm/Cancel plans	5
	Reduced	3
Change perspective	Average	2
	It depends on the context	1
	Increased attention	4
	Opinion forming	2
	Post-purchase precaution	1
Conflicting experiences	Repetitive reviews	5
	Disappoint	4
Fake reviews	Positive experiences	1
	Fake account/ Negative reviews	1
	Repeated photos	1
	Grammar mistakes	1

Source: own processing

Analysing the data in the table above we can state that online reviews have a significant influence on participants' travel decisions. Many of the respondents, specifically 7 out of 12, state that reviews have a very high influence on their booking decisions, which emphasizes their importance in the travel planning process. One respondent state "*Very much, because based on them I form an opinion about a certain service/product and act accordingly*".

Further, these reviews lead to a change in perspective on tourist destinations or services, with 5 out of 12 respondents mentioning that they have caused them to confirm or cancel travel plans or even avoid certain accommodation. For example, one respondent said "*I may change destination*" after reading the reviews.

Other respondents say that reviews have made them more attentive and responsive to certain aspects (4 out of 12 respondents) or helped them form an informed opinion about a service or product (2 out of 12 respondents). One respondent said that reviews made them "*more cautious in case everything is already taken, and they find something they don't like after purchase*".

Conflicting experiences between online reviews and real-life experiences are relatively common in respondents' responses, with 4 out of 12 respondents reporting disappointments specifically related to accommodation. One respondent recounted how he was "*disappointed with a hotel with good reviews*", while another mentioned that his friends "*were disappointed with the conditions found at their accommodation, despite the pictures online*".

Respondents are also aware of the existence of false or misleading reviews, with 8 out of 12 saying they have encountered such reviews. These are identified by characteristics such as repetitiveness, obvious promotional content, major discrepancies between reviews and real experiences, fake accounts or negative reviews, repeated pictures and grammatical mistakes.

In conclusion, **online reviews play a considerable role in the planning process**, influencing respondents' decisions, perceptions and experiences. However, it is important for users to be critical and carefully assess the credibility and authenticity of reviews, given the possibility of false or misleading reviews.

4.2 Focus group results

Further on we will also analyse the focus group data. This focus group was designed to explore respondents' perceptions of the credibility of online reviews in the context of tourism services. The size of the focus group was 7 participants, which is sufficiently large number to ensure diversity of opinions and to provide an overview of the credibility of eWOM and aWOM.

Participants were presented with examples of reviews, some written by humans and some generated by artificial intelligence and asked to assess their credibility. Their discussions and assessments provided insight into the factors that influence how people perceive the veracity of online reviews, and how the presence of AI-generated elements can affect this perception.

The focus group discussion follows from the interview to see on concrete examples the elements that support or inhibit the authenticity and veracity of a review. In this case, the subjects were asked to analyse the credibility of eight reviews, four written by humans and four generated by artificial intelligence. They did not know the type of advertisement throughout the entire discussion.

Following the single question in the focus group, asking participants to analyse credibility, several key factors emerged:

1. Specific details

It was observed that reviews that contained specific details, such as items related to cleanliness, facilities, location or interaction with the owner, were considered more credible than general reviews. These details allow users to form an informed opinion, increasing trust in the reviews but also in the tourist service. One respondent stated that *"The details said in the review seem very experiential, so clearly he has been there on site and experienced it firsthand"*.

2. Authentic tone

In participants' responses, reviews that reflected personal experiences in an authentic way, in a sincere and natural tone, were appreciated. In contrast, reviews that used a formal, stiff or overly positive tone were perceived as less credible. One respondent says *"The friendly and warm tone denotes that it was written by a real person"*.

3. Balancing the pros and cons

Reviews that provide a complete picture, including both positive and negative aspects of the experience, were considered much more credible by the experiment participants. They pointed out that reviews that focus exclusively on positive or negative elements often appear biased or unrealistic. In contrast, balanced reviews, which present the pros and cons of accommodation in an honest and detailed way, are perceived as more authentic. Participants particularly appreciated reviews that describe both the strengths, such as cleanliness, comfort and friendliness of the staff, and the weaknesses, such as noise, lack of facilities or problems with reservations. This detailed and unbiased approach allowed users to get a realistic and comprehensive picture of their accommodation, helping them to make better-informed decisions and manage their expectations more effectively before traveling. One participant said, *"I think it's written by a human, it doesn't glorify accommodation and it's by no means exaggerated. It balances the bad with the good"*.

4. Language used

The language used in the reviews played an important role in assessing credibility. Reviews using language that was natural and close to that of the participants were perceived as more authentic. In contrast, reviews with too formal/informal language or exaggerated expressions raised questions about their authenticity. One participant said: *"The language is quite informal and, I can say, it seems exaggerated. Could be someone from generation Z..."*.

5. Elements generated by AI

Another important thing in a review is transparency. So, in question 8 there was a graphical element denoting the use of artificial intelligence in content generation.

The presence of this element played a significant role in shaping participants' perception of the credibility of that review.

Study participants repeatedly expressed concerns about the authenticity and objectivity of reviews that included AI-generated components. They emphasized that AI-generated reviews can appear artificially constructed and devoid of real personal experiences, which reduces their credibility. Furthermore, participants emphasized the importance of transparency in the use of AI for creation of reviews, suggesting that it would be essential for users to be clearly informed when a review was partially or fully generated by artificial

intelligence. One participant said, *"Even if it's a review that has AI-generated elements we don't know exactly what elements, I think it should say exactly what is being generated."*

In conclusion, to maintain consumer trust and ensure the objectivity of reviews, it is important for online travel service platforms to implement transparency measures to avoid potential misinformation.

A 5-point Likert scale was used to assess participants' perceptions of the credibility of online reviews, specifically comparing human-generated (eWOM) and AI-generated (aWOM) content. This scale is applied to evaluate how credible participants perceive different reviews. In this study, participants were asked to rate the credibility of various reviews, both human-written and AI-generated, based on their specific experiences. Reviews 1, 3, 5 and 7 are written by humans, while reviews 2, 4, 6 and 8 are generated with AI. The responses are quantified to capture the variation in trust levels between the two types of reviews.

Review 1 scored the second highest credibility score with 4,71. Participants' appreciation is evident in the specific and experiential details described, which enhanced their authenticity and relevance. One participant mentioned that *"The mention of the parking lot and the crowding seems to me an authentic detail that someone who has been there would notice"*. The review was a real one, provided by a user for a hostel. This aligns with findings by Litvin *et al.* (2008), who emphasized that reviews rich in experiential and location-specific details significantly boost perceived credibility.

Review 2 received the score 3,86. Some participants appreciated the balance between positive and negative aspects, while others found it too impersonal and possibly artificial intelligence generated. This review generated discussion about the importance of specific details and personal style in assessing credibility. One participant stated that *"It's very much like the review before except that it lacks some details, some more specific details. And it's quite cold in its phrasing, so it could possibly be AI-generated, but I can't say"*. This tension is echoed in Huang and Philp (2021), who showed that AI-generated service reviews are often criticized for lacking emotional depth and contextual specificity.

The following **reviews, number 3 and 4**, received predominantly neutral scores, 3,57 and 3,14 respectively, reflecting participants' uncertainty about their authenticity. They were quite short and general, which raised suspicion. Participants inferred that they might have been written by people close to the owner to help with the promotion of the location. Although we cannot state with certainty the authenticity and purpose of review number 3, given that the location was new on Booking, we can say that review number 4 was an example of aWOM. One participant stated that it *"seems credible enough, although it may have been put up by an acquaintance of the owner"*. This scenario reflects the concept of aWOM (algorithmic word-of-mouth), as discussed by Williams *et al.* (2020), who highlighted how short, vague, or overly favourable reviews may originate from owners rather than genuine guests.

Review number 5 received the score 3,57, reflecting divergent perspectives. Some participants appreciated the honesty of the review and the inclusion of the negative aspects, *"Credible", seems honest as it mentions the weaknesses. It's a bit too short, but gives pertinent details"*, while others found the details insufficient. This review emphasized the importance of balance between positive and negative aspects, but also the need for specific details to give a full picture of the experience. This finding mirrors insights from Sparks and Browning (2011), who noted that balanced reviews, even if critical, often inspire more trust than exclusively positive ones.

Review number 6 received the most polarized scores, with a score of 2,43. Its informal and exaggeratedly positive language was rated as unnatural or unconvincing by most participants, while others rated it as authentic and expressive. This review generated discussion about the impact of writing style and tone on perceptions of credibility. One participant stated, *"The language is quite informal and, I can say, it seems pulled by the hair"*. This polarization can be found in the results of Kim *et al.* (2011), who said that writing style, especially tone and vocabulary which can significantly affect perceived authenticity, often dividing audiences.

In 1st place with the highest credibility score is **review number 7**, where all participants gave it the maximum score, meaning 5. This review was praised for its honesty and transparency, providing both positive and negative aspects with specific and relevant details. One participant said *"I like that the review is straightforward and does not try to sugarcoat reality. The issues mentioned with linen and towels are useful details for anyone looking for an honest description of the accommodation"*. These characteristics are consistent with what Chen and Law (2016) identified as key trust-building factors in credible hospitality reviews.

Review number 8 scored the lowest, with most participants giving it one point, having an exact score of 1,57. The negative tone and lack of any positive aspects were considered unconvincing, with an exaggerated undertone. The mention of AI-generated elements also raised questions about the authenticity of the review. One participant stated *"Personally, I think the review is too biased in the negative direction to be completely credible. While some aspects may be valid, the highly critical tone and the mention of AI-generated elements raises questions about objectivity"*. This resonates with Mauran (2024), who warned that AI-generated reviews often amplify polarity, either excessively positive or overly negative by that reducing their credibility in readers' eyes.

The table below shows the average of the credibility scores given by focus group participants for each review presented. The scores are on a Likert scale from 1 (strongly disagree) to 5 (strongly agree).

Table no. 7 – Average credibility scores of AWOM reviews, own processing

Reviews	Average scores
1 – real	4,71
2 – AI generated	3,86
3 – real	3,57
4 – AI generated	3,14
5 – real	3,57
6 – AI generated	2,43
7 – real	5
8 – AI generated	1,57

Source: own processing

In conclusion, measurement of credibility for the reviews with the Likert scale responses and focus group discussions, highlight the importance of a balance between positive and negative aspects, specific details and an authentic writing style. Transparency about the use of AI in review generation is also considered very important by participants.

This analysis supports the interviews, where participants repeatedly mentioned the importance of specific details and a balanced tone in the reviews. For example, in the first interview, it was stated that "*I look for reviews that provide details about the positive as well*

as the negative". Similarly, in another interview, the importance of "*balancing the pros and cons so I can make the best decision*" was mentioned.

In addition to these aspects, focus group participants mentioned other factors that influence their perception of the credibility of reviews, such as the number of reviews, the overall score of the location, and the existence of AI-generated elements. These factors are also relevant in the context of the interviews, where participants discussed their importance in their decision-making process.

5. DISCUSSIONS

This research utilized a qualitative approach, based on in-depth interviews and a focus group, to explore the perceptions and use of online reviews (eWOM and aWOM) in the tourism industry. The sample consisted of 12 participants, selected based on their experience with online platforms for tourism services. The study aimed to understand how these reviews influence decision-making and expectations of Artificial Intelligence (AI)-generated reviews (aWOM), focusing on aspects such as credibility, persuasiveness, and the impact on purchase intention.

The first objective of the study was to assess the impact of aWOM on purchase intention. Our findings revealed a general reluctance towards aWOM. Participants expressed a stronger preference for eWOM reviews, which they valued for their authenticity and the experiential details they provided. The majority stated that aWOM had little influence on their booking decisions and was often seen only as a source of inspiration or a starting point. This aligns with previous research by Gretzel and Yoo (2008), who found that consumer trust is often rooted in human-generated content, particularly in the tourism sector, where shared experiences are essential for building credibility. Williams *et al.* (2020) also support this by suggesting that while aWOM offers personalization, it lacks the emotional connection and trust that eWOM reviews provide. These results thus challenge the assumption that aWOM can quickly replace eWOM, as eWOM continues to be a stronger driver of purchase intention in tourism.

For the second research objective, which aimed to assess the differences between eWOM and aWOM, the findings indicated that participants could clearly distinguish between the two based on writing style, level of detail, and tone. Participants valued the authenticity and subjectivity of eWOM, which they considered more relevant to their personal experiences. Longoni and Cian (2022) found that eWOM is preferred for hedonic consumption (such as travel), as it offers subjective insights that resonate with individual emotions and needs, unlike the more utilitarian nature of aWOM.

The third objective explored trust levels in aWOM versus eWOM. Our results showed that participants exhibited a low level of trust in aWOM, mainly due to concerns over transparency and the potential for manipulation. One participant remarked, "I choose to trust real users more because reviews also have emotional influence." This perception was reinforced in the focus group, where participants expressed mistrust about the objectivity of aWOM reviews. These findings are consistent with Akdim (2021), who highlighted that aWOM is often viewed with suspicion due to its algorithmic nature and lack of transparency. Longoni and Cian (2022) also noted that while AI can provide personalized recommendations, its absence of emotional engagement and human authenticity raises concerns about its trustworthiness, particularly in sectors like tourism, where emotional connections are vital to the consumer experience.

Finally, in examining how eWOM and aWOM influence consumer decisions, our study revealed that eWOM reviews were predominantly used to form informed opinions about a particular service. Participants were generally less open to aWOM, reflecting doubt regarding its effectiveness. This observation aligns with Serra Cantallops and Salvi (2014), who found that eWOM plays a pivotal role in the decision-making process in the tourism sector, as it provides credible, real-world insights. The low openness to aWOM highlights that while AI-based reviews may offer personalization, they do not yet match the perceived value and influence of eWOM.

In summary, the findings of this study confirm that eWOM remains a dominant and trusted source of information for consumers in the tourism industry, a sentiment that aligns with existing research on consumer behaviour in digital environments. However, our study also reveals a growing interest in aWOM as a complementary tool, especially when used alongside eWOM to offer additional insights. This study expands on previous literature by suggesting that while aWOM has potential, it cannot yet replace eWOM, particularly due to the emotional connection and trust associated with human-generated content. To fully integrate aWOM into the decision-making process, it is crucial for online platforms to address concerns over transparency, bias, and the perceived lack of authenticity in AI-driven reviews.

6. CONCLUSIONS

In conclusion, our study suggests that while eWOM reviews remain an essential source of information for travellers, there is potential for aWOM to play a complementary role in the decision-making process. However, to fully integrate aWOM into the decision-making process, online platforms must address transparency and objectivity concerns in order to increase user trust.

In terms of promoting the use of aWOM within the Booking.com platform, an integrated approach is required, involving both online and offline placements. Being a strong brand with global recognition, out-of-home (OOH) advertisements, such as banners, can be used for offline promotion. These banners were placed nationwide in Romania, specifically in the top six cities with the most airport traffic. For online promotion, posts and advertisements were made on social networks such as Instagram, Facebook, and TikTok, targeting the proposed audience.

Particularly for Facebook and Instagram, we focused on the development of paid advertisements, leveraging prior experience in managing social media pages and a deep understanding of the impact of visuals in marketing.

Overall, the analysis of participant responses and focus group discussions provides detailed insights into how people assess the credibility of online reviews and the factors influencing their perceptions, particularly regarding their openness to new AI-generated reviews. This understanding can be valuable for online review platforms and tourism service providers, helping them to improve how they present and manage online reviews.

Businesses can also use aWOM as a complementary tool to provide general insights and enhance the user experience. However, they must be mindful of the current limitations of this technology and avoid relying on it exclusively.

For online promotion, we recommend that companies focus on delivering visually appealing content. Posts that include short, concise aWOM reviews, accompanied by photos or videos showcasing real experiences, will engage users more effectively. Using relevant

hashtags and interactive features within stories, such as polls, can stimulate conversation with prospective customers.

On platforms like TikTok, short, engaging videos can creatively showcase how aWOM can help users discover new destinations and personalize their travel experiences. Leveraging popular challenges and trends will help increase visibility and appeal to a broader audience.

While this study provides valuable insights into the role of eWOM and aWOM in consumer decision-making within the tourism industry, several limitations must be acknowledged. First, the sample size of 12 interview participants and the focus group of 7 is relatively small, which may limit the generalizability of the findings. Future studies could benefit from a larger and more diverse sample to capture a broader range of perspectives and behaviours.

Another limitation is the scope of the study, which was confined to the tourism industry and platforms like Booking.com and TripAdvisor. Although these are prominent platforms, future research could explore aWOM and eWOM in other sectors, such as e-commerce or retail, to assess the broader applicability of the findings.

Finally, the rapidly evolving nature of AI technology means that the study's conclusions regarding aWOM may be subject to change as new advancements emerge. Future research should consider the dynamic nature of AI and its potential to further transform the landscape of online reviews and consumer decision-making.

Future studies could investigate the long-term effects of aWOM on brand loyalty, trust, and consumer behaviour. Further exploration is also needed into the ethical concerns of aWOM, particularly regarding algorithmic transparency, bias, and its influence on consumer decision-making, as these issues become increasingly important in the digital age.

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ANNEXES

ANNEX 1 – INTERVIEW GUIDE

Hello! We are a group of people conducting research on the consumer behaviour of online tourism services.

I would like to thank you for accepting our invitation to take part in this interview, which aims to discover and analyse information about your preferences in terms of online tourist services and what motivates you in your choice of accommodation.

The information you give me during the interview will be anonymous and confidential. The discussion will be recorded and the research data will not be disclosed to others. Our discussion in this interview will last approximately 15-20 minutes. Everything you tell us is important and will be used to help us better understand your behaviour.

1. Do you travel often in a year?
2. Which online platforms do you frequently consult for information about travel destinations, accommodation, flights or other tourist services? (e.g. TripAdvisor, Booking.com, Facebook, travel-specific discussion forums)
3. What are your criteria for choosing a reliable eWOM platform? (Ex: number of reviews, diversity of opinions, user trust scores)
4. What types of information do you specifically look for in eWOM sources (e.g. detailed descriptions of destinations, real photos and videos, reviews of specific experiences, practical advice from other travellers)?

5. How do you assess the usefulness and credibility of the information found in eWOM sources (e.g. check the sources of the reviews, consider the diversity of opinions, assess the writing style and tone of the reviews)?

6. How much do online reviews influence your travel booking decisions? (Ex: consider only positive reviews, give more weight to detailed and honest reviews, ignore negative reviews)

7. How do you change your perspective on a destination or tourist service after reading online reviews? (Ex: confirm or change travel plans, avoid certain options)

8. Have you ever had conflicting experiences between online reviews and your own actual experience? (Ex: you had a positive experience with a hotel that had negative reviews, you were disappointed with a destination that was praised online)

9. Have you ever spotted fake or misleading online reviews? (e.g. repetitive reviews, obvious promotional content, major discrepancies between reviews and real experiences)

10. What do you think about sponsored or paid reviews? Do you consider them as credible as non-sponsored ones?

11. How do the overall ratings of travel platforms (e.g. Booking.com, TripAdvisor) influence your booking decisions compared to individual reviews?

12. Have you interacted with chatbots, virtual assistants or other AI systems that provide travel recommendations or tourist information? (Ex: chatbots on hotel websites, airline virtual assistants, AI-based travel recommendation platforms)

13. If yes, have you ever received AI-generated AWOM recommendations that were not relevant to your needs or interests? (Ex: accommodation recommendations that did not fit your budget, destination suggestions that did not match your travel preferences)

14. How objective and trustworthy do you consider AI-generated reviews to be compared to those of real users?

15. How do you perceive the credibility and impartiality of AWOM recommendations (e.g. you concerned about potential conflicts of interest, do you consider the limitations of AI systems, do you assess the quality and diversity of information used to generate recommendations)?

16. How much do you think AWOM recommendations would influence your travel booking decisions? (Ex: consider the recommendations as a source of inspiration, compare them with other sources of information, ignore them if they don't suit your needs)

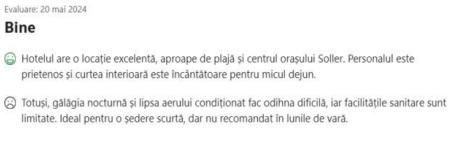
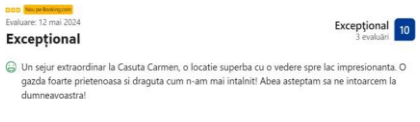
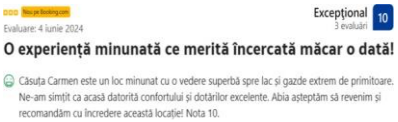
17. How do you think AWOM will develop in the future and what impact will it have on the tourism industry? (Ex: increased use of AI systems, improved accuracy and relevance of recommendations, more sophisticated personalization).

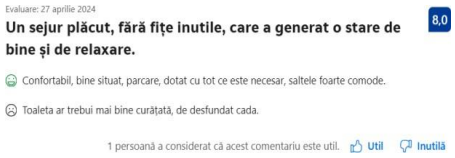
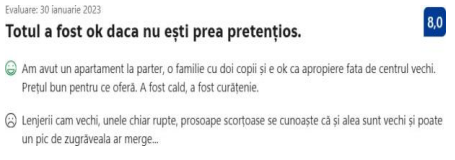
ANNEX 2 – FOCUS GROUP REVIEWS REAL AND AI GENERATED

This focus group aims to explore your views on online reviews for tourism services. Today, we are going to discuss the credibility of AI-generated reviews (AWOM) versus human-generated reviews (eWOM) and how they influence your decisions to choose a hotel or other tourist destination.

During the discussion, we will present examples of eWOM and AWOM reviews and use a rating scale to measure their credibility. We will also ask you a series of questions to find out more about the factors that influence your perception of the credibility of reviews.

Your participation in this focus group is voluntary and confidential. Please do not hesitate to ask any questions during the discussion.

eWOM	aWOM
"The location to the town of Soller was excellent, just a few minutes walk! Loved the nice courtyard and friendly staff. We stayed here for three days and took day trips by car to the surrounding towns. Nearby parking was great and reasonable at 6 EUR for 24 hours - can be crowded during the day, but worth the wait to vacate a spot. A bit noisy at night, but that's the price you pay for being in such a great location for everything!"[3]	"The hotel has a great location, close to the beach and center Soller. The staff are friendly and the inner courtyard is lovely for breakfast. However, the noise at night and lack of air conditioning make it difficult to rest the sanitary facilities are limited. Ideal for a short stay but not recommended in the summer months."[4]
 **Figure no. A1 – Screenshot Booking.com review** *Source:* https://www.booking.com/Share-RseE9g	 **Figure no. A2 – Screenshot AWOM review** *Source*: own processing
"An extraordinary stay at Casuta Carmen, a superb location with a breathtaking lake view. A very friendly host and as pretty as I have never met! We are waiting to come back to you!"	"Carmen's cottage is a lovely place with a beautiful view of the lake and extremely welcoming hosts. We felt at home thanks to comfort and excellent facilities. We can't wait to return and highly recommend this location! Note 10."
 **Figure no. A3 – Screenshot Booking.com review** *Source:* https://www.booking.com/Share-oPYTGV	 **Figure no. A4 – Screenshot AWOM review** *Source*: own processing
"An enjoyable stay, no unnecessary fuss, generated a feeling of well being and relaxation. Comfortable, well located, parking, equipped with everything needed, very comfortable mattresses. Toilet could be better cleaned, unclog bath tub."[7]	"The location of this studio is simply next level! You're right downtown, close to everything you need. The host is super cool and friendly, she even let us park our bikes in the apartment. The studio is tiny but cozy and has all the stuff you need. The

eWOM	aWOM
	bed? OMG, mega cozy! We slept like babies. The hot water comes quickly and the WiFi works great. Bathroom? Spotless! Everything is so clean and well maintained. I highly recommend! The vibe is superb and we will definitely be back!"
 **Figure no. A5 – Screenshot Booking.com review** *Source:* https://www.booking.com/Share-gBnEYw	 **Figure no. A6 – Screenshot AWOM review** *Source*: own processing
"Everything was ok if you're not too picky. We had a ground floor apartment, a family with two kids and it's ok as far as proximity to the center old. Good price for what it offers. It was warm, it was clean. The linens were a little old, some even torn, torn towels, scorched towels, it is known that those are also old and maybe a bit of repainting would work..."	"The rooms were disappointingly small and insufficiently clean, with old and damaged furniture. The major problem was with the plumbing in the king room, which caused a massive water leak into the room with every shower. In In addition, the stifling temperature in the room made it difficult to breathe and the lack of air conditioning made it even more uncomfortable. The price, although affordable, in no way justified the poor conditions. Parking was a nightmare, and the quiet was just a pleasant dream with the constant noise all around. The staff, instead of solving problems, seemed indifferent and uncaring."
 **Figure 7. Screenshot Booking.com review** Source: https://www.booking.com/Share-90ChPq4	 **Figure 8. Screenshot AWOM review** *Source*: own processing

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CSR and Strategic Communication in Spanish-Language Academia: A Systematic Review

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Abstract: The concept of strategic communication has gained importance in the internal and external management of organisations, especially in relation to Corporate Social Responsibility (CSR). This study aims to analyse how CSR communication strategies are addressed in Spanish-speaking academia, identifying key trends and their impact on corporate reputation and competitiveness. The methodology is based on a documentary review of recent studies on CSR communication in various sectors. The results highlight that sectors with greater environmental or social impact adapt their practices to gain public trust. The conclusions reveal that effective CSR communication enhances reputation, consumer loyalty, and long-term competitiveness. This study contributes by systematising Spanish-language scientific production linking CSR and strategic communication, offering theoretical insights and practical tools. Its novelty lies in identifying trends in Spanish-speaking academia and fostering a critical dialogue on responsible corporate management while emphasising the role of Spanish in CSR knowledge dissemination.

