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Volatility Spillover and Risk Transmission between Green and Brown Assets: A Systematic Literature Review with Thematic Analysis

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Abstract

This study presents a systematic literature review (SLR) aimed at synthesizing and assessing the existing state of knowledge within the chosen research domain. Following a systematic approach aligned with the PRISMA guidelines, 67 peer-reviewed journals published between 2015 and 2025 were selected from the Scopus and Web of Science databases. This review presents the results in two different sections: descriptive bibliometric metadata and thematic analysis, and it investigates the principal research themes, theoretical underpinnings, methodological patterns, and existing research gaps. There is a dynamic interconnection of volatility spillovers between the green and conventional assets, and the time-frequency dynamics analysis highlights that the impacts can be very over the different time periods and market scenarios. This study offers directions for future research and conclusions for policymakers, executives, regulatory bodies, and academicians.

Keywords
Spillover, Financial Assets, Volatility, Transmission, Network

1. Introduction

The global transition to the sustainable practice, there is a paradigmatic shift into the sustainable finance, with institutional and retail investors increasingly integrating the environmental, social and governance (ESG) criterion in the investment decision. This evolution has bifurcated financial market into two prominent assets: green assets, aligned with sustainability principles and brown assets aligned with the negative effects with environment (Battiston et al., 2017; Reinders et al., 2023). With theme of sustainable development goals, and Paris Agreement-2015, the raising adoption of green assets, it has become increasingly important to analyze the inter relation and pathways of volatility and systematic risk transmission between green and brown assets.

The volatility transmission and systematic risk spillover across the assets classes has been a central theme in financial econometrics, particular in turmoil, when shocks originating in one segment can cascade through interconnected

financial systems, intensifying systemic fragility (Diebold and Yilmaz, 2012; Baruník and Křehlík, 2018). Due to the evolving regulatory framework, climate transition risk and heterogeneous risks, these dynamics have gained the heightened significance in the context of green and brown finance. Yet, while conventional econometric approaches provide meaningful insights into pairwise volatility spillovers, they often fall short in capturing the intricate web of multilateral interactions and higher-order connections that characterize the increasingly complex landscape of sustainable finance.

The recent advancement in network-based connectedness such as Diebold-Yilmaz approach (2012; 2014) quantifies directional connectedness use forecast error variance decompositions from vector aturegressions (VARs), while the Barunik-Krehlik model (2018) extends this analysis into the frequency domain, enabling a decomposition of connectedness across short-, medium- and long-term investment horizon. These models have been applied to traditional market such equities, commodities, forex, however the application to the green-brown dichotomy remains nascent and fragmented. Additionally, network topologies constructed from the connectedness metrics such as minimum spanning trees, dynamic conditional correlational networks, and spillover index frameworks have been highly effective in detecting the key systematic entities and paths of contagion within financial systems (Billio et al., 2012: Kenett et al., 2015). Integration of these methodologies in area of sustainable finance can provide the detail insights into whether green assets serve as buffers against market instability or act as channels for risk stabilizer during periods of financial stress.

Despite the recent empirical studies on the dynamic association between the green and conventional assets, however, a through and structure of integrated review of all the studies remain largely unexplored. This review contributes existing literatures on volatility spillovers and risk transmission between green and conventional asset**s** in various ways. Firstly, we employed the scientometric assessment to figure out scholarly terrain of the domain, exploring the novel most influential average data like, number of authors, publication time, revision time, citations, references, article page lengths and methodological parameters. Thirdly, we conducted the bolometric thematic analysis and synthesizing the existing body of knowledge through a meta-analysis of leading articles in aggregate offering a qualitative interpretation of prior literature. Lastly, we have offered forward-looking research framework supporting future research agendas in area of spillover of risks. The structure of this study follows; section II presents the methodological justifications of this study; section III shows the results of the study and section IV presents the conclusion and discuss about the future research avenues.

2. Data and Methodology

We follow preferred reporting items for systematic review and meta-analysis (PRISMA) 2020 approach, which has a scientific transparency and dependability, to synthesize and generalize the existing literature on volatility spillover and risk transmission among the financial assets (Page et al., 2021). We used the PRISMA structured methodology to articulate the clear research question, choose the relevant papers, grasp the methodological aspect of the study, and synthesize the key contributions (Rethlefsen et al., 2021; Muchiri et al., 2022; Ed-Dafali et al., 2025). For SLR, we chose journal articles from Scopus and Web of Science because they provide a greater journal scope, unbiased coverage across publishers, more information detail, and more bibliometric data than other sources (Pranckute, 2021).

An initial search was conducted by using a structured keyword string based on PRISMA guidelines as mentioned in Page et al. (2021). The major keywords are *(TITLE-ABS KEY (‘volatility spillover’ OR ‘risk transmission’ OR ‘risk spillover’) AND TITLE-ABS KEY (‘green assets’ OR ‘sustainable assets’ OR ‘green bond’) AND TITLE-ABS KEY (‘carbon assets’ OR ‘brown assets’ OR ‘conventional assets’)).*

The screening process for this SLR was systematically guided by the PRISMA protocol, covering stages, from identifying the related articles, reviewing the titles and abstracts, assessing full text eligibility and final inclusion. We primarily focused on journals published from 2015 onward, recognizing that sustainability policy adoption gained significant momentum after the 2015 Paris Agreement (Meinshausen et al., 2022). To ensure broad accessibility and consistency, we limited our research selection to studies published in English, the dominant language of academic discourse (Ramalingam et al., 2022). Furthermore, we confined the scope to subject areas including the Business Management, Accounting, Economics, Econometrics, and Finance, for relevant theoretical and practical contextual, thereby enhancing the interpretive depth and generalizability of findings (Toth et al., 2023). It can be noted that only peer-reviewed journal articles were included, as these typically adhere to rigorous methodological standards, undergo quality checks, and contribute to reducing the bias and increasing reliability (Khan et al., 2020). After applying all

inclusions, we identified 67 journal articles in between 2015 to 2025. This carefully, structured process ensures the methodological rigor, clarity, and replicability of key findings in SLR (Figure 1).