Keywords: corporate social responsibility; strategic communication; sustainability; business; business growth.

JEL classification: M14; D83; L31.

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1. INTRODUCTION

In a global environment that is increasingly aware of social and environmental issues, Corporate Social Responsibility (hereafter CSR) has established itself as an essential strategic tool for organizations in all sectors (Chavarría Ortiz *et al.*, 2020; Estanyol, 2020). Companies are no longer seen solely as economic agents but also as social actors responsible for their impact on the environment, the well-being of communities, and long-term sustainability (Rodríguez *et al.*, 2021). Zárate-Rueda *et al.* (2020) state that this transformation has led companies that integrate CSR practices into their philosophy and daily operations to not only meet stakeholders' expectations but also to develop a sense of belonging and commitment among their employees, reinforcing their motivation and alignment with corporate objectives. In this framework, strategic communication becomes a fundamental pillar to effectively project CSR actions, managing public perception, and reinforcing corporate credibility.

Despite the extensive body of literature on CSR, there is still a gap in understanding how strategic communication can serve as a catalyst for the effective implementation and visibility of CSR practices, particularly within Spanish-speaking academia. While various studies have examined CSR in specific industries, such as banking (Hinojosa-López and Cogco, 2020; Carpio and Perez, 2021; Castro-González and Vilela, 2021), mining (Díaz *et al.*, 2021), politics and hospitality (Becerra Bizarrón, 2021), fewer works have systematically analyzed the role of communication as a central axis in CSR implementation across multiple sectors. Moreover, the relationship between CSR communication and its influence on consumer trust, corporate reputation, and stakeholder engagement remains a crucial area for further exploration. This study seeks to address this gap by examining how different industries apply and communicate CSR strategies to align with stakeholder expectations and regulatory frameworks.

Contemporary trends show a growing focus on how companies can use strategic communication to leverage their intangible assets, such as reputation, consumer loyalty, and brand trust (Gallardo-Vázquez *et al.*, 2020). These intangible assets, although difficult to quantify, are fundamental to consolidating an organization's competitiveness and positioning in the market, representing an added value that distinguishes it from competitors. The shift in perception and application of CSR within organizational culture highlights the increasing need for transparent and bidirectional communication. Communicating CSR is not merely about disseminating information; it is about fostering dialogue and co-creation with stakeholders, reinforcing ethical and responsible business practices (Niño Benavides and Cortés Cortés, 2018).

Within the framework of the Sustainable Development Goals (SDGs), CSR serves as a crucial mechanism for aligning corporate activities with sustainability principles. This alignment is particularly vital in sectors that face significant scrutiny regarding their social and environmental responsibilities. For example, in the mining sector, where operations impact local communities and natural resources, companies must adopt CSR strategies that demonstrate a commitment to social and environmental sustainability (Criollo-Uyaguari *et al.*, 2020; Díaz *et al.*, 2021). In the banking industry, trust and transparency are pivotal, making CSR initiatives centered on ethical financial practices and community engagement indispensable (Carpio and Perez, 2021). Similarly, in hospitality, sustainability practices and local community support are essential for maintaining a positive reputation and ensuring long-term viability (Becerra Bizarrón, 2021).

Furthermore, in the public space, Third Sector Organizations are increasingly adopting Organizational Social Responsibility (hereafter OSR) as a means to enhance their ethical credibility and social impact. As demonstrated by Ortíz Rodríguez (2020), these organizations are strategically integrating digital media to communicate OSR efforts effectively, fostering greater stakeholder engagement and public trust. The role of emerging technologies, such as social media (Armírola Garcés *et al.*, 2020; Capriotti and Zeler, 2020; Aguirre *et al.*, 2021; Moyaert *et al.*, 2021) web analytics, and podcasts (Barrio-Fraile *et al.*, 2023), has become central to the visibility, dissemination, and promotion of CSR initiatives. These tools enable companies to communicate their sustainability commitments in a transparent, interactive, and engaging manner.

Given these considerations, this study presents a systematic review of the literature in Spanish on the intersection between CSR and strategic communication. By analysing academic contributions in this field, the research aims to (1) identify the key methodologies and approaches used to study CSR communication, (2) examine the sector-specific challenges and opportunities in implementing CSR strategies, and (3) provide a comprehensive framework for understanding the role of communication in shaping CSR practices. As Díez *et al.* (2022) highlighted, well-communicated CSR not only strengthens corporate reputation and consumer loyalty but also contributes to long-term sustainability and competitive advantage. By synthesizing theoretical perspectives and empirical case studies, this work offers valuable insights for academics and practitioners alike, fostering a critical dialogue on how businesses can strategically manage their social and environmental impact.

The academic contribution of this study lies in providing a structured synthesis of the Spanish-language literature linking CSR and strategic communication. By integrating theoretical discussions, methodological perspectives, and industry-specific case studies, this research expands knowledge on the communicative dimension of CSR while offering practical tools for adapting these strategies to diverse business environments. This approach underscores the importance of Spanish as a vehicle for advancing academic discourse in this field and highlights the need for continued research on how communication can drive responsible corporate behavior in an evolving global landscape.

Focusing on the Spanish-speaking context responds to a theoretical necessity rooted in multiple factors. First, scientific production on CSR and strategic communication in Spanish has grown significantly in recent years, justifying the need to systematize and analyze these contributions within a specific framework. Unlike other contexts, CSR in Spanish-speaking countries has developed within socio-economic, cultural, and regulatory environments that shape how organizations adopt and communicate their sustainability strategies.

Moreover, this study identifies distinctive trends and methodological approaches emerging from Spanish-language literature, offering relevant findings on how organizations in these countries manage their corporate image and reputation through CSR communication. A key differentiating factor is the central role of cultural values and corporate identity in shaping public perception and acceptance of CSR strategies, which is not always as prominent in other contexts.

Additionally, by focusing on Spanish-language academic production, this research brings visibility to knowledge that is often underrepresented in international reviews dominated by English-language literature. This provides a complementary perspective to the global debate on strategic communication and CSR, fostering a more inclusive and diverse understanding of the field.

Finally, this approach opens new avenues for future research by facilitating comparative analyses with other linguistic and cultural contexts. Such studies can help identify common patterns and significant differences in CSR communication practices worldwide, enhancing both theoretical and practical applications in corporate sustainability management. To reinforce this justification, the Introduction and Conclusion sections have been expanded, emphasizing the relevance of this analytical framework and the distinctive contributions it offers to the existing body of knowledge. Furthermore, the present study follows the traditional and widely recognized structure of academic research papers – Introduction, Methodology, Results, Discussion, and Conclusion. This organizational framework not only provides coherence and clarity but also strengthens the logical progression of the analysis, ensuring its accessibility and rigor for both academic and professional audiences. Aligned with the PRISMA protocol, this systematic review is guided by the following research question: How is strategic communication used to convey Corporate Social Responsibility (CSR) practices in Spanish-speaking academic contexts, and what trends and methodological approaches can be identified?

2. MATERIALS AND METHODS

2.1 Study design

For this study, we used a fundamental tool for academic evidence-based decision-making: the systematic review (Rodríguez *et al.*, 2024). This methodology allows synthesizing existing scientific information, increasing the validity of the conclusions of individual studies and highlighting areas of uncertainty that need further research (López Cerezo and González García, 2011). The systematic review was conducted according to the criteria of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement, a guideline designed to improve the quality of reporting in systematic reviews. PRISMA is endorsed by more than 200 journals and organizations specialized in this type of studies (Ciapponi, 2021).

In relation to the methodological aspects of this review, a structured approach has been implemented that facilitates the identification, selection, evaluation and synthesis of studies, allowing the objectives set both at a general and specific level to be achieved (Page *et al.*, 2021).

2.2 Selection of studies

The studies were selected based on a set of inclusion criteria: (a) review articles explicitly addressing the relationship between strategic communication and CSR, (b) review articles published in Spanish, and (c) articles published between 2020 and October 2024. The exclusion criteria were: (a) publications not meeting the inclusion criteria. No further limitations were imposed to ensure a sufficient and relevant volume of studies that reflect the scientific reality.

The time frame for this systematic review was confined to the period from 2020 to 2024, driven by the need to focus on recent research reflecting the current state of the field. In fast-evolving areas like digital communication, social networks, and CSR practices, studies published before 2020 may not accurately capture the present-day landscape. Furthermore,

this period encompasses significant developments, such as the rise of emerging platforms and novel digital interaction strategies applied to CSR.

The COVID-19 pandemic marked a pivotal moment in many sectors, including communication, CSR, marketing, and social media behavior. Since 2020, studies have specifically analyzed the effects of this global event, providing a cohesive framework for understanding the recent trends and shifts in the field. This approach yields more relevant and contextualized insights during a time of profound impact for the subject at hand.

By narrowing the time frame, we ensure the quality and comparability of the analyzed sources. Concentrating on research published in the last four years prevents an overly broad scope that might hinder accurate analysis and conclusions. This also responds to the methodological need to standardize the conditions and approaches of the included studies, guaranteeing a rigorous and relevant analysis.

2.3 Study strategies

The authors independently executed a literature search through Scopus, Web of Science (WoS) and Google Scholar databases. The search was conducted with a time limit, which was between 2020 and October 2024. The databases used offer a complete and broad overview of the topic under study, which is why they were chosen for this research. Scopus and Web of Science (WoS) index articles from journals listed in the Journal Citation Reports (JCR), the Scimago Journal Rank (SJR), and similar databases. Google Scholar, however, collects publications on a topic, including those not indexed in these databases. The use of Google Scholar in this research is justified by its ability to index a wider variety of academic documents, including grey literature and publications that may not be included in Scopus or Web of Science. This inclusion provides a more comprehensive view of the state of the art on the studied topic, complementing the analysis with sources from conferences, doctoral theses, and book chapters, which enriches the documentary base and ensures a more exhaustive literature review. According to Torres-Salinas *et al.* (2009), Google Scholar offers broader coverage by indexing a diverse range of sources, including academic and non-academic publications that are often not considered in traditional databases. This broader inclusion enhances the accessibility and visibility of research findings, making it a valuable tool for conducting extensive literature reviews.

The optimization of the searches was based on the definition of key words that synthesize the collection of the sample of records. In line with the object of the research, in Spanish: ‘Responsabilidad Social Corporativa’ AND, (‘comunicación estratégica’ OR ‘comunicación empresarial’ OR ‘gestión de la comunicación corporativa’); as in English: ‘Social Corporate Responsibility’ AND (‘strategic communication’ OR ‘business communication’ OR ‘management corporate communication’). Records were collected using the ‘General Search’ section, with the field ‘all fields’.

2.4 Data collection and synthesis

The collected records were independently reviewed and evaluated by the participating academics, following the guidelines of the PRISMA methodology. The section on data collection and synthesis would benefit from further elaboration to clarify how the data were gathered and synthesized.

3. RESULTS

Following the criteria established by the methodology of the present study (PRISMA statement) for systematic reviews, a total of 14.744 records were obtained from the selected search sources. After removing duplicates (1), 14.743 records remained. However, after applying additional filters to each publication according to the checklist items of the methodology used, as well as the previously mentioned inclusion and exclusion criteria, the final number of publications considered for this review was 50. This document search process, shown in Figure no. 1, includes, by publication characteristics, studies in relation to strategic communication and CSR. The corpus obtained comes almost entirely from Google Scholar (14.736). Web of Science with 6 records and Scopus with 2 were the databases with the lowest volume of records in relation to the criteria determined.

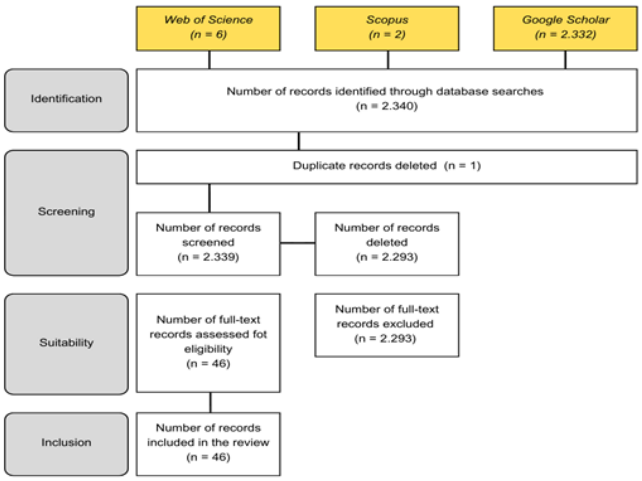

Figure no. 1 – Flow chart of the records obtained

Source: own elaboration

4. DISCUSSION

The list of proposed research and approaches covers a broad and current spectrum of CSR and organisational strategic communication, allowing for an in-depth analysis of how different sectors and strategies approach CSR and sustainability through the prism of communication in different contexts. This study compiles scientific production in various areas related to the object of study.

The records that make up the corpus are reflected in Table no. 1 according to authors, year of publication, publication medium, publication title, most relevant findings and doi-url. The sample consists of forty-five academic articles and spans the years 2020 to 2024. Most of the scientific production is concentrated in the years 2020 (28%), 2021 (34%) and 2022 (28%). The remainder is in the years 2023 (8%) and 2024 (2%) as seen in Figure no. 2.

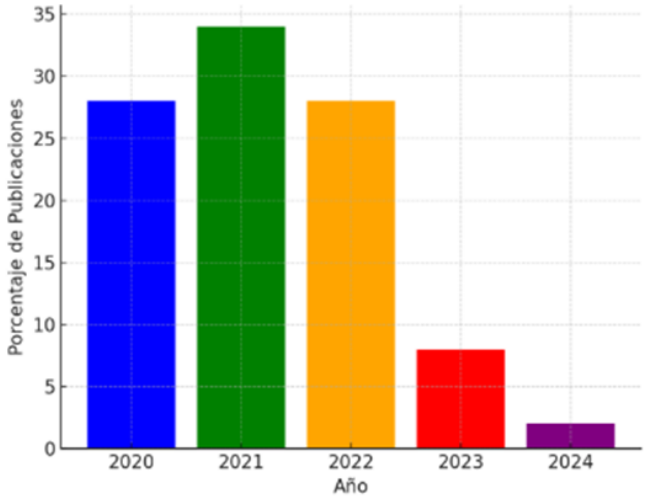

Figure no. 2 – Distribution of publications in the period 2020-2024

Source: own elaboration

In this sense, the records obtained indicate that the journals of scientific impact that publish the most on Corporate Social Responsibility and strategic communication are the SEECI Journal of Communication (5 records), Revista Latina de Comunicación Social (4 records), El Profesional de la Información (3 records) and Anagramas - Rumbos y sentidos de la comunicación (2 records) and Sintaxis (2 records). The rest of the journals with academic impact only have one entry in this systematic review.

Table no. 1 – Characteristics of the records obtained in the search strategy

Author(s) and Year	Publication medium	Title of publication	Study findings	Communication category strategy
Estanyol (2020)	El profesional de la información	Comunicación de la responsabilidad social corporativa (RSC): análisis de las campañas más premiadas en 2018	The analysis highlights successful CSR practices, such as alignment with the SDGs (gender equality, reduction of inequalities and environmental protection), integration with the organisational mission, employee engagement and the use of two-way channels to engage with stakeholders.	CSR Communication & Stakeholders Engagement
Buitrago Betancourt (2021)	Gestión y Organizaciones	La comunicación corporativa de la responsabilidad social empresarial (RSE): el caso de las empresas de la provincia Sabana Centro de Cundinamarca, Colombia	Large and medium-sized companies communicate more about their CSR actions than micro and small companies, although overall the percentage is low. Surprisingly, the mining and quarrying sector is the one that uses web portals and social media the least, despite facing more social pressure.	CSR Communication & Industry Practices
Ramos Rubio (2021)	RECAI Revista de Estudios en Contaduría,	Elementos de responsabilidad social empresarial	The results show that, although there are unimplemented mechanisms, companies have reinforced sustainability strategies,	CSR & Branding Impact

Author(s) and Year	Publication medium	Title of publication	Study findings	Communication category strategy
	Administración e Informática	y mercadotecnia social para la reputación corporativa e impacto en el branding	improving their reputation, branding and positive social and environmental impact.	
Pellicer Jordá (2023)	Revista de Comunicación de la SEECI	Ética y valores en la publicidad. El Branded Content como formato estrella de la responsabilidad social corporativa.	Analyses branded content actions in Spain in CSR during the last four months of 2022, identifying themes, genres, formats, companies involved, advantages and limitations.	CSR & Branded Content
Capriotti and Zeler (2020)	Palabra clave	Comunicación de la responsabilidad social empresarial de las empresas de América Latina en Facebook: estudio comparativo con las empresas globales	The research reveals that companies prioritise economic over social issues on Facebook, using it more as a channel for dissemination than for interactive communication of their CSR, which calls for a more dialogical approach.	CSR & Social Media
Reyes Ramírez *et al.* (2022)	Retos. Revista de Ciencias de la Administración y Economía	Variables de la responsabilidad social corporativa. Un modelo de ecuaciones estructurales	The validation of the model confirmed that CSR has a multidimensional approach, where internal factors such as leadership, communication, values and job satisfaction are significantly correlated with customer perception, in line with previous studies.	CSR & Leadership/Organisational Culture
Díez *et al.* (2022)	Anagramas - Rumbos y sentidos de la comunicación	Tendencias teóricas y desafíos en la comunicación de la responsabilidad social corporativa	The literature review confirmed the need to jointly investigate the four dimensions of CoRSC (identity, integration, interpretation and image) from an ethical perspective that highlights the role of design in CSR communication.	CSR & Communication/Branding
Fernández-Vallejo (2022)	Revista Signos	La legitimación en el discurso de la Responsabilidad Social Corporativa (RSC): El sector energético y financiero del Ibex 35	The results indicate similar legitimisation strategies by sector and year, but with thematic differences: the energy sector prioritises environmental issues, while the banking sector focuses on social issues.	CSR & Reputation Management
Castro *et al.* (2022)	Escuela de Ciencias de la Comunicación. Programa de Comunicación Social y Periodismo Digital. Universidad Sergio Arboleda.	Estrategias de transformación digital organizacional desde la responsabilidad social.	This work highlights the importance of adopting technologies with a focus on social responsibility and sustainable development, as evidenced in the consultancy carried out by students of Social Communication at the Universidad Sergio Arboleda, Bogotá	Digital Transformation & CSR
Barroso *et al.* (2023)	Estudio sobre el Mensaje Periodístico	La dimensión medioambiental y los ODS en la	Although the majority of participants value the environmental dimension, only 2 out of 10 companies consider the SDGs	Environmental communication & SDGs

Author(s) and Year	Publication medium	Title of publication	Study findings	Communication category strategy
		comunicación estratégica de las empresas de triple impacto	as the most relevant issues, indicating a lack of adequate communication of this environmental value to their stakeholders.	
Palma and Sánchez (2021)	Disertaciones: Anuario electrónico de estudios en Comunicación Social	Las reescrituras de la sustentabilidad: comunicación estratégica en el escenario de desastres socioambientales	Sustainability reports and interviews will be analysed to understand how company discourse evolves around sustainability and is used as a strategy to transform social practices.	Sustainability communication & Social Impact
Bravo *et al.* (2021)	RICSH Revista Iberoamericana de las Ciencias Sociales y Humanísticas	La comunicación estratégica como articulador de los intangibles organizacionales	The results will help to identify the role of communication processes in the production of assets, and will guide communication strategies in organisations to generate value and competitiveness.	Strategic communication & Organisational value
Díaz *et al.* (2021)	Investigación y Desarrollo	Gestión de la comunicación en programas de responsabilidad social en el sector minero	This research analysed the role of communications management in engaging with communities through the CSR programmes of the Quebradona and Gramalote mining projects in Antioquia, Colombia, winners of the Sello Social a la Minería Award. Using an interpretive approach and document review.	Corporate Social Responsibility & Community Engagement
Xifra (2020)	El Profesional de la Información	Comunicación corporativa, relaciones públicas y gestión del riesgo reputacional en tiempos del Covid-19	This study reflects on how the Covid-19 pandemic conditions corporate communication, highlighting reputation management as a risk that must be managed with public relations tools and the importance of trusting relationships with audiences.	Crisis communication & Reputation Management
Barrio-Fraile *et al.* (2023)	Revista Latina de Comunicación Social	Uso del podcast corporativo como herramienta de comunicación de los ODS en el sector bancario español	36.1% of the podcasts analysed address the SDGs, showing a significant use of podcasts as a tool for communicating the SDGs, in line with companies' commitment to committed CSR communication. This research advances knowledge of the use of digital platforms, such as podcasts, to communicate CSR issues.	Digital Communication & SDGs
Ortíz Rodríguez (2020)	InMediaciones de la Comunicación	Comunicación publicitaria en medios digitales: La gestión de la responsabilidad social en las Organizaciones del Tercer Sector	UK companies use more advertising communication for OSR than those in Mexico. All face challenges in strengthening their RSO and digital communication, essential to improve reputation and trust with their audiences.	Digital Advertising & Third sector communication
Zárate-Rueda *et al.* (2020)	Revista Espacios	Relacionamiento con stakeholders en el marco de la responsabilidad social empresarial	Stakeholder engagement is key to achieving CSR objectives, but inappropriate stakeholder engagement in an IPS in Bucaramanga, Santander (Colombia) led to stakeholder identification and prioritisation analysis	Stakeholder engagement & CSR communication

Author(s) and Year	Publication medium	Title of publication	Study findings	Communication category strategy
			using Rawlins' systematic model and Grunig's theory of engagement.	
Hernández *et al.* (2021)	Anuario de Investigación de la Comunicación	La Perspectiva en Comunicación Responsable: conceptualización, rasgos y ámbitos de aplicación	The paper characterises the emerging perspective of Responsible Communication as relevant in public and private scenarios, highlighting its framing, importance and areas of relationship for organisations and actors in communication.	Responsible communication & Organizational Communication
Fong Villegas *et al.* (2022)	TELOS: Revista de Estudios Interdisciplinarios en CCSS	Hipocresía corporativa: un concepto poco nombrado de la responsabilidad social empresarial	This paper analyses perceived hypocrisy in CSR from an analytical approach, highlighting the need for congruent and consistent action by all stakeholders to avoid it.	Corporate Social Responsibility & Stakeholder Engagement
Durán *et al.* (2020)	Cuadernos.info	Influencia de la cultura nacional en la gestión de comunicación para la sostenibilidad	National culture influences communication strategies for sustainability: collectivism in Ecuador, accountability in Chile and planning in Colombia stand out in their respective approaches.	Cultural Influence & Sustainability Communication
Herranz de la Casa and García Caballero (2021)	CIRIEC-España. Revista de Economía Pública, Social y Cooperativa	La comunicación de los Objetivos de Desarrollo Sostenible en las organizaciones de la Economía Social	Initiatives have been analysed where participation in organisations has generated recognition in communication management. Strengthening the implementation of the SDGs can differentiate social economy organisations in the next 10 years and have an impact on CSR.	SDGs & Social Economy Communication
Zevallos Oscco *et al.* (2022)	Revista GEON	La comunicación como estrategia de diferenciación competitiva	This study reflects how communication in its various dimensions is a priority for optimal organisational development and, due to the pandemic, faces the challenge of redefining itself in the context of CSR.	Communication & Organizational Strategy
Rodríguez-Ríos and Lázaro Pernias (2023)	Revista Latina de Comunicación Social	El storydoing como modelo innovador de comunicación publicitaria que favorece una mejora en la sociedad	The results show that storydoing improves society through education in values and awareness of issues such as environmental pollution and recycling. Discussion: Despite its effectiveness, some studies show a lack of clarity in corporate strategies based on social causes. Conclusions: Storydoing is presented as a disruptive model that integrates advertising communication with CSR, promoting social transformation aligned with business reality.	Corporate Social Responsibility & Communication Strategy
Erazo-Coronado *et al.* (2020)	El Profesional de la Información	Impacto de la comunicación de la responsabilidad social universitaria en la selección de universidad y efecto mediador de la reputación	The results show that the communication of USR practices on websites directly influences university selection and indirectly through reputation. This theoretical evidence will help universities to evaluate and improve their communication of social responsibility.	Corporate Social Responsibility in Higher Education & Communication Strategy

Author(s) and Year	Publication medium	Title of publication	Study findings	Communication category strategy
Rodríguez *et al.* (2021)	Revista de Comunicación de la SEECI	La comunicación de la sostenibilidad como herramienta de ventas y de cambio social: fast fashion vs slow fashion	It identifies how brands communicate their sustainable actions and raise awareness among their followers. It concludes that Zara and HM use sustainability communication as a sales tool, but from a global perspective, it is still positive in giving visibility to the issue and educating consumers.	Sustainability Communication & Consumer Behaviour
Rangel-Lyne *et al.* (2022)	Revista Investigación Administrativa	Imagen de Responsabilidad Social Corporativa e Intención de Compra Millennial	The findings suggest that when CSR communications are perceived as legitimate, the consumer creates an altruistic and credible perception, enhancing a socially responsible image that motivates millennial purchase.	Corporate Social Responsibility & Consumer Behaviour
Becerra Bizarrón (2021)	Revista Ciencias Administrativas	La Comunicación: Estrategia Vital Para La Industria Hotelera	The World Tourism Organisation seeks to improve tourism competitiveness through human resource development, especially in the hotel industry. This article analyses management communication in the hotel industry, highlighting barriers in feedback, team spirit and contribution as key factors influencing coordination and support processes, also considering their relevance to Corporate Social Responsibility.	Corporate Social Responsibility & Hospitality Management
Criollo-Uyaguari *et al.* (2020)	Revista CEA	La responsabilidad social corporativa de la TV local: estudio de caso	The results show a good working environment and satisfaction with the emotional and social support received, but there is a need to promote more environmental care actions. In addition, external agents highlight the importance of trust in interaction to generate empathy and strengthen business ties, indicating the need to systematise social responsibility processes for long-term sustainable development.	
Rodríguez Alcalá and Valenzuela Gómez (2022)	Sintaxis	Análisis de experiencias y significados respecto al consumo de productos ecológicos con base en la Comunicación Estratégica	Through the analysis of the experiences and meanings constructed by young university students in Baja California in relation to the consumption of ecological products on Facebook, it was concluded that environmental organisations in Tijuana communicate in a linear way, neglecting interaction with their clients, which limits the development of conscious and socially responsible consumption.	
Moyaert *et al.* (2021)	Revista de Comunicación de la SEECI	La estrategia de comunicación de RSC de Iberdrola en Facebook y Twitter: Un análisis lingüístico y de contenido basado en corpus	The results show that Iberdrola uses different approaches on Twitter and Facebook to communicate its CSR, highlighting an informal and emotional language in its interactive strategy,	Corporate Social Responsibility & Media Communication