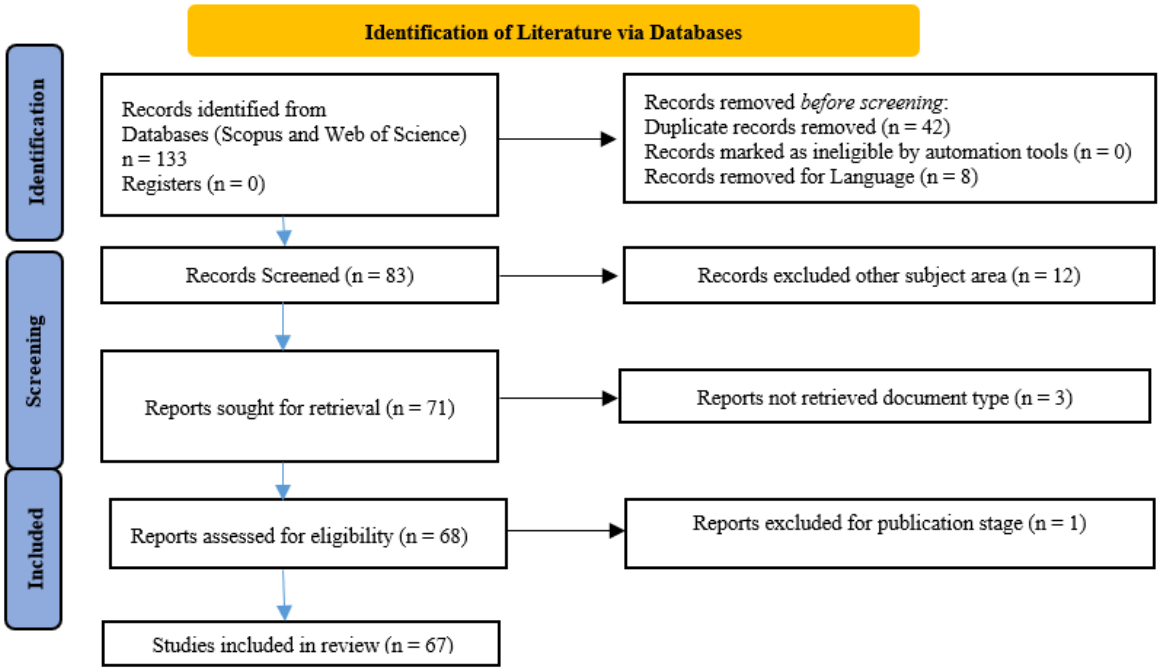

Figure 1. Reporting items for systematic review and meta-analysis

To explore the scholarly landscape in this emerging area of finance, we adopted a bibliometric approach, as employed in previous studies (Paltrinieri et al., 2019; Baker et al., 2021). This method has become increasingly valuable in identifying influential trends, key contributors, and thematic developments in academic research. Following the framework suggested by Khan et al. (2020) and Zairis (2024), our analysis was structured across two main dimensions: descriptive bibliometric metadata and thematic analysis. For data processing and visualization, we relied on widely accepted analytical tools Python, which have been frequently applied in similar research settings (Paltrinieri et al., 2019). In descriptive part, we present the visualizations of essential corpus such as yearly publication trend, journal qualities, most prolific authors, journal paper attributes journals-publishers, cartography, analysis tools, data pints and geographical distribution. The second dimension involved a thematic analysis of existing body of literatures classifying mainly into four themes emerged based on Contagion and Spillover theory. With the aim of outlining the conceptual framework and thematic structures in literatures, we analyze the major scholarly work with publication year, journal quality, and main findings and no of data points used in the study and followed by the conclusions of articles. This offers to generate a visual map of academic relationships and uncover hidden research trends.

3. Results and Discussion

This section presents and interprets the findings in two parts: the descriptive bibliometric analysis, which provides an overview of the data set, and thematic analysis, which examines the underlying patters and thematic structures within the literature.

3.1 Descriptive Bibliometric Metadata: In the first section, we presents descriptive metadata in graphically; general attributes of corpus, annual publications, journal qualities, most prolific authors, journal paper attributes (no of authors, page numbers, and time between submission to publication), journals–publishers, cartography, analysis tools, data pints and geographical distribution of data to analyze the data driven insights in the ESG disclosure.

i. General Attributes of Corpus: The general attributes of the corpus in SLR offers a fundamental overview of scope, credibility and methodological aspect of the reviewed journal articles. Corpus information supports to generalize the scholarly efforts and engagement in this field and close understanding of reviewed area (Table 1).

Table 1. General Attributes of the Corpus Analyzed in SLR

Details	Results
Main Dataset Information	
Timespan	*2015-2025*
Sources	*Scopus and Web of Science*
Subject Area	*Business, Finance and Accounting, Economics, Econometrics*
Document Type	*Articles*
Source Title	*All*
Publication Stage	*Final*
Sources Type	*Journal*
Language	*English*
Nature of Research	*Empirical*
Facts and Figures	
Average No Authors	*3.28*
Average Paper Length	*20.58 Pages*
Average Publication Time	*4.86 Month*
Average Revision Time	*0.77 Time*
Average No. of Citation	*71.27 Per Journal*
Average No of References	*59.14 Per Journal*
Average no of Observations	*3338*
Methodology	
Research Approach	*Deductive Approach (Followed in All Reviewed Journal)*
Research Methods	*Quantitative 67 Journals (Followed in All Reviewed Journal)*
Research Design	*Approx. Autoregressive Models*
Nature of Data	*Secondary data (Green and Conventional Stock Indexes)*
Data Based	*Industry Level*

Table 1 presents the general attributes of corpus of literatures and review examines the 67 peer-reviewed journal articles published in between 2015 to 2025, focusing into volatility spillover and risk transmission among the financial assets. All the empirical journals sourced from Scopus and Web of Science, the journals span business related discipline and written in English. On average, each study has three authors, 20 pages, 59 references, and underwent 0.77 times over the 4.86 months. The literature demonstrates strong citation impact about 71 per journal and conceptual depth. Majority of the papers have followed a deductive, quantitative approach using the industry level secondary data about the 3338 observations, with autoregressive designs supported by rigorous robustness tests to assess ESG's effect on firm value.

ii. Annual Scientific Publications: The annual publications of articles present evolution and growing research interest this research area over the last periods. This visualization identifies the pattern of publications, emerging relevance, and their movement in future.