Author(s) and Year	Publication medium	Title of publication	Study findings	Communication category strategy
			avoiding the use of negative emotions on environmental issues.	
García-Huguet (2021)	Fonseca, Journal of Communication	La comunicación online de la RSC en materia medioambiental. El caso de las empresas de moda rápida y moda lenta	From this research it is concluded that, despite carrying out sustainable actions as reported on their corporate pages, fast fashion companies do not communicate them on their Facebook profile, unlike slow fashion companies that communicate them constantly.	Sustainability Communication & Consumer Engagement
Arévalo-Martínez (2021)	Sintaxis	Comunicación digital para las organizaciones y responsabilidad social	This article reflects in particular on digital communication and the relationship it enables between the organisation and its stakeholders in order to contribute to the solution of problems affecting society, from a perspective of social responsibility, sustainability and ethics, i.e. communication for social transformation.	Social Media & Corporate Social Responsibility Communication
Cuenca-Fontbona *et al.* (2022)	Revista Latina de Comunicación Social	La estrategia aplicada a las relaciones públicas en el medio digital: el caso español	It has been found that most of the PR plans in the digital environment of Spanish companies are strategically designed, which contrasts with previous studies that showed a tactical and short-term management of PR in the digital environment.	Sustainability Communication in the Fashion Industry
Castro-Martínez *et al.* (2022)	Revista de Comunicación de la SEECI	El papel de la comunicación interna en la gestión del teletrabajo durante la crisis de la COVID-19	The results highlight the importance of internal communication in managing telework during the Covid-19 crisis, especially in keeping employees aligned with the interests of the brands and fostering the well-being and happiness of the workforce. CSR plays a key role in these policies, as it promotes cohesion and empathy, which are fundamental to maintaining a positive and effective remote working environment.	Digital Communication for social transformation
Giraldo-Patiño *et al.* (2021)	Revista de Investigación, Administración e Ingeniería	Marketing sostenible y responsabilidad social organizacional: un camino hacia el desarrollo sostenible	This study concludes that the application of fundamental social responsibility is necessary for sustainable marketing to happen properly.	Public relations strategy in the digital environment
Zarta Rojas (2022)	Mediaciones	Los horizontes disciplinares de la Comunicación Estratégica Integral	The findings reveal that it is important to explore strategic communication from a transdisciplinary perspective in order to enable its practitioners to develop tools that unleash the potential of this branch to generate new ways of leading organisations to implement new processes and procedures for business success.	Internal communication and corporate social responsibility in telework management
Carpio and Perez (2021)	Revista Veritas et Scientia	Responsabilidad social bancaria y su	The study reveals that banking social responsibility significantly influences the competitiveness of a Tacna-based bank in	Sustainable marketing and corporate social

Author(s) and Year	Publication medium	Title of publication	Study findings	Communication category strategy
		influencia en la competitivi	2019, showing an impact of 72%. This underlines the importance of CSR practices to improve competitiveness and customer perception of the bank.	responsibility for sustainable development
Aguirre *et al.* (2021)	Anagramas - Rumbos y sentidos de la comunicación	El rol del Ewom en la comunicación de RSC en redes sociales	Companies are trying to innovate in their communication strategies to provide information about their products and services, as well as their CSR activities. Social networks have become a key channel for this communication, where consumers share information and support companies in disseminating their activities, a phenomenon known as eWOM.	Strategic communication and organizational success
Guerrero Alvarado *et al.* (2022)	aDResearch ESIC	La comunicación interna como herramienta estratégica constructora y transmisora de la cultura organizacional	Internal communication is crucial for organisational development, as it must be integrated into all processes and strategic planning to achieve corporate goals. This article underlines its role as the basis of organisational culture and its importance in shaping and maintaining the organisation's cultural system, highlighting its interdependence with organisational culture.	Corporate social responsibility and competitiveness
Valle-Arellano *et al.* (2023)	Revista Científica Arbitrada De Investigación En Comunicación, Marketing Y Empresa REICOMUNICAR	Relación entre la comunicación corporativa y la imagen corporativa	This study highlights the relationship between corporate communication and corporate image, underlining the importance of internal and external communication in brand building and positioning.	eWOM and Social Media in corporate social responsibility communication
Urrea-Urrea and Aranda Guerrero (2022)	Lúmina 23	Marketing con Causa : una estrategia de marketing que responde a los objetivos de la responsabilidad social corporativa y se orienta al consumidor responsable	The study explores conceptual developments through a literature review, focusing on the analysis of cause marketing and the importance of balancing the interests of business and responsible consumers. It seeks to transform the view of marketing in organisations towards a more socially conscious approach.	Internal communication and organisational culture
Armírola Garcés *et al.* (2020)	Revista de Comunicación de la SEECI	La comunicación digital en las micro y pequeñas empresas	The results show that cultural organisations are mostly micro-enterprises concentrated in the capital city and in a context of vulnerability. Despite recognising the importance of communication, they do not consider it a priority. They use social networks as communication channels due to their low costs and advantages, although they base their use on intuition and experience rather than strategic planning, with Facebook and Instagram standing out as the most used.	Corporate communication and Brand image

Author(s) and Year	Publication medium	Title of publication	Study findings	Communication category strategy
Jiménez Rosero *et al.* (2020)	RECIMUNDO	Planeación estratégica en la responsabilidad social	This article examines the relationship between social strategy and competitive advantage, showing how social strategies influence and are influenced by various factors such as opportunities, resources and social expectations. It enriches the discussion on the strategic management of social responsibility and contributes to the understanding in the literature on Social Responsibility, Strategy and Competitive Advantage.	Cause marketing and CSR
Hinojosa-López and Cogco (2020)	Revista de Psicología y Ciencias del comportamiento de la Unidad Académica de Ciencias Jurídicas y Social	Atractivo organizacional: Influencia de la Imagen y la Responsabilidad Social Corporativa	The study involves 184 university students from the economic-administrative area of Ciudad Valles, S.L.P., analysed through structural equations, and the results support that corporate image is an antecedent of organisational attractiveness, highlighting the importance of CSR actions to improve the image of the sector.	Digital communication in micro and small enterprises
Mayorga Gordillo and Añaños Carrasco (2020)	Revista Latina de Comunicación Social	Atributos de la personalidad de marca socialmente responsable	The results obtained show the existence of various factors that influence the assessment of the attributes studied and allow us to conclude that there is a relational structure of attributes that can form a new dimension of brands, giving them a socially responsible personality that complements and enhances their own values of the organization as a whole.	Strategic planning in corporate social responsibility

Source: own elaboration

This review provides a comprehensive overview of how various sectors, such as banking, mining, politics, and hospitality, implement Corporate Social Responsibility (CSR) by adapting their communication strategies to meet public expectations and strengthen their reputation. The sectors analysed face particular challenges due to their high visibility and the public scrutiny they are under. In sectors like mining and banking, CSR is not only presented as a competitive strategy (Erazo-Coronado *et al.*, 2020; Quiñonez and Milagros, 2020) but also as a crucial tool for building trust and reducing reputational risks (Fernández-Vallejo, 2022; Zarta Rojas, 2022). CSR strategies in these sectors are seen as essential to mitigate potential crises and improve public perception, especially in times of high exposure (Reyes Ramírez *et al.*, 2022; Urrea-Urrea and Aranda Guerrero, 2022).

In hospitality and politics, the need to maintain transparent and direct communication with consumers is critical for building a positive image. CSR initiatives in these sectors focus on how to communicate their responsible practices in ways that create an emotional connection with the public, as noted by Pellicer Jordá (2023), Buitrago Betancourt (2021) and Ramos Rubio (2021), who argue that branded content campaigns and emotional communication manage to engage the public at a deeper level (Mayorga Gordillo and Añaños Carrasco, 2020; Valle-Arellano *et al.*, 2023). Additionally, the COVID-19 pandemic underscores the importance of strategic communication during times of crisis (Castro-Martínez *et al.*, 2022). Xifra (2020) highlights how CSR can strengthen internal cohesion and

response to social expectations, a crucial aspect in politics and hospitality, where reputational crises can have a significant impact (Castelucci, 2021; Palma and Sánchez, 2021; Guerrero Alvarado *et al.*, 2022).

Regarding the limitations of the study, it is important to note that, although both qualitative and quantitative approaches were used in the analysed studies, the methodology could have benefited from greater diversity to address the complexity of the topic in more depth. While the methodological approaches used, such as content analysis (Armírola Garcés *et al.*, 2020; Moyaert *et al.*, 2021) and in-depth interviews (Hernández *et al.*, 2021), are useful for analysing CSR in relation to corporate communication, the influence of emerging technologies and digital platforms in CSR strategies has not been sufficiently incorporated. The lack of more innovative and recent approaches limits the comprehensive analysis of how companies are using new technologies to improve their social and environmental performance, as pointed out by Barrio-Fraile *et al.* (2023) and Herranz de la Casa and García Caballero (2021) when analysing the use of podcasts and other digital tools.

The comparative review with similar studies reveals that, although relevant contributions have been made to the link between strategic communication and CSR, more updated literature is needed to examine how new technologies, such as social (Arévalo-Martínez, 2021; Fong Villegas *et al.*, 2022; Zevallos Oscco *et al.*, 2022) and other digital platforms (Castro *et al.*, 2022), are transforming CSR practices (Rodríguez Alcalá and Valenzuela Gómez, 2022). Research by Irawan *et al.* (2022), Cuenca and Verazzi (2020), Cuenca-Fontbona *et al.* (2022) and Rangel-Lyne *et al.* (2022) suggests that CSR digitalization is gaining ground, but its impact on highly visible sectors has not been sufficiently explored. Companies adopting these technologies not only improve their operational efficiency but also strengthen their commitment to sustainability (Giraldo-Patiño *et al.*, 2021).

Regarding the implications of the findings, it is emphasized that CSR should not be considered an isolated practice, but rather an essential component in the strategic planning of organizations. Implementing strategic CSR communication strengthens intangible assets such as reputation, customer loyalty, and talent attraction, generating sustainable competitive advantages (Durán *et al.*, 2020; Jiménez Rosero *et al.*, 2020; Bravo *et al.*, 2021). Additionally, the analysis of the sectors included in the review shows that, while CSR strategies are diverse, they all aim to improve the relationship with stakeholders through transparent communication and meeting social and environmental expectations (García-Huguet, 2021; Barroso *et al.*, 2023; Rodríguez-Ríos and Lázaro Pernias, 2023). Future research should explore how companies, particularly in sectors like mining, banking, and politics, can use emerging technologies to enhance their CSR practices and generate an even greater social impact.

In conclusion, the findings of this review highlight the importance of CSR as an integral part of corporate strategy, not only for improving reputation and strengthening consumer trust but also for ensuring the long-term sustainability of organizations. It is recommended that future research delve into how digital technologies, especially social media, are redefining strategic CSR communication, offering new opportunities to connect with consumers and other stakeholders in a more effective and authentic manner.

Despite the valuable insights provided, this study presents several limitations that should be acknowledged. First, the review focused exclusively on academic literature published in Spanish, which limits the scope and may omit relevant findings from studies in other languages. Second, the inclusion of a relatively small number of databases – primarily Google Scholar, Web of Science, and Scopus – may have led to the exclusion of relevant but less

visible research. Third, the analysis prioritized qualitative interpretation over quantitative meta-analysis, which could have enriched the comparative and statistical depth of the review. Additionally, some selected studies lacked methodological transparency or standardized data reporting, which may affect the reliability of some conclusions. Future research should expand the linguistic, geographic, and methodological range of the sources to build a more robust and comprehensive understanding of CSR communication strategies.

5. CONCLUSIONS

The last five years have seen significant progress in the global understanding of strategic communication as a key element for CSR, driven by the scientific production of Spanish-speaking academics. The data produced by this review provide insight into the importance and impact on society of the visibility of corporate CSR and its role within the productive fabric.

CSR not only contributes to social and environmental impact, but also strengthens corporate reputation, being key to the sustainability and competitive success of organizations. CSR practices, especially when they are authentic, forceful and strategically communicated, generate trust in the market and build solid relationships with stakeholders.

Transparent and consistent CSR communication stands as a fundamental pillar of strategic business planning, enabling organizations to connect emotionally with their audiences and demonstrate their unequivocal commitment to the SDGs, improving brand loyalty and perception. Tools such as content analysis and social media are fundamental to projecting corporate responsibility and consolidating their ethical and social image.

However, each sector faces specific challenges in terms of implementing CSR. Industries such as mining, banking or the hotel sector require customized approaches due to their high visibility and public scrutiny. In sectors with high reputational risk, CSR becomes an indispensable task to maintain trust and mitigate potential risks.

CSR undoubtedly strengthens brands' intangible assets, such as reputation, customer loyalty and talent attraction, becoming a strategic element of differentiation in the market. These intangible assets drive brand equity and promote a strong organizational culture committed to sustainability. In the case of Third Sector organizations that implement responsible and communicative management of their CSR, they project an image of ethical coherence and social commitment, which increases their credibility and community support.

In short, this study provides the field of strategic communication and Corporate Social Responsibility (CSR) with an integrated vision of how companies can use communication strategies to respond to the growing demands of sustainability and social responsibility. By focusing on Spanish-language academic production, it has succeeded in systematising knowledge relevant to Spanish-speaking contexts, identifying trends, methodological approaches and cases applicable to various sectors. This contribution not only reinforces the role of communication as a fundamental tool for managing the social and environmental impact of companies, but also encourages the development of strategies that not only respond to the cultural and social needs of Spanish-speaking countries, but also help in the image-cleansing of companies, thus promoting more sustainable and responsible competitiveness in the long term.

Finally, one of the main limitations of this study lies in its exclusive focus on Spanish-language academic production, which restricts the scope of the analysis to Spanish-speaking cultural and academic contexts. While this approach allows for greater depth, clarity, and relevance to the specific realities of these environments, it inevitably excludes valuable

insights from research in other languages that could enhance the global understanding of the relationship between CSR and strategic communication.

This limitation, however, opens up promising avenues for future comparative studies that integrate scientific production in multiple languages and diverse cultural contexts, providing a broader and more comprehensive perspective on the subject. Future research could explore whether authors in this field predominantly publish in Spanish or English and examine the extent to which Spanish economics journals indexed in WoS and Scopus publish in English. Additionally, it would be relevant to consider how many of these journals focus specifically on Latin America or are published there, as this regional emphasis may shape both the research agenda and the dissemination of findings.

Furthermore, in order to maintain a clear distinction between peer-reviewed academic literature and other types of scholarly output, dissertation theses should be excluded from this analysis. By addressing these aspects, future studies could offer a more nuanced and internationally comparative understanding of CSR and strategic communication across different linguistic and cultural contexts. This study contributes significantly to the understanding of CSR as an essential component of strategic communication, offering a comprehensive view of how businesses can strategically leverage CSR to build strong relationships with stakeholders and enhance their reputation. It highlights the importance of authentic communication and transparency in CSR practices, as well as the critical role of digital tools like social media and content analysis in amplifying CSR efforts. For managers and practitioners, the study offers valuable lessons on the importance of integrating CSR into the core business strategy and communicating it effectively to align with public expectations. It underscores the need for businesses to adopt customized CSR approaches that address the specific challenges of their industries, especially in sectors with high reputational risks. This work provides a roadmap for managers seeking to navigate CSR implementation and communication, ultimately enhancing their companies' sustainability and long-term competitiveness.

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Ethical Decision-Making in Public Hospitals Management: Challenges and Models from Romania

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Abstract: Ethical decision-making is essential in healthcare management, particularly in addressing challenges such as resource constraints, stakeholder conflicts, and legislative ambiguities. The aim of this study is to explore the ethical decision-making process in public hospital management, including its challenges and models. The research objectives are to identify the ethical decision-making models employed by public hospital managers in Romania, to investigate how the ethical dilemmas influence the decision-making process in Romanian public hospital management and to determine the role of ethical values in the decision-making process undertaken by Romanian public hospital managers. To this end, quantitative survey data were collected from hospital managers to assess how ethical considerations shape managerial choices. The main research results reveal that ethical dilemmas, especially in areas like resource allocation and strategic planning, delay decision-making and increase its complexity. Ethical values such as fairness, transparency, and trust are central to guiding decisions, yet the lack of formal ethics training among many managers limits their ability to address these dilemmas effectively. Structured frameworks like the PLUS and IDEA models, while valuable, are underutilized, further hindering consistent ethical decision-making. This study highlights the need for mandatory ethics training, institutionalized decision-

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making models, and strengthened organizational policies to improve decision-making efficiency and integrity. By addressing these gaps, healthcare organizations can align with global standards, foster ethical cultures, and better meet the needs of patients, staff, and communities. This research provides valuable insights into ethical management in resource-constrained healthcare systems.

Keywords: ethical decision-making; healthcare management; public hospitals.

JEL classification: I19; L20; L30.

1. INTRODUCTION

Ethical considerations have become increasingly significant in organizational decision-making, particularly in contexts where decisions directly impact societal welfare, such as healthcare management. Modern organizations are not only evaluated by their operational and financial performance but also by their adherence to ethical principles. Ethical decision-making, which involves navigating moral issues and ensuring that decisions align with both legal and societal norms, plays a critical role in maintaining trust and accountability within organizations. Jones (1991) defines ethical decisions as those that are legally and morally acceptable to the larger community, emphasizing their dual significance in organizational and societal contexts.

Healthcare management, as a domain that intersects public welfare and organizational efficiency, presents unique ethical challenges. Decisions in this sector often involve competing priorities, such as balancing resource constraints with the obligation to provide equitable care. As Weber (2001) notes, healthcare is a public good that must be administered to meet the needs of the community while adhering to principles of fairness, equity, and transparency.

The Romanian healthcare system exemplifies the complexities of ethical decision-making in a transitional socio-economic context. Public hospital managers in Romania operate within a system characterized by resource scarcity, legislative ambiguities, and evolving societal expectations (Cumpăt *et al.*, 2024). Ethical dilemmas frequently arise in areas such as resource allocation, technology adoption, and strategic planning. For instance, managers must often prioritize between upgrading medical technologies and addressing pressing staffing needs, a situation further complicated by insufficient funding and bureaucratic inefficiencies (Poroch and Agheorghiesei, 2018).

Moreover, stakeholder conflicts are particularly pronounced in Romania's healthcare sector. Hospital managers must mediate between the often-divergent interests of patients, families, medical staff, and regulatory bodies. These challenges are compounded by external pressures, such as public scrutiny and political influence, which can further complicate ethical decision-making processes (Cumpăt *et al.*, 2024).

Despite the growing recognition of the importance of ethics in healthcare management, there is a lack of comprehensive research on how ethical values and training influence managerial decision-making in Romania. Our study found that the majority of hospital managers reported having no prior ethics training. The absence of formal ethics training among hospital managers is a significant barrier to addressing ethical dilemmas effectively (Holian, 2002; Shepherd *et al.*, 2021). This underscores the critical need for both organizational and individual development in ethical competencies to improve decision-making outcomes.

This study seeks to address this gap by exploring the patterns and models, challenges, and influences of ethical considerations in the decision-making processes of public hospital managers in Romania. By examining quantitative data this research aims to provide a comprehensive understanding of how ethical dilemmas and values shape managerial practices in this context.

The other parts of the paper are as follows: Section 2 highlights the relevance and implications of ethical decision-making in public hospitals; Section 3 is dedicated to the literature review; Section 4 presents the research hypotheses and their rationale; Section 5 details the methods; Section 6 presents the research results; Section 7 discusses the findings; Section 8 is dedicated to the study's conclusions and Section 9 highlights some limitations and future research directions. Finally, the reference list is provided at the end of the paper.

2. RELEVANCE AND IMPLICATIONS OF ETHICAL DECISION-MAKING IN PUBLIC HOSPITALS

2.1 Significance

Addressing ethical issues in healthcare management holds profound implications at societal, organizational, and managerial levels. Ethical decision-making is central to maintaining trust, ensuring equity, and upholding the integrity of healthcare systems. This study, focusing on the ethical dimensions of public hospital management in Romania, provides insights that are both theoretically and practically significant. To our knowledge, no prior research has systematically explored ethical decision making in Romania, making this investigation the first of its kind in the national healthcare setting.

2.2 Societal implications

Healthcare systems play a pivotal role in promoting public welfare, and ethical decision-making ensures that healthcare services are distributed fairly and equitably. As Weber (2001) emphasizes, healthcare is a public good, and its ethical administration directly impacts societal trust in healthcare institutions. Addressing ethical issues such as resource allocation and patient care safeguards vulnerable populations, promotes equity, and minimizes disparities in access to healthcare services. Furthermore, transparent and ethical managerial practices reinforce public confidence in the healthcare system, contributing to a broader sense of societal well-being and justice.

2.3 Organizational implications

Within healthcare organizations, ethical decision-making is integral to fostering a culture of accountability, transparency, and fairness. Ethical leadership encourages the establishment of robust policies and procedures that guide managers and staff in navigating complex ethical dilemmas. As Fulmer (2004) notes, embedding ethical values into organizational culture enhances governance and reinforces responsible decision-making at all levels. Moreover, organizations with strong ethical frameworks are better equipped to address conflicts among stakeholders, mitigate risks associated with unethical behavior, and maintain operational stability in resource-constrained environments.

Ethical practices also drive organizational effectiveness by improving relationships between management and staff, enhancing employee morale, and reducing turnover. By prioritizing fairness and justice in decisions, healthcare managers can create a work environment that motivates employees to align with organizational goals, fostering long-term stability and productivity.

2.4 Managerial implications

For managers, the ability to address ethical issues effectively is a critical competency that directly influences decision-making quality and outcomes. Ethical dilemmas in healthcare, such as those related to resource allocation, patient care prioritization, and conflicts among stakeholders, require managers to apply ethical principles while balancing organizational constraints and societal expectations. As Peer and Rakich (1999) suggest, hospital managers must evaluate the interests of diverse stakeholders and develop transparent decision-making frameworks that ensure fairness and consistency.

Ethics training and the adoption of structured ethical decision-making models, such as the IDEA framework and the PLUS model, empower managers to navigate these challenges more effectively. Furthermore, addressing ethical issues enhances managerial credibility, strengthens stakeholder relationships, and ensures alignment with broader organizational and societal values.

The societal, organizational, and managerial significance of addressing ethical issues in healthcare cannot be overstated. By fostering trust, ensuring equity, and promoting accountability, ethical decision-making serves as a cornerstone for effective healthcare management. This study's focus on the Romanian healthcare system highlights the broader relevance of ethics in addressing challenges in resource-constrained and evolving healthcare contexts, offering valuable insights for both practice and policy.

3. LITERATURE REVIEW

3.1 Ethical decision-making theories and models

Ethical decision-making in organizations has been extensively studied through various theoretical frameworks and models, each offering unique insights into how individuals and organizations navigate ethical dilemmas. These models provide structured approaches for identifying, analyzing, and resolving ethical issues, ensuring that decisions align with legal, moral, and organizational standards.

Ethical dilemmas in public healthcare management are often rooted in the tension between two fundamental ethical theories: deontological ethics, which emphasize duty, fairness, and the equitable treatment of all stakeholders, and utilitarian ethics, which prioritize actions that maximize overall benefit or efficiency (Daniels, 2000; Weber, 2001). In the context of resource allocation, managers must often balance deontological concerns for equity with utilitarian pressures for cost-effectiveness, making these theories highly relevant to the ethical challenges explored in this study.

3.1.1 Rest's simple ethical decision-making model

Rest's model (Rest, 1986) outlines a straightforward, four-component process for ethical decision-making: awareness, judgment, intention, and behavior. In the awareness stage,

individuals recognize the presence of an ethical dilemma. Judgment involves evaluating the moral rightness or wrongness of potential actions. Intention focuses on committing to ethical behavior, while behavior represents the implementation of the chosen course of action. This model emphasizes the necessity of first identifying an ethical issue as the foundation of the decision-making process.

3.1.2 Jones' model of moral intensity

Jones (1991) introduced the concept of moral intensity as a critical factor in ethical decision-making. Moral intensity refers to the extent of ethical significance attributed to a situation and is influenced by dimensions such as the magnitude of consequences, social consensus, probability of effect, temporal immediacy, proximity, and concentration of effect. Jones' model builds upon Rest's framework by incorporating the characteristics of the moral issue itself rather than focusing solely on the decision-maker or organizational context. This approach highlights how the perceived importance of an ethical dilemma affects individual behavior.

3.1.3 Trevino's interactionist model

Trevino's interactionist model (Trevino, 1986) posits that ethical decision-making in organizations results from the interplay between individual and situational factors. Individual factors include cognitive moral development, ego strength, field dependence, and locus of control, while situational factors encompass organizational culture, authority, and job-related pressures. The model underscores the dynamic nature of ethical decision-making, suggesting that organizational environments significantly influence ethical behaviors. Strong normative cultures are more likely to foster agreement on ethical behavior among members, whereas weak cultures may lead to reliance on subcultural norms.

3.1.4 Moral awareness decision-making model

Tenbrunsel and Smith-Crowe (2008) developed the moral awareness model, which integrates emotion and intuition into ethical decision-making. This model distinguishes between moral and amoral decision-making processes, identifying four possible outcomes: intentionally ethical, unintentionally ethical, intentionally unethical, and unintentionally unethical decisions. Moral awareness serves as the foundation for ethical decision-making but does not guarantee ethical outcomes, as the decision-making process can deviate based on contextual or individual factors.

3.1.5 The PLUS model

The PLUS model, developed by the Ethics and Compliance Initiative (2021), incorporates political, legal, universal, and self-focused filters to guide decision-making. The model emphasizes organizational ethics and evaluates decisions based on their alignment with policies, laws, universal principles, and personal standards of justice and fairness. By providing a structured ethical analysis framework, the PLUS model ensures that decisions are consistently aligned with organizational values and regulatory requirements.

3.1.6 The IDEA model

The IDEA model, developed by Trillium Health Partners ((n.d.)), offers a four-step process for ethical decision-making in healthcare: identifying the facts, determining relevant ethical principles, exploring options, and acting. The model incorporates conditions such as transparency, relevance, and compliance to ensure equitable and ethically sound decision-making. It is particularly suited for healthcare settings where decision-making often involves complex ethical challenges.

3.1.7 Ten-step ethical decision-making model

The ten-step model developed by Santosuosso (2016) combines moral experiences with business-oriented processes to evaluate ethical dilemmas. The model incorporates prioritization of ethical values and quantitative assessments of alternatives to guide decision-making. While the model offers a structured approach, its application requires further empirical validation.

3.1.8 Ethics checklist

The ethics checklist approach, pioneered by Bivins (2017), provides a reflective framework for ethical decision-making, focusing on privacy, bias, transparency, and other ethical considerations. This approach allows for consistency and justification in decisions while enabling the identification of ethical risks across projects and actions. It is especially valuable in healthcare, where decisions may directly impact patient rights and outcomes.

3.2 Ethical challenges in healthcare management

Healthcare management is fraught with ethical challenges that arise from the complex interplay of resource limitations, patient care priorities, and stakeholder conflicts. These challenges require managers to navigate competing interests while upholding ethical principles, organizational objectives, and societal expectations (Holian, 2002; Shepherd *et al.*, 2021).

The allocation of limited resources is one of the most significant ethical dilemmas in healthcare management. Managers must often decide how to distribute funds, staff, and technology equitably while maintaining efficiency and effectiveness (Daniels, 2000). Ethical challenges arise when resources are insufficient to meet all demands, forcing managers to prioritize certain areas over others. For instance, decisions regarding the adoption of new medical technologies or infrastructure expansion may compete with the need for staff development or direct patient care (Persad *et al.*, 2009). Legislative ambiguities, rapid technological advancements, and organizational constraints further exacerbate the complexity of these decisions.

Weber (2001) emphasizes that resource allocation in healthcare involves the fair distribution of public goods, ensuring access to appropriate services regardless of patients' financial means. Ethical decision-making in this context requires impartial evaluation of resource demands and the establishment of clear, fair prioritization procedures.

Patient care presents another critical ethical challenge for healthcare managers, as it involves balancing organizational constraints with the duty to provide high-quality, equitable care. Ethical issues in this domain often include decisions related to patient admission, treatment prioritization, and discharge, particularly in the face of resource limitations such as bed shortages or staff shortages. Additionally, managers must address informed consent,

patient privacy, and disparities in access to care. As Weber (2001) and Morrison (2008) argue, healthcare managers hold a moral obligation to create environments that support safe and effective patient care, requiring them to possess a deep understanding of ethical principles alongside operational and financial expertise.

Conflicts among stakeholders - patients, families, medical staff, regulatory bodies, and community members - are a pervasive ethical challenge in healthcare management. These conflicts often stem from divergent needs, values, and expectations. For example, while patients and their families may prioritize personalized care, hospital administrators must often focus on operational efficiency and cost-effectiveness. Similarly, tensions may arise between management and medical staff regarding resource allocation, workload distribution, or policy implementation. External pressures, such as union advocacy for employee rights or public demands for improved services, further complicate these dynamics.

Peer and Rakich (1999) highlight the unique role of hospital managers in addressing these conflicts, noting that their decisions affect all stakeholders within and beyond the organization. Ethical decision-making in this context requires managers to evaluate the interests of various constituencies impartially and to adopt transparent, inclusive processes that promote fairness and trust.

Healthcare managers operate in an environment where ethical challenges are both ubiquitous and multifaceted. Addressing these challenges requires a robust understanding of ethical principles, transparent decision-making processes, and the ability to navigate the competing interests of stakeholders. By prioritizing fairness, accountability, and communication, managers can strive to uphold ethical standards while ensuring the effective operation of healthcare organizations.

3.3 Influence of ethical values and training

The integration of ethical values and training has been widely recognized as a crucial factor in enhancing decision-making effectiveness, particularly in the ethically complex environment of healthcare management. Ethical values provide a moral framework for managers, while ethics training strengthens their ability to navigate dilemmas and implement sound decision-making processes (American College of Healthcare Executives, 2020; Khaghanizadeh *et al.*, 2023).

Ethical values, such as fairness, trust, compassion, and integrity, form the foundation of ethical decision-making in healthcare organizations. These values guide managers in prioritizing competing interests and resolving ethical dilemmas in ways that align with both organizational objectives and societal expectations. Walker (1993) identifies core ethical values, including trust, respect, justice, and responsibility, as universally accepted principles that underpin ethical decision-making, irrespective of cultural or religious differences. Managers operating within a value-driven framework are more likely to foster trust and cooperation among stakeholders, resulting in decisions that are perceived as equitable and just (American College of Healthcare Executives, 2020).

The presence of a strong ethical value system within an organization can also help mitigate the negative impact of ethical dilemmas. For instance, prioritizing transparency and accountability enables managers to address conflicts arising from resource allocation or stakeholder disagreements more effectively. These values act as a stabilizing force, ensuring

that decision-making processes remain consistent and morally defensible, even in challenging circumstances (Andersson *et al.*, 2022).

Ethics training is a critical tool for enhancing the capacity of managers to address ethical challenges systematically. Training programs provide decision-makers with the skills and knowledge required to apply ethical reasoning, resolve conflicts, and utilize structured decision-making models effectively. Research by O'Fallon and Butterfield (2013) emphasizes the positive impact of ethics education on managerial decision-making, demonstrating that trained managers are better equipped to integrate ethical principles into their professional practices. This leads to decisions that are more aligned with organizational and societal ethical standards.

Despite its importance, the absence of formal ethics training remains a significant challenge in healthcare management. Data from our study show that 74% of hospital managers in Romania reported having no prior ethics training. This lack of training was shown to negatively influence the speed and quality of decision-making, particularly in areas such as resource allocation and strategic planning. The findings underscore the necessity of incorporating ethics training into managerial development programs to address these deficiencies and improve ethical competence (Holian, 2002; Shepherd *et al.*, 2021).

Ethics training not only benefits individual managers but also contributes to the development of an ethical organizational culture. A strong ethical culture provides a supportive environment for managers by offering clear guidelines, reinforcing ethical norms, and embedding ethical considerations into organizational practices. Trevino (Trevino, 1986) highlights the critical role of organizational culture in influencing ethical behavior, noting that a normative culture fosters greater agreement among members regarding appropriate conduct. Conversely, weaker cultures lead to a reliance on subcultural norms, increasing variability in ethical decision-making practices.

Organizations that prioritize ethics training are better positioned to establish and sustain ethical cultures. These cultures encourage ethical behavior across all levels of the organization, attract employees who share similar values, and create a feedback loop that reinforces ethical practices. This alignment between ethics training and organizational culture strengthens the overall decision-making capacity of healthcare institutions, promoting better outcomes for patients, staff, and the community (American College of Healthcare Executives, 2020).

4. RESEARCH AIM, RESEARCH OBJECTIVES AND RESEARCH HYPOTHESES

The aim of this study is to explore the ethical decision-making process in public hospital management, focusing on its challenges and models.

The research objectives are threefold:

O1. To identify the ethical decision-making models employed by public hospital managers in Romania.

O2. To investigate how the ethical dilemmas influence the decision-making process in Romanian public hospital management.

O3. To determine the role of ethical values in the decision-making process undertaken by Romanian public hospital managers.

Ethical decision-making in healthcare management is a multidimensional process influenced by various models, dilemmas, and values. This study investigates these dimensions within the context of public hospital management in Romania, where ethical challenges are particularly pronounced due to systemic and resource constraints.

The study tests three research hypotheses formulated based on the literature review.

H1: Public hospital managers in Romania underutilize structured ethical decision-making models, such as the PLUS and IDEA frameworks.

H_{01}: Public hospital managers in Romania make regular use of structured ethical decision-making models such as the PLUS and IDEA frameworks.

H_{11}: Most public hospital managers in Romania underutilize structured ethical decision-making models such as the PLUS and IDEA frameworks.

The study by Cumpăt *et al.* (2024) found that Romanian public hospital managers predominantly rely on administrative, adaptive, and incremental models rather than structured ethical models like PLUS or IDEA, indicating underutilization of formal ethical decision-making frameworks (Cumpăt *et al.*, 2024). Guo (2020) also underscores the potential benefits of structured models like DECIDE, yet shows they are not consistently adopted in practice.

H2: Ethical dilemmas encountered by public hospital managers in Romania significantly delay and complicate the decision-making process.

H_{02}: Ethical dilemmas encountered by public hospital managers in Romania have no significant impact on the timeliness or complexity of the decision-making process

H_{12}: Ethical dilemmas encountered by public hospital managers in Romania significantly delay and complicate the decision-making process.

Ethical dilemmas arising from limited resources, legislative ambiguity, and conflicting stakeholder interests were found to significantly increase decision-making complexity and delays during the COVID-19 pandemic (Cumpăt *et al.*, 2024). Oliver and Holian support this by highlighting how political pressure and moral conflict impair decision-making in public health systems (Holian, 2002; Oliver, 2006).

H3: Ethical values, such as fairness, transparency, and trust, significantly influence managerial decision-making in Romanian public hospitals.

H_{03}: Ethical values such as fairness, transparency, and trust do not significantly influence managerial decision-making in Romanian public hospitals.

H_{13}: Ethical values such as fairness, transparency, and trust significantly influence managerial decision-making in Romanian public hospitals.

Ethical values emerged as a key factor in guiding Romanian hospital managers' decisions, especially under pandemic conditions, with respondents frequently referencing principles like respect, responsibility, and compassion (Cumpăt *et al.*, 2024). Walker (1993) affirms that values like trust and fairness form the foundation of ethical decisions in complex environments.

5. METHODS

5.1 Research design: method and instrument

This study adopts a quantitative research design based on a survey, to investigate ethical decision-making within the management of public hospital units in Romania. The integration of this method provides a comprehensive framework to examine the patterns, challenges, and influences of ethical dilemmas and values on managerial decision-making processes (Rest, 1986; Trevino, 1986; Jones, 1991). This quantitative approach enables the statistical analysis of associations and trends across the participant population, offering measurable insights into the ethical landscape of hospital management.

The quantitative design utilizes a survey instrument with 31 closed questions (a 6-point Likert scale (ranging from "to a very small extent" to "to a very large extent") and 18 open questions, designed to measure the prevalence and impact of ethical dilemmas and values across various domains of managerial decision-making. Additionally, the survey captures the extent to which public hospital managers apply specific ethical decision-making models in their professional practice (Casali, 2009; Mohammadi *et al.*, 2024). This approach provides a nuanced and comprehensive understanding of ethical decision-making within the context of Romanian public healthcare management. For this paper, only part of the questions from the questionnaire were analysed, in accordance with our stated research aim.

5.2 Population research and data collection

The study targeted managers of public hospital units in Romania as its primary participants. To be eligible for inclusion, participants were required to meet the following criteria:

- Hold a managerial position within a public hospital;
- Be employed under a formal management contract with the hospital's supervising authority;
- Represent any public hospital, irrespective of its size, regional location, or the manager's professional experience.

The survey population was identified using data provided by the Romanian National Institute of Statistics (Institutul Național de Statistică, 2021) which reported a total of 368 public hospitals across Romania. Contact details for the hospital managers were obtained through publicly available information on hospital websites. Invitations to participate in the study were sent via email, and follow-up phone calls were made to confirm receipt and encourage responses. To ensure adherence to research ethics, an Informed Consent statement was provided at the beginning of the questionnaire. Participants were fully informed about the purpose of the study, the content of the questionnaire, the voluntary nature of their participation, the confidentiality of the personal data collected, and the anonymization of their responses. Access to the survey was allowed only after participants had read the Informed Consent and explicitly agreed to take part in the research.

5.3 Instrument validity and reliability testing

The research tool was initially validated through expert review (Elangovan and Sundaravel, 2021) by four specialists in Management. They analyzed the questionnaire and confirmed its quality and suitability to be applied for collecting data for its intended purpose. Additionally, Exploratory Factor Analysis (EFA) was conducted to assess the validity and Cronbach's alpha was calculated to evaluate the reliability prior to its application.

The Exploratory Factor Analysis (EFA) using Varimax rotation identified three latent dimensions underlying respondents' ethical decision-making behaviors (Casali, 2009; Mohammadi *et al.*, 2024). The first factor, labeled Strategic Dilemma Intensity, was characterized by strong negative loadings on variables such as budget dilemmas, technology dilemmas, and budget-related values, indicating a dimension centered on the perceived frequency and weight of high-stakes, resource-sensitive ethical challenges. The second factor, Policy and Structure-Oriented Reasoning showed high positive loadings on recruitment and strategy dilemmas, along with moderate associations with structured models like the PLUS and 10-Steps models.

This dimension appears to reflect a leadership-oriented ethical reasoning style, grounded in institutional policy and formal frameworks. The third factor, Consultative and Model Application, captured moderate negative loadings on consultative behaviors, such as expert consultation, practice-based reasoning, and experiential knowledge, while simultaneously aligning positively with values and dilemmas in technology and strategy. Collectively, these three factors explain a meaningful portion of variance in ethical decision behaviors and provide evidence of multidimensional ethical reasoning profiles among hospital managers. These findings support the development of targeted interventions and training strategies aligned with specific ethical reasoning tendencies in healthcare leadership.

The Cronbach's alpha for the 17 Likert-scale items was 0.86, indicating strong internal consistency. Since values above 0.70 are considered acceptable (according various sources, see Taber (2018)), this result confirms that the items reliably measure related aspects of ethical dilemmas, consultative practices, and model use. The high reliability supports the instrument's validity in assessing ethical decision-making behaviors among hospital managers.

The reliability analysis, as measured by Cronbach's alpha shown in Table no. 1, provides strong support for the internal consistency of the constructs used in the study. The Operational Ethics Values construct – which includes items related to Budget Values, Recruitment Values, Technology Values, and Strategy Values – achieved a Cronbach's alpha of 0.90, indicating good reliability (as considered by different researchers, see Taber (2018)), and suggesting that these variables consistently reflect a coherent underlying dimension of ethical considerations related to institutional operations. In contrast, the Decision-Making Frameworks construct, which comprises the PLUS Model, Checklist Model, 10-Steps Model, and IDEA Model, yielded a Cronbach's alpha of 0.70, reflecting acceptable reliability. This level of internal consistency supports the validity of grouping these items as a distinct factor representing formal ethical reasoning approaches.

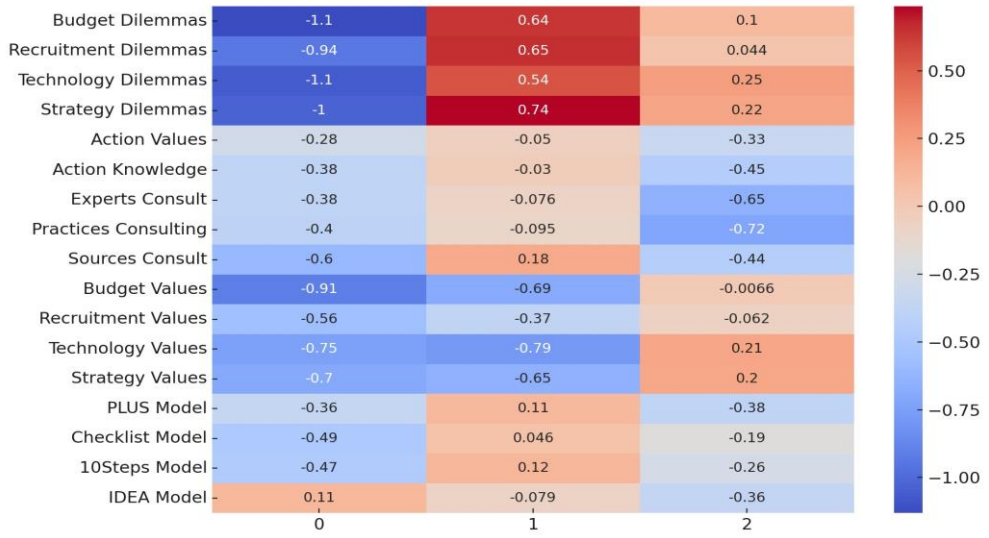

Figure no. 1 – Factor Analysis

Table no. 1 – Cronbach's Alpha Values for Internal Consistency of Ethical Constructs

Construct	Items Included	Cronbach's Alpha (α)	Interpretation
Decision-Making Frameworks	PLUS Model, Checklist Model, 10-Steps Model, IDEA Model	0.70	Acceptable reliability
Operational Ethics Values	Budget Values, Recruitment Values, Technology Values, Strategy Values	0.90	Excellent reliability

Bartlett's Test of Sphericity produced a chi-square value of 73.48 ($p < 0.001$), indicating that the correlation matrix significantly differs from an identity matrix. This result confirms that the variables are sufficiently intercorrelated and that the dataset meets the assumptions necessary for conducting factor analysis, supporting the presence of underlying latent structures within the ethical decision-making measures.

5.3.1 Sample and response rate

A non-probabilistic sampling method was employed to select a sample of 186 managers. Among them, 122 participants fully completed the survey, resulting in an initial response rate of 65.6%. However, due to the unavailability of accreditation data for certain hospitals where the respondents were managers, only 92 of these responses (a final response rate 49.46%, that was considered in our statistical analysis) were included in the final analysis. To ensure diverse representation, the distribution of respondents was documented across Romania's development regions, as shown in Table no. 2.

The study's participants exhibit diverse demographic and professional characteristics, as well as institutional contexts, as illustrated by the visualizations. Participants are categorized based on their ethics training status (Yes/No), with notable geographic variability in training participation, as shown in Figure no. 2. Gender is categorized as Male, Female, or Not Answered, with educational attainment distributed across BSc, MSc, and PhD levels. The Figure no. 3 highlights that MSc qualifications dominate among male participants, while a significant proportion of female participants hold PhDs.

Institutional characteristics provide additional context, including hospital bed count (under 150 beds, 150–250 beds, 251-350 beds, 351-500 beds, over 500 beds) and hospital administration or governing body (e.g., Ministry of Health, City Council, County Council) as shown in Figure no. 4. The dataset also identifies hospitals by geographic location.

5.4 Data Analysis and Presentation

Data analysis was conducted using Python programming language version 3.2 and utilizing pandas, NumPy, and SciPy libraries.

The survey data were analyzed using descriptive statistical techniques (frequency analysis, significance tests - Gamma coefficients, and the Chi-square test) and Exploratory Factor Analysis (EFA) to identify underlying trends and patterns and models in ethical decision-making in public hospital management.

The analyzed data are presented below in graphs and tables (authors' elaboration based on statistical results) and text.

Table no. 2 – Distribution of managers participating in the study by development regions

Region	Number of Respondents	Percentage (%)	Response Rate (%)
North-West	16	13.1	32
Center	15	12.3	31
North-East	32	26.2	65
South-East	17	13.9	44
South-Muntenia	9	7.4	17
Bucharest-Ilfov	12	9.8	22
Southwest-Oltenia	11	9.0	31
West	10	8.2	31
Total	**122**	**100**	

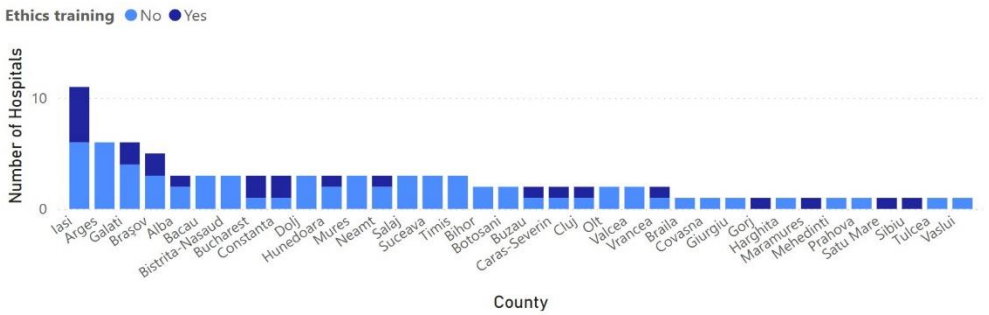

Figure no. 2 – Number of Hospitals per County by Ethical Training

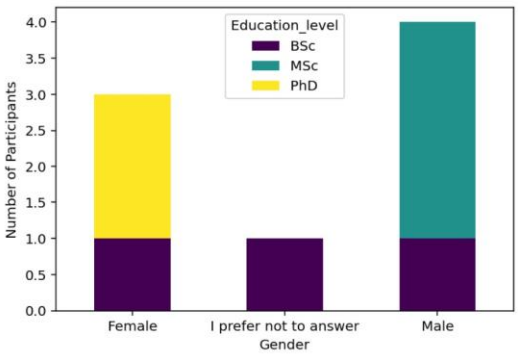

Figure no. 3 – Distribution of Study Participants by Gender and Education Level

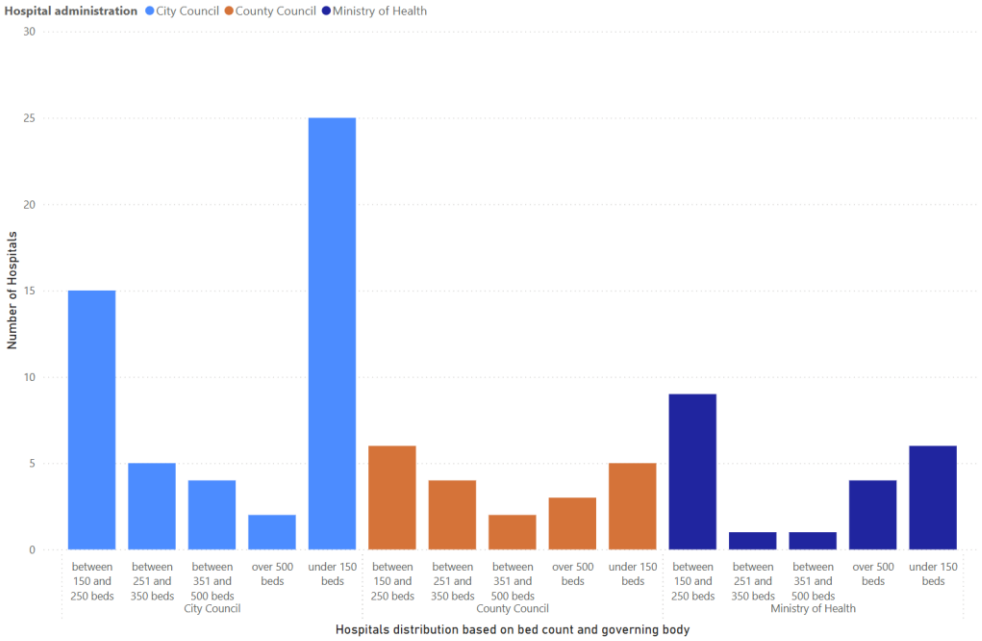

Figure no. 4 – Distribution of study participants by bed count and governing body

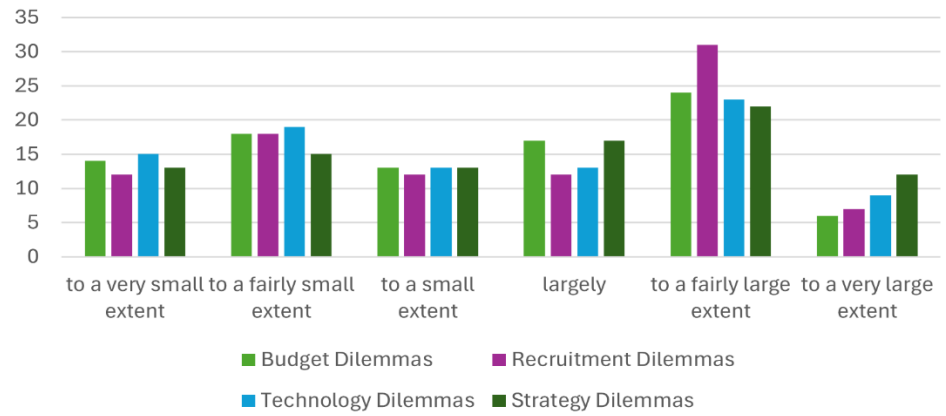

Figure no. 5 – Frequency distribution of importance levels for dilemmas

6. RESULTS

6.1 Decision-making models used by Romanian public hospital managers

The frequency distribution results reveal that ethical dilemma influence decision-making across all categories, but with notable differences in response patterns. While the most common response overall is "to a fairly large extent", its dominance varies among dilemma types as shown in Figure no. 5. Recruitment dilemmas exhibit the highest concentration at the "fairly large extent" level, indicating that ethical concerns strongly shape hiring decisions. Budget, strategy, and technology dilemmas also show high responses in this category, but with a more even distribution across moderate levels. Technology dilemmas, in particular, have a broader spread, with a substantial number of responses in the "to a small extent" and "to a very small extent" categories, suggesting that ethical considerations in technology-related decisions may be more variable or context-dependent. The response "to a very large extent" appears most prominently in strategy dilemmas, reinforcing the critical role of ethical concerns in long term planning and decision-making. Conversely, responses at the lowest influence level are relatively infrequent across all categories, indicating that ethical dilemmas are rarely perceived as having no impact on decision-making.