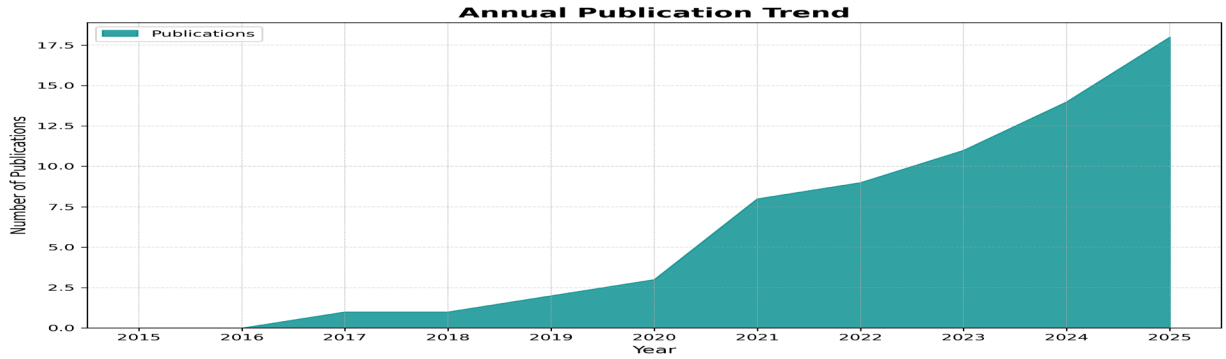

Figure 2. Annual Publication of Journals

Figure 2 presents the number of publications has generally increased over the years, reflecting the growing academic interest in this area. Particularly, after 2020, likely driven by evolving global sustainability policies and financial disclosure regulations. The peak in 2025 (18 publications) suggests that this area is rapidly emerging as a key research domain.

iii. Journal Ranking: In the review, article ranking through different ranking offer to assess the quality and credibility of the literatures included in review, ensuring that the review is based on the high impactful, academic rigor and relevance papers, thereby enriching the overall validity of the review.

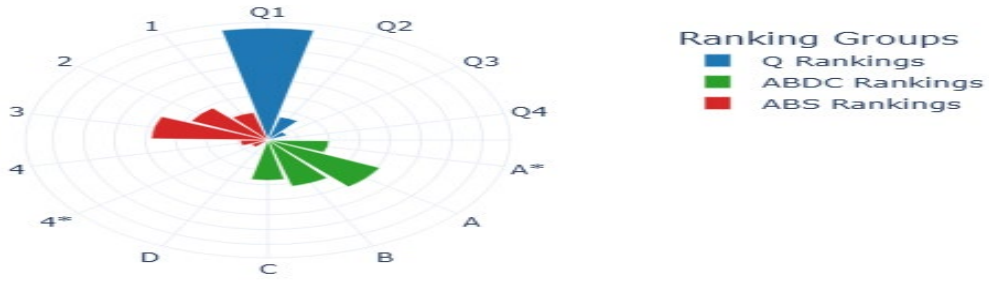

Figure 3. Journal Rankings

Figure 3 presents the journal quality ranking of articles included in this review. This analysis primarily draws from high impact and academically rigorous journals, with majority articles have published in top tier journal. Based on the ABDC classification, the review includes in percentage A* (20), A (41), B (32), and C (7) ranked journals. According to the SCImago Journal Rank (SJR), the distribution includes Q1 (75), Q2 (16), Q3 (9), and Q4 (2) journals. Additionally, the ABS ranking comprises 4* (6), 4 (9), 3 (38), 2 (28), and 1 (19) rated journals. These distributions underscore the review's strong foundation in high-quality, peer-reviewed academic literature.

iii. Most Prolific Authors: This analysis presents a few key researchers as the most prolific of authors, contributing extensively to publications and collaboration in this research arena. Basically, their scholarly work helps to note the foundations of research, gaps prevail in this area and future research directions. We have presented top twenty authors based with attributes of at least first author one time in journals.