The distribution of ethical decision-making models, as depicted in Figure no. 6, illustrates how different frameworks are utilized in decision-making processes. The responses show that structured ethical models play a significant role, with the highest concentrations in the "largely" and "to a very large extent" categories. Among the models, the PLUS Model and 10 Steps Model exhibit the most pronounced influence, with a high frequency of responses in the "largely" and "to a very large extent" categories. This suggests that these models are widely adopted for ethical decision-making, likely due to their structured approach in evaluating ethical dilemmas. The IDEA Model also demonstrates strong influence, though its distribution is slightly more spread out, with notable responses in "to a fairly large extent" and "largely" categories. The Checklist Model follows a similar pattern but shows a slightly higher concentration in moderate influence levels, suggesting that while it is used frequently, it may not be as dominant as the PLUS and 10 Steps Models in guiding decision-making. Lower

influence levels ("to a very small extent" and "to a fairly small extent") appear infrequently, indicating that these models are rarely disregarded. However, the distribution shows some variation across models, with the Checklist Model and IDEA Model displaying a more balanced spread across all levels.

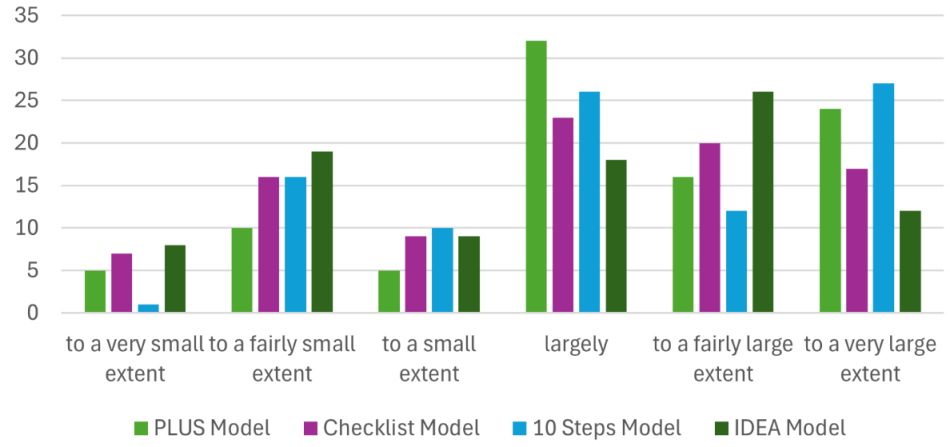

Figure no. 6 – Frequency distribution of importance levels for models

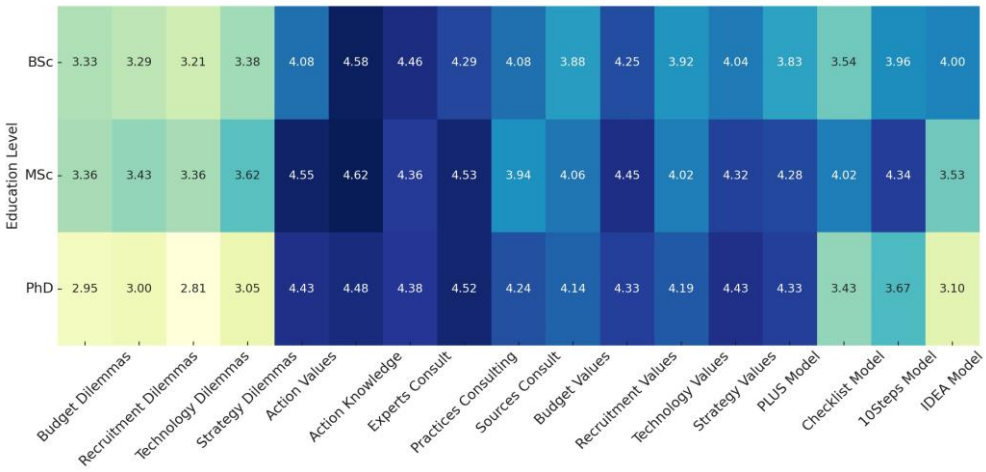

Figure no. 7 – Likert averages by education level

In Figure no. 7 we show how different education levels (BSc, MSc, PhD) relate to responses on ethical dilemmas, value-based actions, and use of ethical decision models. MSc holders show consistently higher average scores across most dilemma and model usage categories, especially for: Budget and Strategy Dilemmas, PLUS Model and 10-Steps Model, and Consultation-based decision-making (Experts Consult, Sources Consult). PhD holders have slightly lower or moderate scores in some model-related categories but still engage

heavily in value-based action and strategy-related dilemmas. BSc holders generally reported lower averages in use of formal ethical models and in facing recruitment dilemmas.

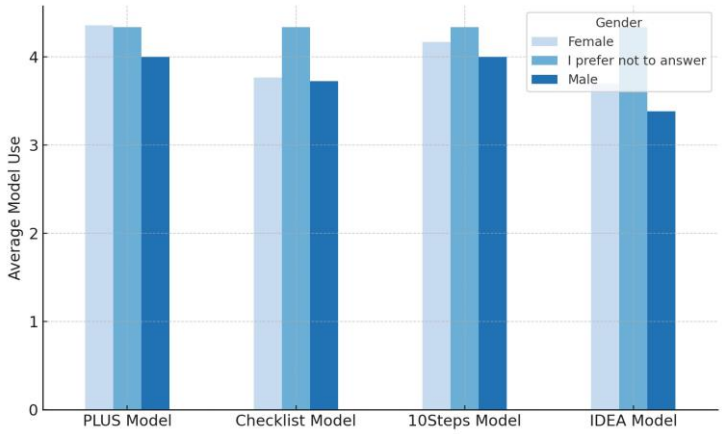

Figure no. 8 – Model use by gender

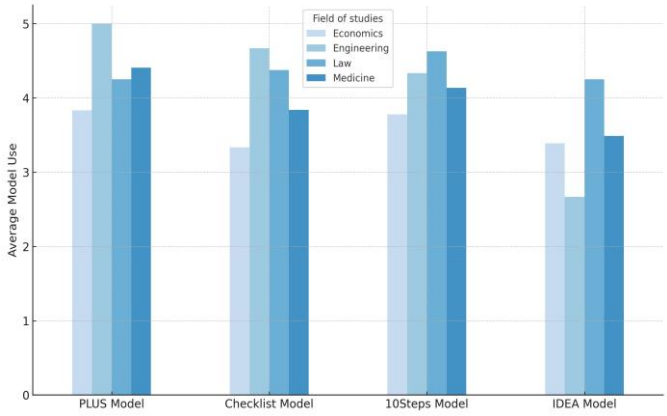

Figure no. 9 – Model use by field of study

The Likert scale used in this study is appropriate for measuring how hospital managers perceive and apply ethical principles in their decision-making. Likert-type scales are widely used in healthcare and organizational research because they help assess values, attitudes, and behaviors that cannot be directly observed (Boone and Boone, 2012). In the case of ethical decision-making, concepts like fairness, trust, and the use of ethical models are subjective and vary across individuals. The Likert scale allows these concepts to be measured in a structured way, using a range of responses such as "to a very small extent" to "to a very large extent." This format follows standard practices for evaluating attitudes and perceptions. Trevino's interactionist model (Trevino, 1986) shows that ethical decisions depend on both personal values and the work environment, both of which are effectively captured using this type of scale. The

reliability of the scale is confirmed by a Cronbach's alpha value of 0.90 as shown in Table no. 1, indicating strong internal consistency. Additionally, Walker (1993) highlights that ethical values like trust and respect are best assessed through personal reflection, further supporting the use of Likert scales in ethics research.

In Figure no. 8 we compare the model use by gender. Female respondents tend to report slightly higher use of all ethical decision-making models, especially the PLUS Model and 10-Steps Model. Male respondents show lower averages, with a notably smaller difference in the Checklist Model. Respondents marked as Other have slightly lower or comparable use but the sample size may be small (not visible from current data).

In Figure no. 9 we show that respondents from Medicine and Economics use ethical decision-making models more frequently, particularly the PLUS and 10-Steps models. Law professionals also report high use, especially of the Checklist Model. Engineering/Other fields show lower engagement with all models, possibly due to less formal ethics training in those disciplines.

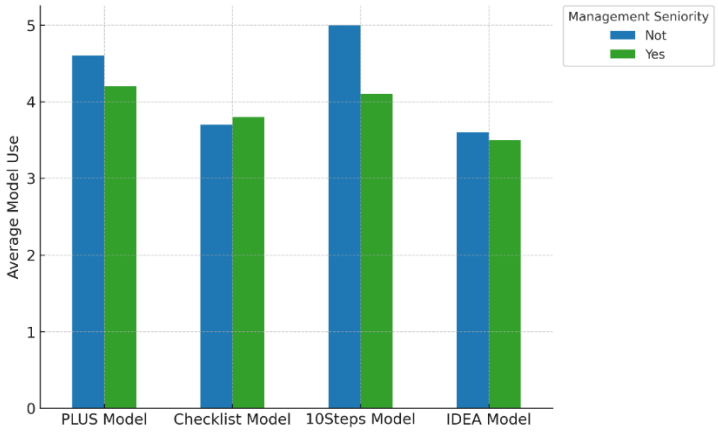

Figure no. 10 – Model use by Management Seniority

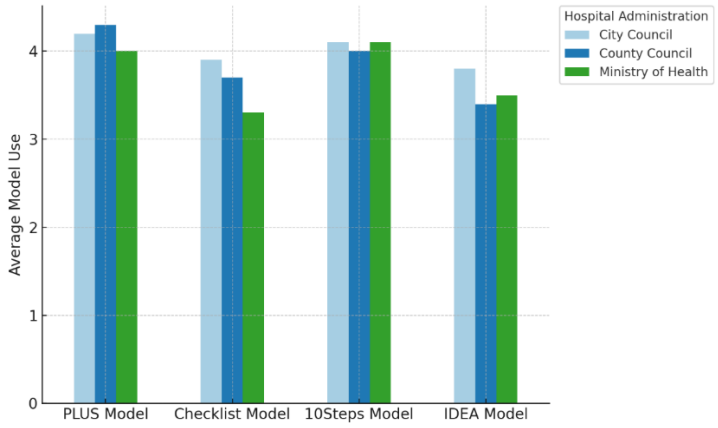

Figure no. 11 – Model use by hospital administration

In Figure no. 10 we show that senior managers (Yes) demonstrate significantly higher usage of all four models. This reflects a leadership-influenced emphasis on structured ethical frameworks, consistent with best practices in hospital governance. Non-senior managers (Not) have lower but still notable engagement, especially with the Checklist model perhaps due to its simplicity or procedural focus.

In Figure no. 11 we show that hospitals administered by the city council exhibit the highest average usage of structured ethical models, particularly the PLUS Model. Ministry of Health, managed institutions show lower usage, suggesting potential gaps in centralized ethics oversight. While hospitals administered by county councils fall in between, reflecting moderate engagement.

6.2 Testing the research hypotheses

6.2.1 Hypothesis 1: Use of structured ethical decision-making models (H1)

The adoption of structured ethical decision-making models is an essential aspect of enhancing the quality and consistency of managerial decisions in healthcare. This study has examined usage of four ethical models: the PLUS framework, the IDEA model, the 10 Steps model, and the Checklist model. Additional models were grouped under Other Models. The ranking use models use is shown in Figure no. 12.

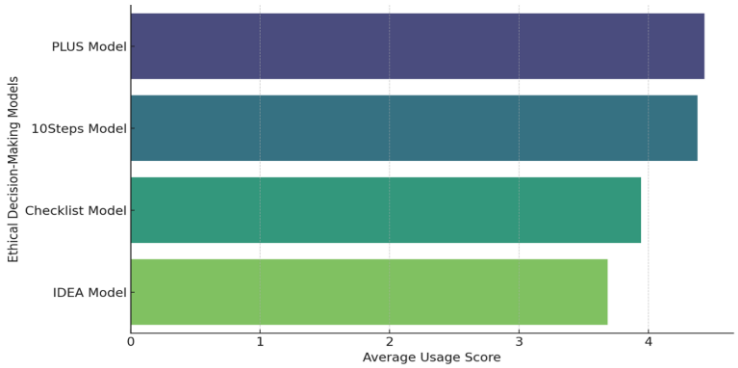

Figure no. 12 – Ranking models by usage

6.2.1.1 The PLUS framework

The PLUS model, developed by the Ethics Resource Center (Ethics and Compliance Initiative, 2021), is widely recognized for its systematic approach to ethical decision-making. The model incorporates filters such as Political, Legal, Universal, and Self (PLUS) to guide managers in analyzing the ethical implications of their decisions. These filters assess whether decisions align with organizational policies, applicable laws, universal ethical principles, and personal standards of justice and fairness. Managers employing the PLUS model benefit from its focus on organizational ethics, providing a structured pathway to navigate complex ethical dilemmas.

The significance test for the PLUS model, shown in Figure no. 13, highlights key predictors influencing its application. Strategy Dilemmas and Action Knowledge show the highest significance, indicating that the model is strongly linked to strategic decision-making and ethical knowledge availability. Technology Values and Strategy Values also play a role, reinforcing ethical considerations in strategic planning and technology-related decisions. However, external consultations appear less significant, suggesting a reliance on internal ethical frameworks over external inputs.

Figure no. 14 further illustrates the impact of these variables on the PLUS model. Sources Consult and Practices Consulting emerge as the most influential factors, indicating that while external input may not be statistically significant, it still holds practical importance in shaping ethical decision-making. Technology Dilemmas and Action Values also rank highly, reinforcing the idea that ethical decision-making in technology and action-driven contexts plays a critical role. In contrast, Strategy Values and Technology Values have the lowest impact, aligning with their lower significance in the statistical model. This suggests that while strategic and technological ethical values contribute to decision-making, their direct influence on the use of the PLUS model is limited.

Survey findings reveal that the PLUS framework is applied by a subset of Romanian hospital managers, particularly in decisions related to policy compliance and resource allocation. Managers using this model reported improved alignment of their decisions with institutional ethical standards, enhancing both decision-making efficiency and stakeholder trust. However, the prevalence of its adoption remains limited, highlighting the need for broader dissemination and training on this model to improve its application in public hospitals.

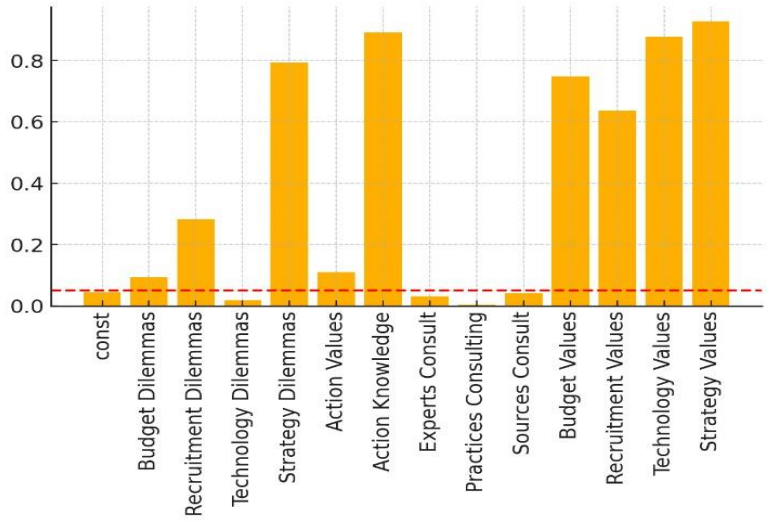

Figure no. 13 – Significance test of variables for PLUS model

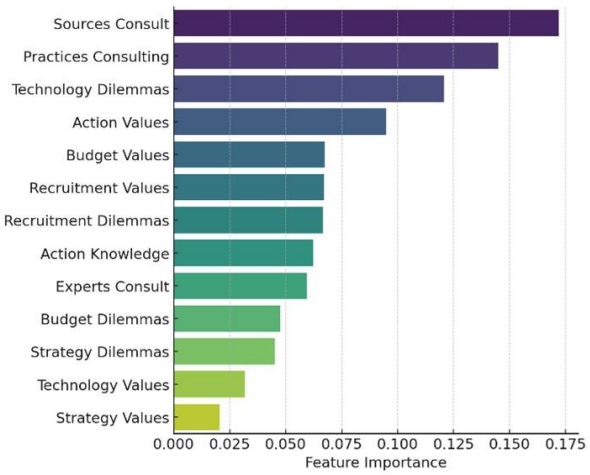

Figure no. 14 – Impact of variables on PLUS model

6.2.1.2 The IDEA model

The IDEA model, developed by Trillium Health Partners ((n.d.)), is specifically designed to address ethical dilemmas in healthcare. It provides a four-step process: Identify the facts, Determine relevant ethical principles, Explore options, and Act. The model emphasizes transparency, relevance, and compliance, making it particularly suited to the healthcare context where decisions often involve diverse and conflicting stakeholder interests.

Among the surveyed managers, the IDEA model was noted for its practical application in clinical and organizational decisions. Managers reported using the framework to guide decisions on patient care, technology acquisitions, and strategic planning, particularly in scenarios requiring a balance between competing ethical priorities. The model's emphasis on fairness and its structured approach to evaluating options were identified as key strengths. Nevertheless, its application remains inconsistent, as many managers lacked formal training in ethical frameworks.

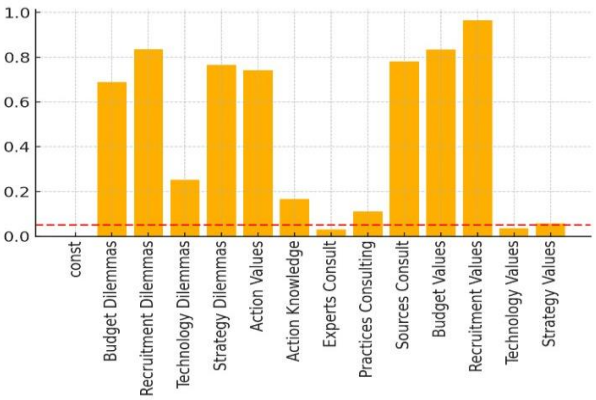

Figure no. 15 – Significance test of variables for IDEA model

The significance test results for the IDEA model, shown in Figure no. 15, highlight key factors influencing its use. Strategy Dilemmas and Action Values have the highest significance, indicating that the model is primarily applied in strategic decision-making and situations requiring strong ethical principles. Action Knowledge and Sources Consult also show notable significance, suggesting that access to ethical knowledge and external references contribute to its effectiveness.

The impact analysis in Figure no. 16 reinforces these findings, with Strategy Dilemmas and Action Values emerging as the most influential variables. Budget Dilemmas and Recruitment Dilemmas also have a significant impact, indicating that the IDEA model is widely used in financial and hiring-related ethical decisions. Meanwhile, Technology Values and Strategy Values show relatively low impact, suggesting that while strategic dilemmas are important, the specific ethical values associated with technology and strategy have a lesser role in driving the application of this model.

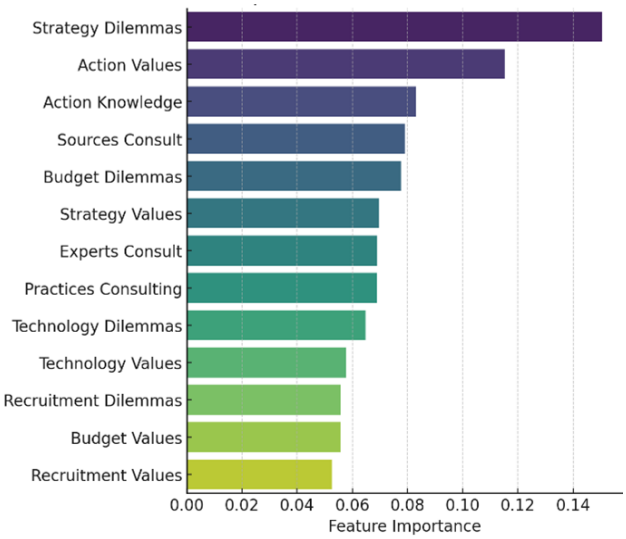

Figure no. 16 – Significance test of variables for IDEA model

6.2.1.3 The 10 steps model

The significance test results for the 10 Steps model, shown in Figure no. 17, highlight key variables influencing its application. Budget Dilemmas, Recruitment Dilemmas, and Technology Dilemmas show the highest significance, indicating that this model is widely applied in financial, hiring, and technology-related ethical decision-making. Strategy Dilemmas and Action Values also demonstrate notable significance, reinforcing the model's role in guiding ethical actions within strategic contexts.

The impact analysis in Figure no. 18 further supports these findings. Sources Consult and Practices Consulting emerge as the most influential factors, suggesting that while budget and recruitment dilemmas are significant, external consultation plays a crucial role in applying the 10 Steps model. Additionally, Technology Dilemmas, Budget Values, and Action

Knowledge show substantial influence, indicating that financial and technological ethical concerns are key drivers of this model. On the other hand, Strategy Values and Action Knowledge exhibit relatively lower importance in both significance and impact analyses, suggesting that while strategic ethical values are relevant, they are not primary determinants in the use of this model.

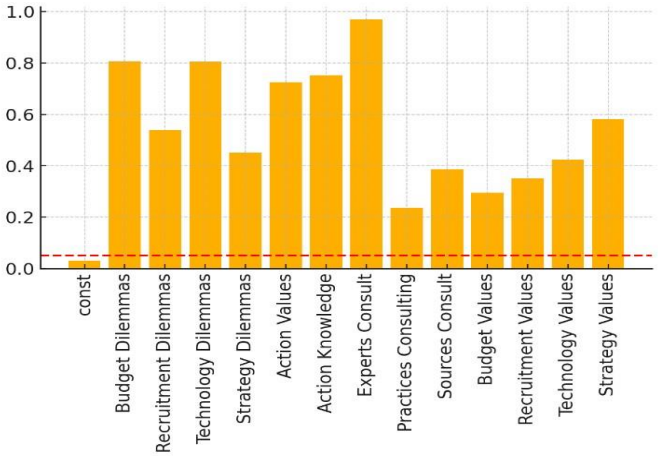

Figure no. 17 – Significance test of variables for 10 Steps model

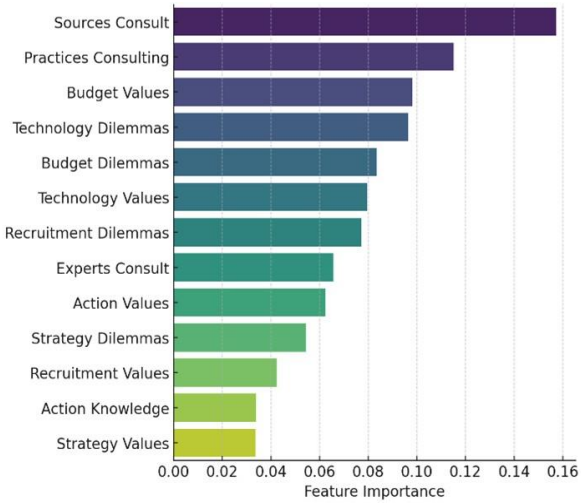

Figure no. 18 – Significance test of variables for 10 Steps model

6.2.1.4 The checklist model

The significance test results for the Checklist model, shown in Figure no. 19, identify key predictors influencing its application. Budget Dilemmas, Strategy Dilemmas, and Action Values

have the highest significance, suggesting that this model is particularly relevant for financial and strategic ethical decision-making. Action Knowledge and Practices Consulting also show notable significance, highlighting the role of structured ethical practices in decision-making.

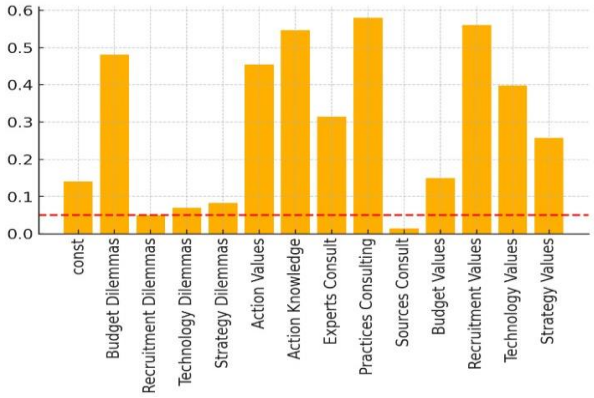

Figure no. 19 – Significance test of variables for Checklist model

The impact analysis in Figure no. 20 further supports these findings, with Sources Consult and Technology Dilemmas emerging as the most influential factors. This suggests that while budget and strategy dilemmas are statistically significant, external sources and technology-related ethical concerns also play a crucial role in applying the Checklist model. Budget Values and Action Values also demonstrate strong impact, reinforcing the model's reliance on ethical frameworks and financial considerations. On the other hand, Strategy Values and Recruitment Values exhibit lower significance and impact, indicating that while strategic and hiring ethical values are relevant, they are not primary drivers in the application of this model.

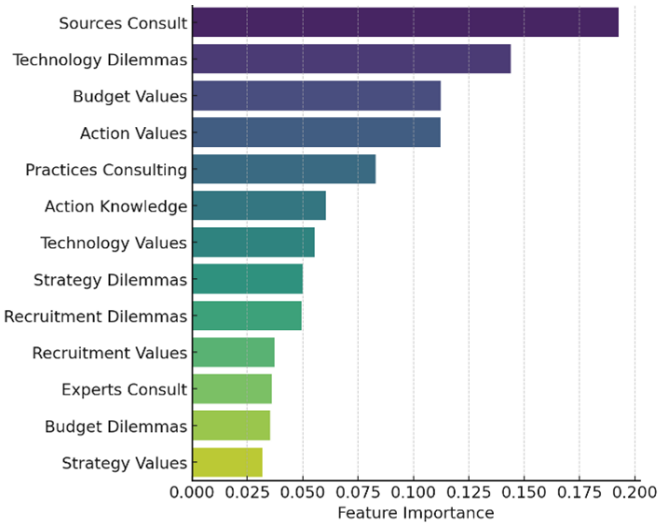

Figure no. 20 – Significance test of variables for Checklist model

In Figure no. 21 we compare the average use four ethical decision-making models between respondents who received ethics training and those who did not. Respondents with ethics training consistently show higher average usage of all four models. The 10-Steps Model and PLUS Model are especially more prominent among trained individuals. The Checklist Model sees the smallest difference between groups, suggesting it may be more universally accessible or simpler to apply without training.

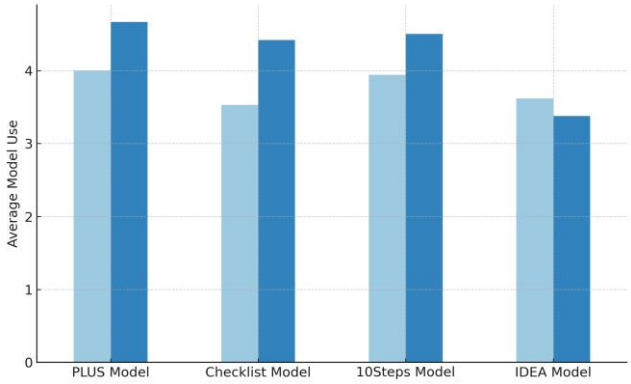

Figure no. 21 – Ethics Training vs. Model Use

The results of the study indicate that Romanian public hospital managers underutilize structured ethical decision-making models, thereby supporting H_{11} and rejecting the null hypothesis H_{01}. Although models such as the PLUS, IDEA, 10-Steps, and Checklist frameworks are recognized and available, their adoption remains inconsistent across institutions.

Figures no. 6 and no. 21 demonstrate that while some models (PLUS and 10-Steps) are used to a "fairly large" or "very large" extent by certain managers, the overall distribution of responses reveals significant variability and lower average use in larger hospitals and among managers without formal ethics training. Additional analyses in Figures no. 8, no. 9, no. 10, no. 11, no. 22 confirm that model usage correlates positively with prior ethics training, educational level, and managerial seniority. The significance and impact tests presented in Figures no. 13, no. 14, no. 15, no. 16, no. 17, no. 18, no. 19, no. 20 further highlight that while certain ethical dilemmas (especially strategy and budget-related) prompt the use of these models, other influencing factors, such as lack of formal training and institutional constraints, limit their widespread application.

These patterns validate the hypothesis that the majority of Romanian hospital managers do not routinely integrate structured ethical models into their decision-making processes.

6.2.2 Hypothesis 2: Influence of ethical dilemmas on decision-making complexity (H2)

Ethical dilemmas significantly affect the decision-making processes of public hospital managers, particularly by reducing the speed of response across critical areas such as budget allocation and strategic planning. Ethical dilemmas arise when

managers face conflicts between competing moral values or stakeholder interests, often requiring trade-offs that delay decision-making and complicate the prioritization of organizational objectives.

The study findings reveal that ethical dilemmas negatively influence decision-making speed in public hospital management. Respondents indicated that dilemmas related to resource allocation, stakeholder pressures, and legal ambiguities frequently result in delays in critical decisions. For example, decisions regarding budget adoption and resource allocation were significantly affected by ethical dilemmas, with respondents reporting a 19% influence to a large extent and over 50% reporting a notable influence across all specified areas (e.g., recruitment, technology acquisition, and strategic planning.

Budget allocation is one of the areas most impacted by ethical dilemmas. Managers must often decide how to distribute limited financial resources among competing priorities, such as upgrading technology, hiring staff, or expanding services. These decisions are further complicated by conflicting demands from stakeholders and insufficient guidance from legislation, which exacerbate delays. Strategic planning is similarly affected, as long-term decisions require balancing immediate organizational needs with the broader ethical implications of policies and actions. Respondents highlighted that legislative ambiguities and external pressures from stakeholders, such as unions or community groups, further contribute to delays in strategic planning.

Key factors contributing to the negative impact of ethical dilemmas on decision-making speed include a lack of ethics training, insufficient managerial experience, and the size of hospital units. For instance, statistical analysis showed significant correlations between the influence of ethical dilemmas and the number of hospital beds or the lack of ethics training among managers. Gamma coefficients revealed negative relationships, such as a -0.286 value for the effect of ethical dilemmas on budget allocation and hospital size, and a -0.196 value for the relationship between ethical dilemmas in technology acquisitions and ethics training studies.

The negative impact of ethical dilemmas on decision-making speed highlights the need for enhanced ethics training and organizational support to equip managers with the tools and frameworks required to address these challenges effectively. Ethical dilemmas not only slow decision-making processes but also increase the complexity of managerial responsibilities, requiring careful evaluation of competing interests and long-term consequences. Addressing these issues is essential to improving both the efficiency and ethical integrity of public hospital management.

The chi-square test results shown in Table no. 3 revealed several statistically significant associations between demographic characteristics and ethical behavior indicators. Notably, gender was significantly associated with multiple types of ethical dilemmas, including technology, strategy, recruitment, and budget dilemmas, suggesting that male and female respondents may experience or report ethical challenges differently. Ethics training was also significantly associated with engagement in technology and strategy dilemmas, indicating that formal training may heighten awareness or sensitivity to ethical issues in these areas. Additionally, age showed a significant relationship with the use of the PLUS and Checklist models, with mid-career professionals (aged 41–50) demonstrating higher reliance on structured ethical decision-making tools.

These findings highlight the importance of demographic and experiential factors in shaping how healthcare managers perceive and respond to ethical challenges in their institutions.

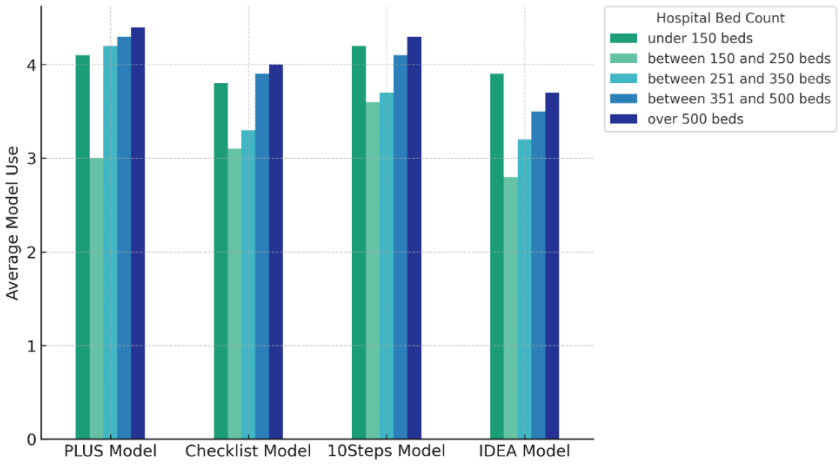

Figure no. 22 – Model Use by Hospital Bed Count

Table no. 3 – Chi-square test results

Independent Variable	Dependent Variable	p-value
Gender	Technology Dilemmas	0.0085
Ethics Training	Strategy Dilemmas	0.0119
Gender	Strategy Dilemmas	0.0146
Ethics Training	Technology Dilemmas	0.0157
Gender	Recruitment Dilemmas	0.0160
Gender	Budget Dilemmas	0.0185
Age	PLUS Model	0.0300
Age	Checklist Model	0.0422

In Figure no. 22 we show that respondents from hospitals with under 150 beds have the highest average use across nearly all models. As hospital size increases (especially beyond 500 beds), average model use tends to decrease, potentially reflecting bureaucratic or procedural barriers in larger institutions. Hospitals with 151-300 and 301-500 beds show moderate model engagement. Larger hospitals (over 500 beds) reported slightly higher average use of the PLUS and 10Steps models compared to smaller hospitals (under 150 beds), suggesting that greater institutional capacity and resources in larger facilities may support the adoption of more structured ethical frameworks. Nonetheless, the overall use of the IDEA model was consistently low across all hospital size categories, and the Checklist model showed only modest differences between groups. These findings indicate that while hospital size may play a modest role in shaping the uptake of certain ethical decision-making models, the underuse of structured frameworks remains a widespread issue in Romanian public hospitals, regardless of institution size. This underscores the need for targeted interventions to promote structured ethical practices across the system.

The analysis clearly supports H_{12}, confirming that ethical dilemmas significantly delay and complicate the decision-making processes of Romanian public hospital managers. Across all surveyed domains, particularly budget allocation, recruitment, technology acquisitions, and strategic planning, respondents reported that ethical concerns frequently introduced

uncertainty and slowed decision timelines. As shown in Figures no. 17, no. 18, no. 19, and no. 20, a large proportion of managers indicated that dilemmas impacted their decisions to a "fairly large" or "very large" extent. Statistical associations reinforce these perceptions: gamma coefficients revealed negative relationships between decision-making speed and hospital size or lack of ethics training, while chi-square tests in Table no. 3 identified significant links between demographic variables (gender, training, age) and dilemma-related constraints. These findings reject the null hypothesis H_{02} and confirm that ethical dilemmas are not peripheral but rather central challenges that shape both the timing and complexity of managerial decisions in Romanian public hospitals.

6.2.3 Hypothesis 3: Role of ethical values in decision-making (H3)

Ethical values play a central role in guiding managerial decision-making, particularly in the ethically complex environment of healthcare management. Core values such as fairness, transparency, compassion, and integrity provide a moral framework for managers, influencing their ability to navigate ethical dilemmas and make decisions that align with organizational and societal expectations. This section explores the relationship between ethical values, training, and decision-making efficiency, drawing on empirical findings from the Romanian healthcare context.

6.2.3.1 Correlations between ethical values and decision-making efficiency

The findings indicate that ethical values significantly influence decision-making efficiency in key managerial areas such as budget allocation, staff recruitment and development, technology acquisitions, and strategic planning. Managers who prioritize ethical principles, such as equity and transparency, are better equipped to resolve conflicts and address resource constraints effectively. For example, fairness and shared decision-making enable managers to evaluate competing priorities impartially, ensuring that decisions are not only efficient but also morally defensible.

In this study, 55% of respondents reported that ethical values, such as competence, community benefit, and sustainability, largely influenced the speed and quality of decision-making across all specified areas. This demonstrates that the integration of ethical values into managerial processes can enhance both the effectiveness and ethical integrity of decision.

6.2.3.2 Impact of ethics training on decision-making

Ethics training emerges as a critical factor in strengthening the role of ethical values in managerial decision-making. Managers who have undergone formal ethics training demonstrate a higher capacity to apply ethical principles systematically, resulting in more efficient decision-making processes. For instance, the study found significant positive correlations between ethics training and decision-making efficiency in areas such as resource allocation and technology acquisitions. Gamma coefficients of 0.320 and 0.279 were reported for the influence of ethics training on decision-making efficiency in these domains, underscoring the importance of formal ethical education.

Conversely, the absence of ethics training was associated with reduced decision-making efficiency. A substantial proportion (74%) of respondents reported no prior ethics training, a factor that likely contributed to slower responses in addressing ethical dilemmas. This

highlights the need for targeted ethics training programs to enhance managers' ability to integrate ethical values into their decision-making processes.

6.2.3.3 Ethical values and organizational culture

The role of ethical values extends beyond individual decision-makers to shape organizational culture, which in turn influences decision-making efficiency. Organizations that foster a strong ethical culture provide managers with clear guidelines and a supportive environment for implementing ethical values. As Trevino (1986) notes, a normative organizational culture enhances alignment among members regarding ethical behavior, reducing ambiguity and increasing decision-making speed and effectiveness.

The findings also indicate that managers in organizations with a well-established ethical culture are more likely to make decisions that reflect core ethical values. This alignment promotes consistency, reduces conflicts, and ensures that decisions align with both organizational goals and societal expectations.

The frequency distribution of ethical decision-making practices, as illustrated in Figure no. 23, reveals notable patterns in how individuals engage with ethical considerations in their decision-making processes. The results indicate that the most common responses fall within the "largely" and "to a very large extent" categories, highlighting the strong reliance on structured ethical frameworks across all practice areas. Among the different practices, Action Knowledge and Practices Consulting exhibit the highest concentrations at "largely" and "to a very large extent", suggesting that ethical decision-making is strongly informed by established knowledge and consultation practices. Action Values also follow a similar pattern, reinforcing the idea that ethical principles play a fundamental role in guiding decisions. Experts Consult and Sources Consult show a slightly more distributed pattern, with a significant number of responses in the "to a fairly large extent" category. This distribution suggests that while expert advice and external sources are widely used, they may not always be the primary determinants in ethical decision-making compared to direct knowledge and internal practices. Conversely, responses at the lowest influence levels ("to a very small extent" and "to a fairly small extent") are minimal across all categories, indicating that ethical practices are rarely disregarded in decision-making. However, some variation exists in the frequency of moderate responses, particularly in Sources Consult, which shows a wider spread across influence levels.

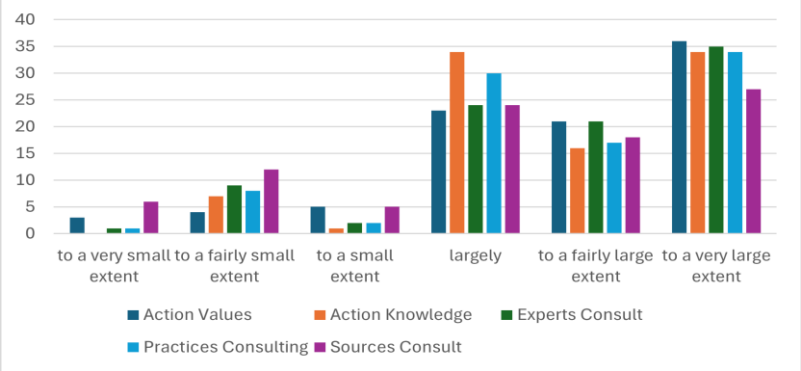

Figure no. 23 – Distribution of importance levels for practices

The distribution of ethical values, as shown in Figure no. 24, highlights how different value dimensions influence decision-making across budget, recruitment, technology, and strategy contexts. The data indicates a strong emphasis on ethical values, with the most common responses clustered in the "largely" and "to a very large extent" categories. Recruitment Values and Budget Values show the highest frequency at "to a very large extent", underscoring the strong ethical considerations applied in financial decisions and hiring practices. Strategy Values and Technology Values also display significant representation at this level, though their distribution is slightly more balanced, with notable responses in "to a fairly large extent" and "largely" categories. A more even distribution appears in the moderate influence categories, with responses in "to a small extent" and "to a fairly small extent" across all value types. Budget Values show a broader spread, suggesting that financial considerations may sometimes allow for more flexibility in ethical prioritization compared to recruitment and strategy-related decisions. Responses at the lowest influence levels ("to a very small extent") are minimal across all categories, reinforcing that ethical values are rarely disregarded in decision-making. However, slight variations exist, particularly within Technology Values, where responses are distributed more widely.

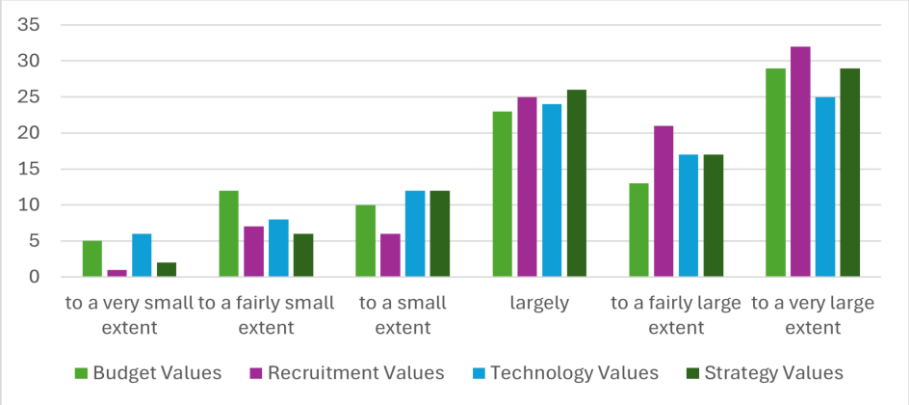

Figure no. 24 – Distribution of importance levels for values

The findings provide strong support for H_{13}, affirming that ethical values such as fairness, transparency, and trust play a significant role in shaping managerial decisions in Romanian public hospitals. Survey responses consistently reflected high ratings for the influence of ethical values across all decision-making domains, with over 55% of managers reporting that these values guided their actions "to a very large extent." Figures no. 23 and no. 24 illustrate the widespread prioritization of ethical considerations in budget allocation, recruitment, strategy development, and technology decisions. Furthermore, statistical analysis revealed that managers with ethics training were significantly more likely to apply these values systematically. The strong internal consistency of value-related items (Cronbach's alpha = 0.90) further reinforces the validity of these constructs. These results reject the null hypothesis H_{03} and confirm that ethical values are not only abstract principles but function as practical decision-making tools that enhance both efficiency and integrity within public hospital management.

6.2.3.4 Prevalence and challenges

Despite the potential benefits of structured ethical models, their adoption among public hospital managers in Romania is not widespread. A significant proportion of managers indicated limited familiarity with these frameworks, citing a lack of formal ethics training as a primary barrier. Moreover, organizational constraints, such as resource limitations and legislative ambiguities, further impede the consistent application of these models.

7. DISCUSSION

7.1 Implications for hospital management

The interplay of ethical dilemmas, values, and decision-making frameworks has significant implications for hospital management. Ethical dilemmas, often arising from conflicts between competing interests or limited resources, negatively impact decision-making speed and quality, as demonstrated in our study and supported by (Holian, 2002; Shepherd *et al.*, 2021). Areas such as budget allocation, technology acquisition, and strategic planning are particularly vulnerable to delays caused by ethical ambiguities and stakeholder pressures (Peer and Rakich, 1999; Casali, 2009). Managers must balance these challenges while ensuring their decisions align with ethical principles and organizational goals (Trevino, 1986; Jones, 1991).

Ethical values, such as fairness, trust, and transparency, provide a moral foundation for navigating these dilemmas (Walker, 1993). Managers who integrate these values into their decision-making processes are more likely to achieve equitable outcomes that foster trust among stakeholders (Weber, 2001; Fulmer, 2004). However, the absence of ethics training among a significant proportion of managers in Romania has been identified as a critical barrier, limiting their ability to effectively apply ethical principles and decision-making frameworks (Holian, 2002; Shepherd *et al.*, 2021; Khaghanizadeh *et al.*, 2023). Structured decision-making models, such as the PLUS and IDEA frameworks, offer practical tools for addressing ethical dilemmas systematically (Trillium Health Partners, n.d.; Ethics and Compliance Initiative, 2021). These models enhance transparency, consistency, and accountability in decision-making (Santosuosso, 2016; Bivins, 2017). However, their limited adoption in Romanian public hospitals indicates a need for increased training and awareness to maximize their potential benefits (Holian, 2002; Shepherd *et al.*, 2021). By adopting these models more broadly, hospital managers can improve the ethical and operational efficiency of their decisions.

7.2 Theoretical implications

The findings of this study contribute to the theoretical understanding of ethical decision-making in public healthcare management by confirming and extending existing knowledge in several ways. First, our results confirm prior research suggesting that structured ethical decision-making models, despite their recognized utility (Holian, 2002; Guo, 2020) remain underutilized in practice due to lack of training and institutional support. This aligns with findings from other public sector and healthcare contexts, which highlight the persistence of intuitive and ad hoc decision-making approaches (O'Fallon and Butterfield, 2013; Shepherd

et al., 2021). Second, the study reinforces earlier evidence that ethical dilemmas significantly delay and complicate managerial decisions (Daniels, 2000; Oliver, 2006), especially in resource-constrained environments such as Romania's public healthcare system. Finally, the strong influence of ethical values, such as fairness, transparency, and trust—on decision-making supports the theoretical models that emphasize the normative role of individual and organizational ethics in public service management (Walker, 1993; Weber, 2001). By situating these findings within the broader theoretical context, this study underscores the need to integrate ethical principles, structured frameworks, and institutional support to improve decision-making efficiency and integrity in healthcare management.

7.3 Comparison to global practices

When compared to global practices, the findings from this study highlight areas of alignment and divergence in ethical decision-making within Romanian public hospitals. Internationally, ethical decision-making frameworks such as the PLUS model and IDEA model are widely recognized and implemented across healthcare institutions to navigate complex dilemmas effectively (Trillium Health Partners, n.d.; Guo, 2020; Ethics and Compliance Initiative, 2021). Countries with robust healthcare ethics infrastructures often mandate ethics training as part of managerial development programs, ensuring that decision-makers are equipped with the necessary tools and knowledge to address ethical challenges (American College of Healthcare Executives, 2020; Andersson *et al.*, 2022).

In contrast, the Romanian context reveals significant gaps in ethics training and the adoption of structured models (Holian, 2002; Shepherd *et al.*, 2021). While international practices emphasize proactive measures, such as regular ethics audits and the institutionalization of ethical cultures, Romanian hospitals face challenges such as legislative ambiguities, resource constraints, and limited training opportunities (Daniels, 2000; Persad *et al.*, 2009). These systemic issues hinder the consistent application of global best practices in ethical decision-making.

Nevertheless, some parallels can be drawn. Similar to other countries, Romanian managers grapple with stakeholder conflicts, resource allocation dilemmas, and the tension between operational efficiency and ethical accountability (Oliver, 2006; Mohammadi *et al.*, 2024). The findings underscore the importance of integrating global ethical standards into local healthcare systems while addressing context-specific challenges to ensure effective decision-making.

7.4 Recommendations

To enhance ethical decision-making in Romanian public hospitals, several improvements are recommended:

- Strengthen Ethics Training Programs: Mandatory ethics training for hospital managers should be introduced, focusing on practical applications of decision-making models such as the PLUS and IDEA frameworks. Training should include case studies, workshops, and simulations tailored to the healthcare context to build capacity and confidence in ethical decision-making (American College of Healthcare Executives, 2020; Andersson *et al.*, 2022; Khaghanizadeh *et al.*, 2023).

- Develop Comprehensive Organizational Policies: Hospitals should implement robust ethical policies that provide clear guidelines for addressing common dilemmas, such as resource allocation and stakeholder conflicts. These policies should be aligned with international best practices while considering the specific challenges of the Romanian healthcare system (Daniels, 2000; Morrison, 2008; Khaghanizadeh *et al.*, 2023).
- Foster Ethical Leadership Practices: Leadership development programs should emphasize the role of ethical values in decision-making. Ethical leadership, characterized by transparency, fairness, and accountability, can serve as a model for organizational behavior, encouraging a culture of ethical integrity across all levels of the institution (Trillium Health Partners, n.d.; Santosuosso, 2016; Bivins, 2017; Ethics and Compliance Initiative, 2021).
- Institutionalize Ethical Decision-Making Models: Hospitals should formally adopt decision-making frameworks like the PLUS and IDEA models, integrating them into organizational procedures and managerial workflows. This can be achieved through policy revisions, training sessions, and regular evaluations of ethical decision-making practices (Trillium Health Partners, n.d.; Santosuosso, 2016; Bivins, 2017; Ethics and Compliance Initiative, 2021).
- Enhance Stakeholder Engagement: Transparent and inclusive processes should be implemented to involve stakeholders in ethical decision-making. This includes creating ethics committees or forums where diverse perspectives can be considered, promoting fairness and accountability (Holian, 2002; Oliver, 2006; Casali, 2009; Shepherd *et al.*, 2021).

By addressing these recommendations, Romanian public hospitals can strengthen their ethical decision-making processes, align with global standards, and ensure better outcomes for patients, staff, and the broader healthcare system. These improvements will not only enhance operational efficiency but also reinforce public trust in the integrity of healthcare institutions.

8. CONCLUSIONS

This study highlights the significant influence of ethical dilemmas and values on managerial decision-making model in Romanian public hospitals. Ethical dilemmas, particularly in areas such as budget allocation, strategic planning, and resource distribution, negatively impact decision-making speed and efficiency. These challenges often stem from conflicts between competing stakeholder interests, legislative ambiguities, and limited resources. The findings emphasize that ethical dilemmas can complicate managerial responsibilities, delay critical decisions and increase the complexity of balancing organizational and societal demands. These findings should be interpreted within the Romanian public healthcare context, which is also shaped by challenges such as legislative ambiguities and political pressures, as previously documented, alongside the ethical issues explored in this study

Ethical values, such as fairness, transparency, and trust, were found to be pivotal in guiding decision-making processes and model. Managers who integrate these values into their practices achieve more consistent and equitable outcomes. However, the study also revealed a critical gap in ethics training, with a significant proportion of managers lacking formal education in ethical decision-making frameworks. Structured models such as the PLUS and IDEA frameworks, while beneficial, remain underutilized, underscoring the need for greater awareness and training.

The interplay of ethical dilemmas, values, and decision-making frameworks highlights the importance of fostering an ethical organizational culture and implementing targeted ethics education to address these challenges effectively.

While the recommendations proposed in this study, such as mandatory ethics training and the development of institutional policies, are grounded in the findings and are concrete and applicable, we acknowledge that the study did not collect data on the potential costs or organizational barriers to implementation, such as financial constraints or resistance to change. Future research should explore these aspects to support a more comprehensive understanding of the feasibility and sustainability of such interventions in the Romanian healthcare context.

9. LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

This study is subject to several limitations. The sample size, while representative of Romanian public hospital managers, was first constrained by a relatively moderate response rate. However, other studies involving Romanian public hospital managers also reveal the difficulty of data collecting in this field and similarly low response rates in questionnaire-based research (see for example, the research of Țurlea *et al.* (2011) or a more recent one conducted by Rotaru and Edelhauser (2024)). Another limitation might be considered the non-probabilistic sampling method used, which may limit the generalizability of the findings, but despite its disadvantages, this method is based on the availability of the respondents (Creswell, 2014). Additionally, the study's cross-sectional design captures a snapshot of managerial practices but does not account for the evolving nature of ethical challenges over time, therefore future research is needed to address this aspect.

The methodological limitations of this study may have implications for interpreting the findings. The use of a non-probabilistic, availability-based sample and a cross-sectional design limits generalizability and precludes causal inference. The response rate of approximately 49% also raises the possibility of self-selection bias. For example, it is possible that managers more interested in or attentive to ethical issues were more likely to participate, which could result in an overestimation of the use of ethical models. However, as our study did not collect data on non-respondents, this remains a potential bias that future research should examine using more representative sampling strategies.

Future research should address these limitations through longitudinal studies that explore changes in ethical decision-making practices over extended periods. Such studies could provide deeper insights into the long-term impact of ethics training, organizational culture, and policy interventions. Expanding the sample size and incorporating managers from diverse healthcare contexts, including private hospitals and international settings, would also enhance the applicability of findings. Furthermore, comparative studies examining the adoption of ethical models in different cultural and institutional environments could provide valuable insights into global best practices in ethical healthcare management.

By addressing these gaps, future research can contribute to a more comprehensive understanding of ethical decision-making, enabling healthcare organizations to navigate ethical dilemmas more effectively and align their practices with both organizational goals and societal expectations.

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Effects of Price Clustering on African Stock Markets

Tatiana Pinheira*, Júlio Lobão, Luís Pacheco*****

Abstract: The phenomenon of price clustering refers to the empirical finding that some prices in financial markets occur significantly more frequently than others. The phenomenon is important theoretically as it challenges the efficient market theory and empirically as it suggests that predictability patterns can be used by investors to devise strategies and investments capable of generating abnormal returns. In this paper, we study the phenomenon for the first time in the context of African markets. Our study includes data from the period spanning 2018-2022 for the stock markets of Egypt, Kenya, Morocco, Nigeria, South Africa, and Tunisia. Our results provide compelling evidence of price clustering within all markets under analysis. Univariate analysis confirms widespread clustering, particularly favoring closing prices ending in zero and five. The results of the multivariate analysis suggest that stocks with higher prices, lower turnover, and lower liquidity tend to exhibit a higher level of clustering. Contrary to the expectations of the Panic Selling Hypothesis, a more intense clustering did not occur during the COVID-19 pandemic. Collectively, our results offer partial support for the Attraction Hypothesis and the Negotiation/Price Resolution Hypothesis.

Keywords: price clustering; COVID-19 pandemic; efficient market theory; behavioral finance; African stock markets.

JEL classification: G01; G12; G14; G40.

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1. INTRODUCTION

The Efficient Market Hypothesis (EMH) has been a cornerstone in financial theory, asserting that market prices incorporate all available information, rendering attempts to predict future price movements futile (Fama, 1965). According to the EMH, asset prices should reflect all available market information, resulting in evenly distributed prices without apparent clustering around specific digits. However, empirical research over time has revealed instances where market prices exhibit patterns challenging the fundamental principles of EMH. One such pattern is the phenomenon of price clustering, initially identified in studies by Osborne (1962) and Niederhoffer (1965).

Early investigations found that prices in the US market often cluster around whole numbers or fractions. Numerous subsequent studies on price clustering in the US market, including those by Harris (1991), Christie *et al.* (1994), and Ikenberry and Weston (2008), among others, expanded our understanding. As time progressed, evidence surfaced indicating stock price clustering in other markets, such as Australia (Aitken *et al.*, 1996), Singapore (Hameed and Terry, 1998), various Asia-Pacific markets (Brown *et al.*, 2002), Tokyo (Ohta, 2006; Aşçıoğlu *et al.*, 2007), and more. Price clustering, however, extends beyond stock markets alone, affecting diverse asset types and markets, including the commodity market (Ball *et al.*, 1985), derivatives (Ap Gwilym *et al.*, 1998), foreign exchange market (Mitchell, 2001), betting market (Brown and Yang, 2016), and cryptocurrencies (Urquhart, 2017; Baig *et al.*, 2019).

With numerous studies, various hypotheses emerged to explain this clustering phenomenon. Ball *et al.* (1985) proposed the Price Resolution Hypothesis, Harris (1991) suggested the Negotiation Hypothesis based on increased uncertainty, Curcio and Goodhart (1991) introduced the Attraction Hypothesis related to individual number preferences, and Christie *et al.* (1994) proposed the Collusion Hypothesis, implying collusion among market participants. More recently, the Panic Selling Hypothesis (Narayan and Smyth, 2013) posits that during crises, the clustering effect intensifies.

This paper represents a pioneering effort dedicated to exploring price clustering in African stock markets. Our primary goal is to contribute to existing literature by compiling comprehensive evidence on price clustering in six African nations: Egypt, Kenya, Morocco, Nigeria, South Africa, and Tunisia. These markets, with market capitalization values in 2018 relative to their GDPs of 16%, 24.32%, 47.97%, 7.47%, 19.51%, and 214.11%, respectively, have gained significance within the African continent. Our research spans the onset of the COVID-19 pandemic, allowing us to examine whether the pandemic influenced price clustering within these markets. To achieve this, we divided the sample from each market into three distinct periods, facilitating an in-depth analysis of the pandemic-induced financial crisis' impact on variations in price clustering.

Following methodologies outlined by Ikenberry and Weston (2008) and Lobão *et al.* (2019), our approach includes both univariate and multivariate analyses. The initial analysis aims to ascertain the uniformity of the frequency distribution of last digits and discern any disparities in price clustering between the periods. Subsequently, the multivariate analysis explores factors contributing to fluctuations in price clustering, including the influence of the COVID-19 crisis.

In summary, our study provides compelling indications of price clustering within the examined markets. However, it offers limited validation for the Attraction Hypothesis and the Price Negotiation and Resolution Hypothesis. Surprisingly, the impact of the COVID-19 pandemic on the extent of price clustering does not align with the anticipated outcomes documented in the Panic Selling Hypothesis.

Price clustering is a focal point in financial research, offering insights into investor behavior, market efficiency, and the impact of various market mechanisms on price formation. Understanding the patterns and drivers of price clustering contributes to a deeper comprehension of how financial markets operate and how investor psychology interacts with market structure.

The subsequent sections structure the paper as follows. Section 2 delves into existing literature, offering a comprehensive review of price clustering concepts, hypotheses, and empirical findings. Section 3 describes the research questions, the data used for the analysis, as well as the methodology adopted. Section 4 presents the outcomes revealed by univariate and multivariate analysis for each sample. Finally, Section 5 summarizes the main conclusions and presents future avenues of research.

2. LITERATURE REVIEW

2.1 Price Clustering Definition

Price clustering denotes the recurring tendency of financial asset prices, including stocks, commodities, and currencies, to aggregate around specific numerical values or price levels sharing common ending digits or fractions. Instead of a uniform distribution, price clustering leads to a disproportionate frequency of certain endings, often round numbers or fractions. Rooted in psychological, cognitive, and market structure factors, investor behavior, influenced by perceptions of significance, contributes to increased trading activity around these levels. Market mechanics and regulations also play a role, impacting liquidity at specific price levels. Pioneers Osborne (1962) and Niederhoffer (1965) documented this phenomenon during the 1960s, challenging the expectations of the efficient market hypothesis.

Following their work, various hypotheses emerged, such as the Price Resolution Hypothesis (Ball *et al.*, 1985), Negotiation Hypothesis (Harris, 1991), Attraction Hypothesis (Curcio and Goodhart, 1991), Collusion Hypothesis (Christie *et al.*, 1994), and Panic Selling Hypothesis (Narayan and Smyth, 2013). Besides those, the Culture Hypothesis (Curcio and Goodhart, 1991), and the Strategic Trading Hypothesis (Sonnemans, 2006) are two other theories mentioned in the literature, albeit not tested in this paper.

2.2 Price Resolution Hypothesis

The Price Resolution Hypothesis, articulated by Ball *et al.* (1985), delves into the intricate dynamics of price clustering, asserting that this phenomenon arises from the deployment of coarser price grids. These grids are influenced by the amount of information available in the market and the inherent uncertainty investors face regarding the underlying value of each asset. According to this hypothesis, larger companies, endowed with greater information access due to comprehensive analyses and rankings by analysts, exhibit lower degrees of clustering. The reasoning is that as the value of the asset increases, market participants are more inclined to employ a coarser price grid, negotiating at round prices. Notably, the high liquidity of larger companies minimizes information asymmetry, subsequently reducing trade uncertainty and contributing to less clustering. In essence, the hypothesis contends that as market information increases, uncertainty decreases, resulting in a higher degree of price resolution and a lower probability of price clustering.

Ikenberry and Weston (2008) further explored the implications of the Price Resolution Hypothesis by examining the impact of decimalization on the clustering phenomenon in US stock prices. Their study revealed a reduction in price clustering post-decimalization, indicating that finer tick sizes allowed for higher price granularity, thereby deviating from previous clustering patterns. Furthermore, the shift to decimal pricing altered investors' perspectives and trading approaches towards stocks, subsequently impacting the clustering tendencies of stock prices. The empirical substantiation of the Price Resolution Hypothesis is evident in various studies conducted by researchers such as Harris (1991), Aitken *et al.* (1996), Ap Gwilym *et al.* (1998), Ohta (2006), Narayan and Smyth (2013), and more recently, Lobão *et al.* (2019).

2.3 Negotiation Hypothesis

Harris (1991) expanded the Price Resolution Hypothesis into the Negotiation Hypothesis, suggesting that negotiation convenience leads to clustering around round numbers or fractions. As negotiating costs rise, observed price clustering increases. Aitken *et al.* (1996) and Hameed and Terry (1998) provided supporting evidence, emphasizing the influence of negotiation costs, trading volume, and price levels on clustering. Additional investigations by Ap Gwilym *et al.* (1998), Palao and Pardo (2012), Narayan and Smyth (2013), Hu *et al.* (2019), Lobão *et al.* (2019), Narayan (2022), and Lobão (2024) further substantiated this hypothesis's explanatory power.

2.4 Attraction Hypothesis

Curcio and Goodhart (1991) investigated the clustering phenomenon of bid and ask prices within the foreign exchange market, recognizing its significance for the bid-ask spread and, consequently, traders' transaction costs and market liquidity. The Attraction Hypothesis proposed by Curcio and Goodhart (1991) posits that each number possesses a "gravitational" force, with certain values perceived as more attractive. Rooted in behavioral psychology, this theory suggests a preference for prices ending in zero followed by five, and an inclination towards even numbers, particularly the digits two and eight. Their conclusion highlights the correlation between price clustering, trading costs, and participants' desired price resolution. Aitken *et al.* (1996) corroborate the Attraction Hypothesis in the Australian Stock Exchange, revealing a tendency for price clusters ending in digits zero and five. The nuanced interplay of market dynamics and psychological factors influencing price clustering is further emphasized by Kandel *et al.* (2001) in their examination of stock price levels during initial public offerings (IPOs) in the Israeli market. Brown *et al.* (2002), Aşçıoğlu *et al.* (2007), Narayan *et al.* (2011), Palao and Pardo (2012) and Lobão *et al.* (2019) also confirmed the Attraction Hypothesis in their studies, concluding that prices ended at zero (0) were preferred, followed by those ending in five.

2.5 Collusion Hypothesis

The Collusion Hypothesis, proposed by Christie *et al.* (1994), suggests that price clustering may stem from tacit collusion among market participants. This hypothesis implies that traders or investors may coordinate their activities to keep prices close to certain levels, potentially benefiting their interests. However, proving such coordination empirically is challenging.

Christie *et al.* (1994) evidenced how the multi-dealer structure in the NASDAQ market creates an incentive to maintain uncompetitive offer-sale spreads, increasing profit margins per transaction and causing price clustering. Huang and Stoll (1996) argue that collusion in markets with multiple dealers is rare, and Aşçıoğlu *et al.* (2007) find indications of price clustering even in an electronic trading market that does not permit explicit collusive behavior. While some studies support the notion of collusion, such as Barclay (1997), Bessembinder (1997), and Geoffrey Booth *et al.* (2000), the empirical evidence remains mixed.

2.6 Panic Selling Hypothesis

The Panic Selling Hypothesis, proposed by Narayan and Smyth (2013), posits that political instability has a positive effect on price clustering. In times of anxiety or fear among market participants due to adverse news or uncertain economic conditions, a rush to sell assets may occur, leading to a concentration of sell orders at specific price levels. This hypothesis underscores the influence of market psychology and emotional reactions on price clustering, particularly during market uncertainty. Lobão *et al.* (2019) found support for the Price Resolution, Negotiation, and Attraction Hypotheses in their analysis of price clustering in European and American banks during the 2008 global financial crisis. Contrary to expectations, they identified a reduction in price clustering during the crisis, challenging the Panic Selling Hypothesis. Narayan (2022) explored price clustering in the oil market during the COVID-19 pandemic, aligning with the Panic Selling Hypothesis and revealing potential shifts in investor behavior and market dynamics during crises.

3. DATA AND METHODOLOGY

3.1 Hypotheses

Our research questions are inspired by theories discussed in the literature, leading to the formulation of hypotheses. Initially, we aim to empirically verify the presence of price clustering in the analyzed markets. Hypothesis H_1 posits that the final digits of daily closing prices do not follow a uniform distribution, aligning with the "gravitational" influence of each number as proposed by Curcio and Goodhart (1991).

***H1**: The final digits of daily closing prices do not present a uniform distribution.*

Subsequently, if evidence of price clustering is found, we explore the impact of COVID-19 on clustering patterns. Hypothesis H_2 anticipates an increase in price clustering during the COVID-19 period, aligning with the Panic Selling Hypothesis (Narayan and Smyth, 2013) and the Price Resolution Hypothesis (Ball *et al.*, 1985).

***H2**: There is an increase in price clustering in the markets during the period of COVID-19, compared to the previous or subsequent period.*

Following the Negotiation Hypothesis (Harris, 1991) and the Price Resolution Hypothesis (Ball *et al.*, 1985), we propose additional hypotheses related to variables influencing price clustering:

***H3a**: Stock with higher prices exhibit higher price clustering.*

***H3b**: Stocks with lower capitalization exhibit higher price clustering.*

***H3c**: Stocks with lower turnover exhibit higher price clustering.*

***H3d**: Higher market volatility is associated with higher price clustering.*

***H3e**: Stock with lower liquidity exhibit higher price clustering.*

3.2 Data

We analyze price clustering effects using daily closing prices of shares listed in six African markets over five years (January 1st, 2018, to December 31st, 2022): Egypt, Kenya, Morocco, Nigeria, South Africa, and Tunisia. We follow Lobão (2018) criteria to select these markets. We use the daily closing prices of the stocks listed in Egypt (29 stocks quoted on the EGX 30 Index), Kenya (17 stocks from the NSE 20 Index), Morocco (46 stocks from the MASI Index), Nigeria (75 stocks from the NSE All Share Index), South Africa (103 stocks from the FTSE/JSE All Share), and Tunisia (78 stocks from the Tunindex). To ensure a fair examination of the clustering effect, we exclude prices hindered by tick sizes that prevent specific digit endings, following the standard practice in price clustering studies. Daily data is retrieved from Datastream by Refinitiv.

For COVID-19 analysis, we split the sample into three periods standardized across markets: before, during, and after COVID-19. Period start and end dates for each market are detailed in Table no. 1, using confirmed coronavirus infection dates as per Medhat and El Kassas (2020) and Takyi and Bentum-Ennin (2021). The COVID-19 period concludes uniformly on August 31st, 2021, facilitating consistent data processing and analysis.

Table no. 1 – Period split dates for each market

Markets	Before COVID-19	COVID-19	After COVID-19
Egypt	01/01/2018 to 13/02/2020	14/02/2020 to 31/08/2021	01/09/2021 to 31/12/2022
Kenya	01/01/2018 to 12/03/2020	13/03/2020 to 31/08/2021	
Morocco	01/01/2018 to 01/03/2020	02/03/2020 to 31/08/2021	
Nigeria	01/01/2018 to 26/02/2020	27/02/2020 to 31/08/2021	
South Africa	01/01/2018 to 04/03/2020	05/03/2020 to 31/08/2021	
Tunisia	01/01/2018 to 01/03/2020	02/03/2020 to 31/08/2021	

3.3 Methodology

3.3.1 Univariate Analysis

We commence with a univariate analysis to affirm the presence of price clustering, focusing on the frequency distribution of the final digit in stock prices. In the absence of clustering, each digit (0-9) would ideally occur with a frequency of 10%. Building on the methodologies of Ikenberry and Weston (2008), Palao and Pardo (2012), Lobão *et al.* (2019), among others, we utilize the Herfindahl-Hirshmann index (HHI). Although traditionally assessing market concentration, in our context, HHI substitutes market shares with the percentage of prices ending with specific digits. The formula is expressed as follows:

$$H = \sum_{i=1}^{B} (f_i)^2 \tag{1}$$

where f_i denotes the percentage frequency of closing stock prices within specific fractional divisions (bins), with $i = 1,2, \dots, B$. A unity HHI indicates complete clustering, while the null hypothesis suggests an HHI of 0.1, assuming uniform distribution.

To evaluate changes in clustering during a crisis, we employ the Chi-square statistic of goodness-of-fit (D), as used by Palao and Pardo (2012). The formula is given by:

$$D = \sum_{i=1}^{N} \frac{(O_i - E_i)^2}{E_i} \tag{2}$$

where O_i is the frequency of occurrence for the final digit within bin $i = 1,2, \dots, N$. and E_i is the frequency that would be observed in a scenario of uniform distribution. This statistic follows a Chi-square distribution with N-1 degrees of freedom. Elevated D values signify increased clustering.

To assess consistency across three samples, we calculate the ratio-based statistic $\widetilde{D}$, allowing us to identify shifts in clustering between periods preceding (D_1), during (D_2), and after (D_3) COVID-19.

$$\begin{aligned} \widetilde{D} &= \left(\frac{D_2}{D_1}\right) \sim F_{N_2-1,N_1-1} \\ \widetilde{D} &= \left(\frac{D_3}{D_2}\right) \sim F_{N_3-1,N_2-1} \end{aligned} \tag{3}$$

Using this statistic, we test the null hypothesis (H_2) that the three samples exhibit equal clustering levels. An elevation in the values of $\widetilde{D}$ signifies a heightened degree of price clustering within their corresponding subsets.

3.3.2 Multivariate Analysis

The multivariate analysis aims to identify factors driving price clusters across the considered markets. The dependent variable is the HHI, which quantifies price clustering while considering the tick size inherent to each stock in each market. To ensure comparability and diminish asymmetry, each independent variable will be transformed logarithmically and standardized. This entails subtracting the sample mean from the variable and dividing by the standard deviation, effectively centralizing the means at zero and standardizing the variances to unity. This procedure enables the comparison of the magnitude of the various coefficients (Ikenberry and Weston, 2008). Using this approach, we formulate the following model through Ordinary Least Squares (OLS) regression:

$$\begin{aligned} Clustering - E(Clustering) \\ = \alpha + \beta_1 StockPrice + \beta_2 CompSize + \beta_3 Turnover \\ + \beta_4 Volatility + \beta_5 Iliquidity + e_i \end{aligned} \tag{4}$$

Explanatory variables align with existing literature, addressing the Price Resolution and Negotiation Hypotheses (Ball *et al.*, 1985; Harris, 1991; Aitken *et al.*, 1996; Ikenberry and Weston, 2008). Table no. 2 provides a summary of the model's variables and their expected signs according to the literature.

Table no. 2 – Description of the variables and expected signs for the independent variables coefficients

	Variables	Description		References
Dependent variable	Clustering-E (Clustering)	HHI (measure of price clustering at the last digit) minus the level of clustering expected in the null hypothesis (HHI=0.1)		Ikenberry and Weston (2008)
	Variables	**Description**	**Expected sign**	**References**
Independent variable	*Stock Price*	Average daily price of the company's shares over the sample period	+	Harris (1991); Aitken *et al.* (1996)
	Compsize	Daily average of the stock market value of the company	-	Harris (1991)
	Turnover	Average turnover of the company over the sample period	-	Ball *et al.* (1985); Ikenberry and Weston (2008)
	Volatility	Squared deviation of the time series of daily returns over the sample period	+	Harris (1991)
	Illiquidity	Arithmetic mean of the bid-ask spread ratio, centered at its midpoint, over the sample period	+	Palao and Pardo (2012)

4. RESULTS AND DISCUSSION

4.1 Univariate analysis

Table no. 3 presents the occurrence frequency of closing price last digits across the six countries, clustering test outcomes, and associated HHI values. Table no. 4 outlines clustering tests across three periods. A joint analysis of these tables follows.

Upon jointly examining Tables no. 3 and no. 4, we observe signs of price clustering across the three periods in the Egyptian sample, notably with an increased presence of digits zero and five, consistent with the Attraction Hypothesis. Statistical tests confirm this clustering across the analyzed periods. Null hypothesis H_1 is dismissed, highlighting divergences between observed and expected uniform distributions in the three periods, at a significance level of 1%. Notably, HHI values decline from the pre-COVID-19 to the COVID-19 period; however, the results suggest that this variation lacks statistical significance. Hence, we deduce that the level of price clustering remains unchanged between these two periods. In contrast, a sharp increase in HHI values occurs from the COVID-19 period to the post-COVID-19 period. The results underscore the statistical significance of this contrast, indicating a discernible shift in the degree of price clustering between these two sample intervals.

Turning to the Kenyan sample, the results also confirm the existence of price clustering across the three periods. Regardless of the period considered, roughly 30% of prices have last

digits zero or five. The Kenyan sample substantiates dismissing null hypothesis H_1 and affirming the presence of a statistically meaningful distinction. Despite an increase in HHI values between the first two periods, the evaluation of the H_2 hypothesis establishes that this increment lacks statistical significance, affirming stability in price clustering levels.

Table no. 3 – Price clustering: last digit frequency – whole period

Last Digit	Egypt		Kenya		Morocco		Nigeria		South Africa		Tunisia	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Panel A: Distribution of last digit of the price												
0	4961	15.81	2068	20.06	18620	53.31	17251	29.61	31126	25.39	21021	29.42
1	3120	9.94	957	9.28	1901	5.44	4622	7.93	9754	7.96	4274	5.98
2	2765	8.81	851	8.25	1322	3.78	4542	7.80	9228	7.53	4893	6.85
3	2828	9.01	857	8.31	1132	3.24	3917	6.72	9101	7.42	4644	6.50
4	2771	8.83	852	8.26	1223	3.50	3970	6.81	9418	7.68	5352	7.49
5	3339	10.64	1071	10.39	3965	11.35	7155	12.28	15566	12.70	8326	11.65
6	2676	8.53	875	8.49	1229	3.52	4338	7.45	9253	7.55	4264	5.97
7	2874	9.16	836	8.11	1201	3.44	4109	7.05	9163	7.47	5247	7.34
8	2949	9.40	918	8.90	1561	4.47	4083	7.01	9614	7.84	6283	8.79
9	3093	9.86	1026	9.95	2776	7.95	4270	7.33	10362	8.45	7158	10.02
Total	31376		10311		34930		58257		122585		71462	
% at 0 and 5		26.45		30.44		64.66		41.89		38.09		41.07
Panel B: Clustering tests and indices												
χ^2_9	1292.34		1214.54		74906.82		26281.06		35046.87		32096.48	
H_1 (p-value)	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
HHI (%)	10.41		11.18		31.44		14.51		12.86		14.49	

Notes: Panel A displays both the absolute and relative price frequencies. Panel B presents the p-values for the H_1 hypothesis, along with the Herfindahl-Hirshmann index (HHI).

Table no. 4 – Price clustering: comparison between periods – before COVID-19 (I), COVID-19 (II) and after COVID-19 (III)

	Egypt			Kenya			Morocco		
	I	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
χ^2_9	288.0	114.4	1354.7	234.8	441.5	586.5	33546.4	19279.1	22610.8
H_1 (p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
HHI (%)	10.24	10.12	11.43	11.21	11.26	11.21	35.61	27.21	31.27
$F_{9,9}$	0.40		11.84	1.88		1.33	0.57		1.17
H_2 (p-value)	0.9073		0.0005	0.1804		0.3396	0.7891		0.4081
	Nigeria			**South Africa**			**Tunisia**		
	I	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
χ^2_9	7500.7	10570.1	8514.1	15663.8	11338.2	8169.9	10720.5	9382.8	12736.9
H_1 (p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
HHI (%)	13.94	15.30	14.42	13.05	13.05	12.40	13.36	14.49	16.82
$F_{9,9}$	1.41		0.81	0.72		0.72	0.88		1.36
H_2 (p-value)	0.3088		0.6237	0.6810		0.6834	0.5771		0.3281

Notes: The table presents the p-values for the H_1 and H_2 hypotheses, along with the Herfindahl-Hirshmann index (HHI). Periods I, II and III represent, respectively, the periods before COVID-19, COVID-19 and after COVID-19 (see Table no. 1 for specific dates for each country).

Analyzing the Moroccan dataset reveals a greater concentration of prices compared to the Egyptian dataset. In this sample, and regardless of the period considered, more than 50%

of prices have the last digit zero, while roughly 11% end with the digit five. These outcomes support the Attraction Hypothesis. Statistical tests convincingly refute null hypothesis H_1 across all three periods, confirming the presence of price clustering. Additionally, HHI values show a decline from the period before COVID-19 to the COVID-19 period. However, the evidence suggests that this decrease lacks statistical significance. Conversely, HHI values increased from the COVID-19 period to the period after COVID-19, indicating the inability to reject the null hypothesis H_2. Thus, no substantial disparities in the level of price clustering are discerned among the three time periods.

Analyzing the results for Nigeria, the most frequently occurring final digits are again zero and five, comprising approximately 42% of prices. Regarding statistical examinations, significant disparities between the observed distribution and the expected uniform distribution were evident across all three periods. Consequently, we can confidently reject null hypothesis H_1 due to the statistical significance of these differences. Our analysis indicates an increase in HHI values from the period before COVID-19 to the COVID-19 period, while a slight decrease in HHI values was observed from the COVID-19 period to the subsequent period. However, the test of the H_2 hypothesis revealed that these differences between the periods lack statistical significance. As a result, we can conclude that no discernible alterations in the level of price clustering were observed throughout these three periods.

In South Africa, the findings are analogous to those obtained in other markets. During the different periods, the digit zero appears in around 25% of prices, while the digit five appears around 13%. The first statistical test led to the rejection of null hypothesis H_1, given the significance of the differences between observed and expected distributions in all periods. Furthermore, the second test indicated a marginal decrease in HHI values from the pre-COVID-19 to the COVID-19 period, as well as from the COVID-19 to the post-COVID-19 period. The are unable to reject the null hypothesis H_2, thereby affirming consistent price clustering levels throughout the three periods.

Finally, the results for the Tunisian sample further support the presence of price clustering. More than 40% of closing prices end in zero or five. Analogous to findings in other samples, disparities exist between the observed distributions and anticipated uniform distributions, warranting the rejection of null hypothesis H_1. Furthermore, albeit the increase in HHI values from the pre-COVID-19 period to the COVID-19 period, the results indicate a consistent level of price clustering between these two periods. As for the COVID-19 period to the post-COVID-19 period, there was again an increase in HHI values but this increase lacks statistical significance.

In summary, the univariate analysis across all six markets underscores a consistent pattern: the last digit of stock prices does not conform to a uniform distribution, providing strong evidence of price clustering. Our findings reveal a consistent trend across the three analyzed periods within the six samples, with digits zero and five emerging as the most frequently observed. The highest level of clustering is observed in the Moroccan sample, indicated by notably high HHI values, followed by the Tunisian sample. The results validate the Attraction Hypothesis (Curcio and Goodhart, 1991), thus supporting H_1. Regarding H_2, the analysis does not reveal statistically significant disparities in clustering levels pre- or post-COVID-19 and during the COVID-19 period across the six market samples. There was only a slight increase in the level of price clustering in the Nigerian and Tunisian samples during the COVID-19 period. From this standpoint, it can be deduced that investors appear relatively less influenced by behavioral factors during periods of heightened pessimism and uncertainty, contrary to the implications of the Panic Selling Hypothesis."

4.1 Multivariate Analysis

To begin, it is essential to note that two models will be estimated for each of the six market samples across the three periods. The first model will include all explanatory variables, while the second model will address potential multicollinearity by excluding variables with correlation coefficients exceeding 0.55 with other factors (specifically, variables "CompSize" and "Volatility").

Tables no. 5A (Egypt, Kenya, and Morocco) and no. 5B (Nigeria, South Africa, and Tunisia) present the outcomes of the multivariate analysis conducted on the six countries. Tables no. 6A and no. 6B showcase the results obtained with the reduced model.

The results for Egypt in Table no. 5A evidence that during the periods prior to COVID-19 and following COVID-19, independent variables explain approximately 74% and 44% of the variance in the degree of price clustering, respectively. However, within the COVID-19 period, this proportion experiences a significant decline, dropping to around 14%. These notable disparities can be attributed to shifts in economic conditions that impact the underlying relationships. Nonetheless, in the context of the reduced model (Table no. 6A), it was observed that during the period before COVID-19 and in the period of COVID-19, there was a marginal uptick in the explanatory capability of the independent variables to 75% and 17%, respectively. However, during the period following COVID-19, a slight decrease was noted, to 43%, compared to the model encompassing all variables. The variable "Illiquidity" tends to be statistically significant and presents the expected sign, at least in the periods prior to and after COVID-19. Additionally, in the COVID-19 period, the variable "Turnover" holds statistical significance at a 10% significance level. These results persist in the reduced model, although small differences emerge. In the COVID-19 period, the "Turnover" variable becomes statistically significant at a 5% significance level within the same period. This underscores the prominence of "Illiquidity" across two periods and "Turnover" during the crisis period as the pivotal explanatory factors for price clustering within this sample, aligning consistently with the literature's expectations. In summation, the analysis suggests that the Egypt sample provides only partial confirmation of the hypothesis of price negotiation.

Regarding the results for Kenya, the adjusted R-squared coefficient for the sample periods is not notably high, but in the case of the reduced model there is an improvement in the coefficients. It is observed in Table no. 5A that in the period preceding COVID-19 only the variables "StockPrice" and "Volatility" align with the theoretical expectations. In the complete model, we observe that the variables "Turnover" and "Illiquidity" attain statistical significance at levels of 10% and 5%, respectively. However, these variables present some explanatory power in this model only in the periods before the pandemic and after the pandemic, respectively. On the other hand, within the model excluding "CompSize" and “Volatility”, the variable "Turnover" achieves statistical relevance in the two initial periods. In the periods before and after COVID-19, the variable "StockPrice" exhibit explanatory significance, as well as the variable "Illiquidity" in the last period, to a level of 1%. The variables that offer the most insightful explanation for the fluctuations in the clustering level are the "Illiquidity" variable during the post-COVID-19 period in both models, as well as the “StockPrice” and "Turnover" variables during the reduced model. Once again, our findings lead us to the conclusion that the theories scrutinized are only partially validated within the Kenyan sample.

The results for the Moroccan sample indicate that during the periods before COVID-19, COVID-19, and after COVID-19, the independent variables account for only approximately

4%, 19%, and 8% of the variance evident in price clustering, respectively. Only the variable "Illiquidity" attains statistical significance for the periods preceding COVID-19 and during COVID-19, at a 10% significance level. However, its inverse correlation with the dependent variable, render it incongruent with the study's focus. Furthermore, the variable "StockPrice" exhibits a p-value of 11% during the COVID-19 period and the post-COVID-19 period. The model excluding the variables "CompSize", and "Volatility" mirrors the results of the comprehensive model for the variable "Illiquidity". However, in the last two periods of analysis, the variable "StockPrice" attains statistical significance at a 5% significance level. Hence, it becomes evident that solely within the reduced model and during the COVID-19 and post-COVID-19 periods does the variable "StockPrice" emerge as an explanatory factor for the phenomenon of price clustering, aligning with the hypotheses posited by the literature. To sum up, our findings within the Moroccan sample do not substantiate the hypotheses of price resolution and negotiation across the three examined periods.

Table no. 5A – Determinants of price clustering: before COVID-19 (I), COVID-19 (II) and after COVID-19 (III)

	Expected sign	Egypt			Kenya			Morocco		
		(I)	(II)	(III)	(I)	(II)	(III)	(I)	(II)	(III)
Intercept		0.0177	0.0096	0.0287	0.0433	0.0257	0.0280	0.2668	0.2067	0.2429
		(0.0040)	(0.0032)	(0.0046)	(0.0230)	(0.0081)	(0.0090)	(0.0208)	(0.0205)	(0.0218)
StockPrice	+	-0.0038	-0.0023	-0.0030	0.0399	0.0098	0.0516	-0.0458	0.0784	0.0765
		(0.0094)	(0.0077)	(0.0113)	(0.0485)	(0.0263)	(0.0288)	(0.0519)	(0.0477)	(0.0468)
CompSize	-	0.0040	0.0007	0.0130	0.0069	0.0105	0.0144	0.0596	-0.0629	-0.0232
		(0.0085)	(0.0070)	(0.0108)	(0.0528)	(0.0236)	(0.0392)	(0.0444)	(0.0463)	(0.0389)
Turnover	-	-0.0045	-0.0087*	-0.0098	0.0653**	-0.0305	0.0013	-0.0388	0.0358	0.0340
		(0.0057)	(0.0048)	(0.0066)	(0.0245)	(0.0194)	(0.0248)	(0.0450)	(0.0400)	(0.0427)
Volatility	+	0.0022	0.0000	0.0013	0.0017	-0.0101	-0.0200	0.0060	0.0306	0.0219
		(0.0044)	(0.0039)	(0.0056)	(0.0478)	(0.0138)	(0.0124)	(0.0277)	(0.0332)	(0.0305)
Illiquidity	+	0.0375***	0.0054	0.0180***	-0.0157	0.0058	0.0575**	-0.0478*	-0.0715**	-0.0287
		(0.0045)	(0.0036)	(0.0053)	(0.0266)	(0.0131)	(0.0190)	(0.0276)	(0.0273)	(0.0314)
R^2		0.7862	0.2900	0.5417	0.5029	0.5416	0.6551	0.1491	0.2779	0.1833
Adjusted R^2		0.7398	0.1356	0.4421	0.2770	0.3333	0.4983	0.0427	0.1876	0.0812
F-statistic		16.9197	1.8786	5.4373	2.2258	2.5997	4.1780	1.4017	3.0785	1.7953
Prob (F-statistic)		0.0000	0.1373	0.0019	0.1249	0.0867	0.0225	0.2445	0.0192	0.1359

From the analysis conducted on the Nigerian sample it is observable in Table no. 5B that the independent variables account for approximately 36% of the variance in the level of price clustering in the period before COVID-19. In contrast, during the pandemic and post-pandemic periods, the coefficients of determination are notably higher. A similar pattern emerges when considering the reduced model (Table no. 6B), where the results are largely consistent. During the periods preceding and following COVID-19, only the variables "StockPrice", "Turnover", and "Illiquidity" exhibit signs aligned with the hypotheses of price resolution and negotiation. However, in the period of COVID-19, only the variables "StockPrice" and "Illiquidity" evidence the expected positive relationship with price clustering. The variable "Illiquidity" holds statistical significance across all three periods at a significance level of 1%, while the variable "Volatility" also exhibits explanatory capability regarding the price clustering phenomenon across the entirety of the sample, with statistical significance at a level of 5%. In the COVID-19 period, the variable "StockPrice" also maintains statistical relevance, as well as the variable "CompSize" in the post-COVID-19

period. Despite the statistical significance of the variables "Volatility" and "CompSize" within the model, the signs of their coefficients contradict the predictions from the literature. The outcomes from the reduced model reveal that in the period before COVID-19, only the variable "Turnover" lacks statistical relevance within the model. In contrast, during the COVID-19 period as well as in the post-COVID-19 period, all variables maintain statistical significance. In summary, the results indicate partial validation of the analyzed theories, with the variable "Illiquidity," followed by "StockPrice," emerging as the pivotal explanatory factors for price clustering within the two estimated models.

Table no. 5B – Determinants of price clustering: before COVID-19 (I), COVID-19 (II) and after COVID-19 (III)

	Expected sign	Nigeria			South Africa			Tunisia		
		(I)	(II)	(III)	(I)	(II)	(III)	(I)	(II)	(III)
Intercept		0.1841	0.1814	0.1625	0.0432	0.0501	0.0398	0.0077	0.0930	0.01269
		(0.0217)	(0.0190)	(0.0188)	(0.0045)	(0.0036)	(0.0030)	(0.0086)	(0.0086)	(0.0105)
StockPrice	+	0.0615	0.0801*	0.0358	0.0255**	0.0363***	0.0312***	0.0387*	0.1010***	0.1131***
		(0.0477)	(0.0450)	(0.0429)	(0.0109)	(0.0131)	(0.0110)	(0.0204)	(0.0207)	(0.0211)
CompSize	-	0.0571	0.0510	0.0877**	0.0098	-0.0079	0.0058	0.0164	0.0012	0.0069
		(0.0421)	(0.0426)	(0.0436)	(0.0096)	(0.0076)	(0.0069)	(0.0165)	(0.0153)	(0.0187)
Turnover	-	-0.0410	0.0209	-0.0016	-0.0149	-0.0092	-0.0038	-0.0133	0.0190	-0.0164
		(0.0377)	(0.0346)	(0.0357)	(0.0100)	(0.0115)	(0.0105)	(0.0167)	(0.0174)	(0.0171)
Volatility	+	-0.0595**	-0.0960***	-0.1044***	-0.0075	-0.0060	-0.0063*	0.0122	-0.0163	-0.0154
		(0.0276)	(0.0219)	(0.0218)	(0.0055)	(0.0044)	(0.0036)	(0.0115)	(0.0126)	(0.0136)
Illiquidity	+	0.1125***	0.1661***	0.1290***	0.0437***	0.0362***	0.0534***	0.0262**	0.0315**	0.0135
		(0.0312)	(0.0258)	(0.0277)	(0.0086)	(0.0107)	(0.0089)	(0.0125)	(0.0141)	(0.0143)
R^2		0.4069	0.5611	0.5603	0.4966	0.6073	0.7150	0.4356	0.5468	0.6278
Adjusted R^2		0.3639	0.5293	0.5285	0.4707	0.5871	0.7003	0.3964	0.5153	0.6020
F-statistic		9.4660	17.6424	17.5860	19.1398	30.0011	48.6659	11.1153	17.3714	24.2909
Prob (F-statistic)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

*Notes: Standard errors presented in parenthesis. The significance levels of 10%, 5%, and 1% are denoted as *, **, and *** respectively. Periods I, II and III represent, respectively, the periods before COVID-19, COVID-19 and after COVID-19 (see Table 1 for specific dates for each country).*

Regarding the South African sample, we can observe that over 58% of the variability in the level of price clustering is explained by the independent variables used in the model during the last two periods. However, in the period before COVID-19, the independent variables explain only 47% of the variations observed in the studied phenomenon. These findings are consistent even when examining the estimated model without the "CompSize" variable (Table no. 6B). Upon examination, it becomes apparent that during the periods prior to and following the pandemic, the variables "StockPrice," "CompSize," and "Illiquidity" exhibit positive correlations with price clustering. Nonetheless, these results for the "CompSize" and "Volatility" variables diverge from the expected outcomes as suggested by Ball *et al.* (1985) and Harris (1991). Conversely, during the pandemic period, it is revealed that only the "Volatility" variable contradicts the anticipated relationship with the dependent variable in the literature. Moreover, the conclusions drawn from the reduced model align with the previously described findings, with the exception being that in the post-pandemic period, the variable "Turnover" exhibits a positive relationship with price clustering. In contrast, we have ascertained that the statistically significant variables encompass: the "StockPrice" variable, which holds a significance level of 5% in the period prior to the pandemic, 1% across the remaining periods in the comprehensive model, and consistently across all periods in the reduced model; as well as the "Illiquidity" variable, exhibiting a significance level of 1% for all periods in both analyzed models.

Table no. 6A – Determinants of price clustering (reduced model): before COVID-19 (I), COVID-19 (II) and after COVID-19 (III)

	Expected sign	Egypt			Kenya			Morocco		
		(I)	(II)	(III)	(I)	(II)	(III)	(I)	(II)	(III)
Intercept		0.0177	0.0096	0.0287	0.0433	0.0257	0.0280	0.2668	0.2067	0.2429
		(0.0039)	(0.0031)	(0.0046)	(0.0212)	(0.0077)	(0.0093)	(0.0208)	(0.0206)	(0.0214)
StockPrice	+	0.001	-0.0017	0.0087	0.0469*	0.0097	0.0452***	0.0129	0.0484**	0.0698**
		(0.0045)	(0.0038)	(0.0057)	(0.0224)	(0.0106)	(0.0141)	(0.0239)	(0.0222)	(0.0266)
CompSize	-									
Turnover	-	-0.0030	-0.0084**	-0.0056	0.0658**	-0.0238*	0.0078	0.0079	0.0033	0.0228
		(0.0046)	(0.0036)	(0.0057)	(0.0222)	(0.0113)	(0.0142)	(0.0283)	(0.0283)	(0.0354)
Volatility	+	0.0026	0.0001	0.0029						
		(0.0042)	(0.0037)	(0.0054)						
Illiquidity	+	0.0370***	0.0054	0.0179	-0.0175	0.0044	0.0499**	-0.0465*	-0.0664**	-0.0252
		(0.0043)	(0.0035)	(0.0053)	(0.0221)	(0.0124)	(0.0170)	(0.0271)	(0.0270)	(0.0307)
R^2		0.7842	0.2896	0.5130	0.5016	0.5049	0.5727	0.1104	0.2382	0.1689
Adjusted R^2		0.7482	.01712	0.4318	0.3866	0.3906	0.4741	0.0469	0.1838	0.1095
F-statistic		21.7994	2.4464	6.3201	4.3613	4.4187	5.8080	1.7379	4.3771	2.8449
Prob (F-statistic)		0.0000	0.0739	0.0013	0.0248	0.0238	0.0096	0.1739	0.0091	0.0490

Table no. 6B – Determinants of price clustering (reduced model): before COVID-19 (I), COVID-19 (II) and after COVID-19 (III)

	Expected sign	Nigeria			South Africa			Tunisia		
		(I)	(II)	(III)	(I)	(II)	(III)	(I)	(II)	(III)
Intercept		0.1841	0.1814	0.1625	0.0432	0.0501	0.0398	0.0777	0.0930	0.1269
		(0.0219)	(0.0190)	(0.0192)	(0.0045)	(0.0036)	(0.0030)	(0.0086)	(0.0086)	(0.0105)
StockPrice	+	0.1105***	0.1252***	0.1099***	0.0331***	0.0271***	0.0382***	0.0614***	0.0878***	0.1082***
		(0.0314)	(0.0245)	(0.0223)	(0.0079)	(0.0096)	(0.0072)	(0.0111)	(0.0122)	(0.0128)
CompSize	-									
Turnover	-	-0.0157	0.0491*	0.0469*	-0.0079	-0.0167*	0.0026	-0.0005	0.0130	-0.0176
		(0.0329)	(0.0253)	(0.0269)	(0.0073)	(0.0089)	(0.0072)	(0.0135)	(0.0151)	(0.0146)
Volatility	+	-0.0668**	-0.0966***	-0.1137***	-0.0092*	-0.0045	-.0073**			
		(0.0273)	(0.0220)	(0.0217)	(0.0052)	(0.0041)	(0.0034)			
Illiquidity	+	0.1105***	0.1696***	0.1301***	0.0439***	0.0335***	0.0562***	0.0246*	0.0294**	0.0131
		(0.0314)	(0.0257)	(0.0283)	(0.0086)	(0.0104)	(0.0082)	(0.0124)	(0.0137)	(0.0136)
R^2		0.3910	0.5520	0.5346	0.4913	0.6029	0.7129	0.4210	0.5361	0.6240
Adjusted R^2		0.3562	0.5264	0.5080	0.4705	0.5867	0.7012	0.3975	0.5173	0.6050
F-statistic		11.2371	21.5631	20.1006	23.6622	37.2045	60.8424	17.9328	28.5031	40.3094
Prob (F-statistic)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes: Standard errors presented in parenthesis. The significance levels of 10%, 5%, and 1% are denoted as *, **, and *** respectively. Periods I, II and III represent, respectively, the periods before COVID-19, COVID-19 and after COVID-19 (see Table no. 1 for specific dates for each country).

Furthermore, in the reduced model during the period preceding the pandemic, as well as in the complete model, in the periods subsequent to the pandemic, the "Volatility" variable maintains statistical relevance at a significance level of 10%. However, its relationship, contrary to the expectations of the theories under study, diminishes its significance in our analysis. The final discrepancy between the models is identified in the pandemic period within the model excluding the "CompSize" variable, where the "Turnover" variable gains statistical significance. In brief, the essential variables in elucidating fluctuations in the price clustering are "StockPrice" and "Illiquidity".

Finally, considering the Tunisian sample, we observe that the adjusted coefficient of determination exhibits notable levels of adequacy for the periods during and after the

pandemic (52% and 60%, respectively). In contrast, for the period prior to the pandemic, the coefficient stands at 40%. The values derived from the reduced model mirror the outcomes of the complete model. With respect to the hypotheses examined, it was discerned that in the period before COVID-19, solely the "CompSize" variable diverges from the expected relationship with the studied phenomenon. However, in the COVID-19 period, the variables "CompSize," "Turnover," and "Volatility" do not conform to the anticipated relationship. Subsequently, during the period following COVID-19, the variables "CompSize" and "Volatility" deviate from the expected pattern. The model excluding the "CompSize" and "Volatility" variables yields congruent results for the variables included within the model. Furthermore, it is evident that the "StockPrice" variable holds explanatory power for the phenomenon of price clustering across the three periods scrutinized, in both estimated models. Similarly, the "Illiquidity" variable maintains statistical significance during the pre-pandemic and pandemic periods in both models. In conclusion, these variables emerge as the primary contributors to elucidating the variations in the phenomenon under scrutiny.

In summary, contrasting outcomes across different markets reveals varying degrees of explanatory power, with a higher degree observed in the South African sample, while encountering substantial challenges in the Moroccan sample. These variations may stem from divergent investor profiles, cultural factors, and other influences.

Examining outcomes across all time periods within each sample indicates that the constant term consistently holds statistical significance. In situations where independent variables show no variance, there is no observable price clustering, but when these variables lack variability, a pronounced level of price clustering tends to occur. This effect can be attributed to individual behavioral tendencies or psychological biases that lead individuals to exhibit a heightened attraction for specific numerical values, as argued by Ikenberry and Weston (2008).

Multiple variables contribute to elucidating the extent of price clustering across samples. The variables "Illiquidity," "StockPrice," and "Turnover" emerge as statistically significant factors supporting the Negotiation and Price Resolution hypotheses. "Illiquidity" stands out as pivotal, exhibiting statistical significance across several periods within all samples, except for Morocco, generally aligning with hypothesis H_{3e}. "StockPrice" exhibits explanatory power, except for Egypt, partially aligning with hypotheses H_{3a}. "Turnover" holds significance in clarifying fluctuations in price clustering, partially aligning with hypotheses H_{3c}. However, "CompSize" and "Volatility" consistently reject theoretical expectations, leading to the rejection of hypotheses H_{3b} and H_{3d}.

Observations suggest that disparities among coefficients between periods preceding COVID-19 and the COVID-19 period lack statistical significance, contrary to expectations of intensified clustering during economic crises. Counteracting trends, such as declines in variables like "Volatility," are observed. Similarly, differences in coefficients between the COVID-19 period and the post-COVID-19 period lack statistical relevance. The constant term shows no considerable deviation between periods, with a slight decrease during the crisis period across almost all samples.

Additionally, when applying the model to the entire period for each sample, the findings largely corroborate previous conclusions. "Illiquidity" continues to be the primary explanatory factor, except in the samples from Kenya and Morocco. "StockPrice" remains relevant in explaining the phenomenon in the Kenyan and Tunisian samples. Lastly, "Turnover" exhibits statistical significance in emphasizing the phenomenon within the South African sample.

5. CONCLUSION

Price clustering, the tendency for stock prices to concentrate around specific digits or numbers, is a non-random pattern with implications for market efficiency, trading strategies, and investor behavior. This study explores price clustering in African markets, aiming to enhance the analysis of this phenomenon and assess the impact of the COVID-19 pandemic on it. Data from six African markets were analyzed to uncover insights into the prevalence and influencing factors behind the clustering of stock price digits.

The study affirms the presence of price clustering across various periods in the analyzed markets. Univariate analysis indicates a non-uniform distribution of the last digits of stock prices, with a preference for digits zero and five. Unexpectedly, some periods and samples show a higher frequency of stock prices ending in digits one and nine, partially confirming the Attraction Hypothesis. Notably, the three analyzed periods do not exhibit significant differences, challenging expectations of heightened uncertainty and volatility during the COVID-19 period influencing investor behavior, contrary to the Panic Selling Hypothesis.

Multivariate analysis sheds light on variables significantly contributing to fluctuations in price clustering levels. "Illiquidity," "StockPrice," and "Turnover" emerge as influential factors across samples, revealing variations in how these variables explain the phenomenon over different periods. The recurring significance of the constant term suggests psychological biases and attractions to specific numbers, partially confirming the Attraction Hypothesis. The results also partially support the Negotiation and Price Resolution Hypotheses, with some variables adhering to anticipated relationships and others exhibiting contrary associations.

The tendency for prices to settle more frequently at certain levels than others carries practical implications for investors. Prior research has shown that investors can construct profitable trading strategies that exploit these clustering effects, even after accounting for the bid-ask spread (Niederhoffer, 1965; Mitchell, 2001). Niederhoffer (1965) provides specific examples of such strategies.

Consistent with univariate findings, limited consistency in coefficient variations between pre- and post-COVID-19 periods compared to the COVID-19 period indicates the economic crisis's varied impact on price clustering across markets. This highlights the complex interplay between market dynamics, investor sentiments, and the clustering phenomenon. Similar to Lobão *et al.* (2019), our research challenges the notion that economic crisis uniformly changes investor behavior, providing nuanced insights that do not strongly support the Panic Selling Hypothesis.

Our research is not free from limitations. Although our insights largely confirm existing hypotheses in a new regional context, potential omitted variables, such as regional market microstructure, institutional features, or regulatory constructs, could bias our results. Unexplained fluctuations persist, suggesting the influence of factors like investor behavior, cultural nuances, and specific market dynamics. Future research could explore alternative COVID-19 periods and include additional variables to enhance explanatory power. Specifically, market microstructure variables like bid-ask spread or measures capturing different dimensions of liquidity, such as the Amihud ratio could be included.

In summary, this paper delves into the nuanced phenomenon of price clustering in African markets, shedding light on its existence and underlying factors. The findings enrich our understanding of investor behaviors and market complexities in the financial landscape.

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