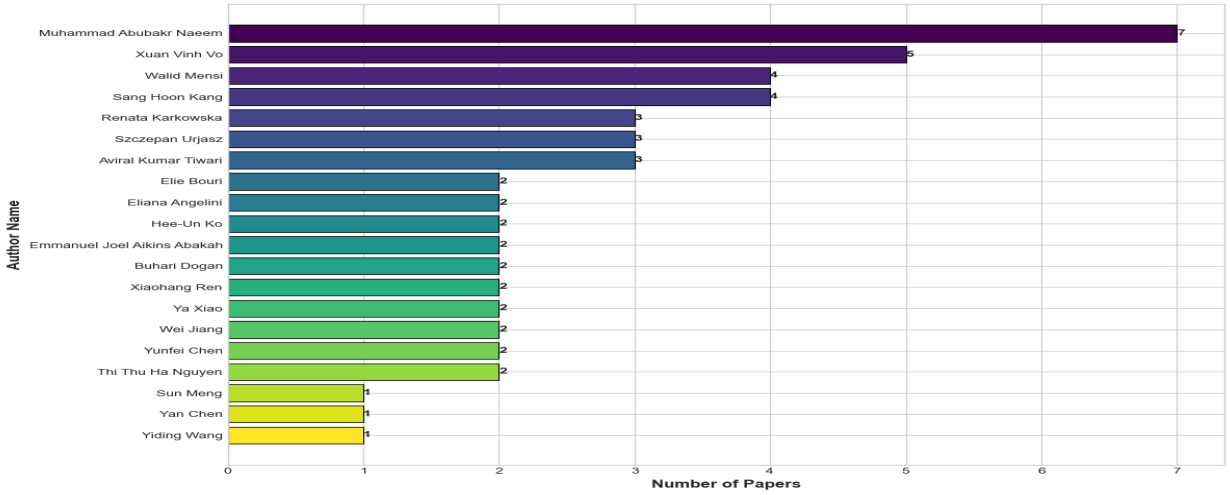

Figure 4. Most Prolific Authors

The Figure 4 shows the top 20 most prolific authors in journals reviewed in this SLR. Muhammad Abubakr Naeem leads with 7 publications, followed by Xuan Vinh Vo with 5, Walid Mensi and Sang Hoon Kang with 4 each. Several other have contributed 2 to 3 papers, highlighting a concentration of output among a few contributors in the field.

iv. Journal attributes: Presenting journal attributes (no of authors, submission to publication time, article pages length imparts an insight into publication patterns and editorial standards in this research domain. It assists to analyze depth or reteach, efficiency of publication and level of collaborations, thereby enhancing the transparency, and also guides future researchers for selecting the best articles in this academia.

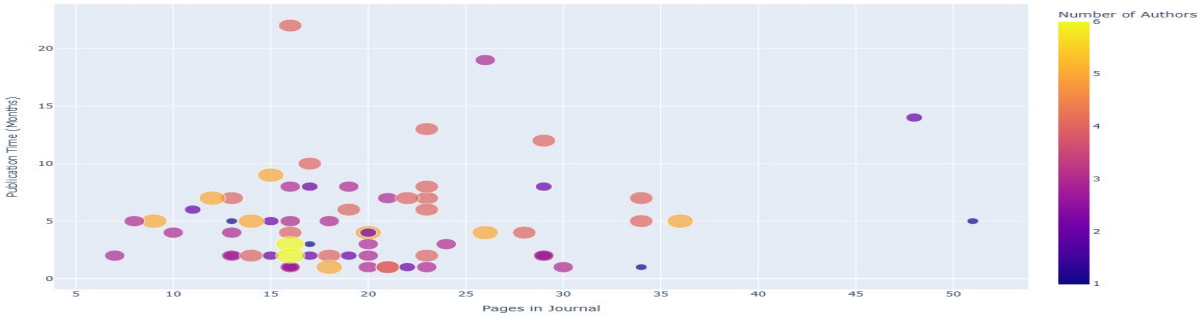

Figure 5. Journal Attributes

In Figure 5, the reviewed literatures present about 3 authors per journal, indicating a moderate collaboration, with authorship ranging from 1 to 6. Similarly, the average article publication timeline is 5 months, varying from 1 to 22 months, denoting differences in journal review process. Furthermore, the average length of article is 20 pages, with a ranging from 7 to 43 pages, presenting the variation in depth and scope of research. These pattern presents the diversity and academic rigor present in reviewed literature.

v. Journals and Publishers: In the SLR process, critical assessment of journal-publishers assist to examine the academic rigor, peer review integrating, and potential bias influencing the body of knowledge. This scrutiny presents the dynamics in knowledge dissemination, highlighting how dominant publisher can figure out research agendas.

Figure 6. Journals-Publishers Distributions

Figure 6 presents the distribution of articles across the publishers' revels the strong concentration into a few academic publishers dominantly. Elsevier is the most prominent, publishing the majority of the reviewed articles across a wide range of journals such as *Energy Economics*, *International Review of Financial Analysis*, *Resources Policy*, *Journal of Cleaner Production*, and *Finance Research Letters*. MDPI follows, contributing through open-access outlets like *Sustainability*, *Mathematics*, and *Energies*. Springer**,** Taylor & Francis, and Wiley also appear consistently, each hosting several high-impact journals relevant to ESG and financial research. This pattern highlights the role of a few key publishers in shaping scholarly discourse in the ESG-finance domain, as visualized in the Sankey diagram.

vi. Keyword Analysis: Visualizing the keywords pattern identifies the central themes, research tends, and evolving emphasizes in the existing body of knowledge. It helps to mapping the technical structure of this research area, and uncovers the emerging concepts, which helps to locate the major contributions, issues, and future research areas.

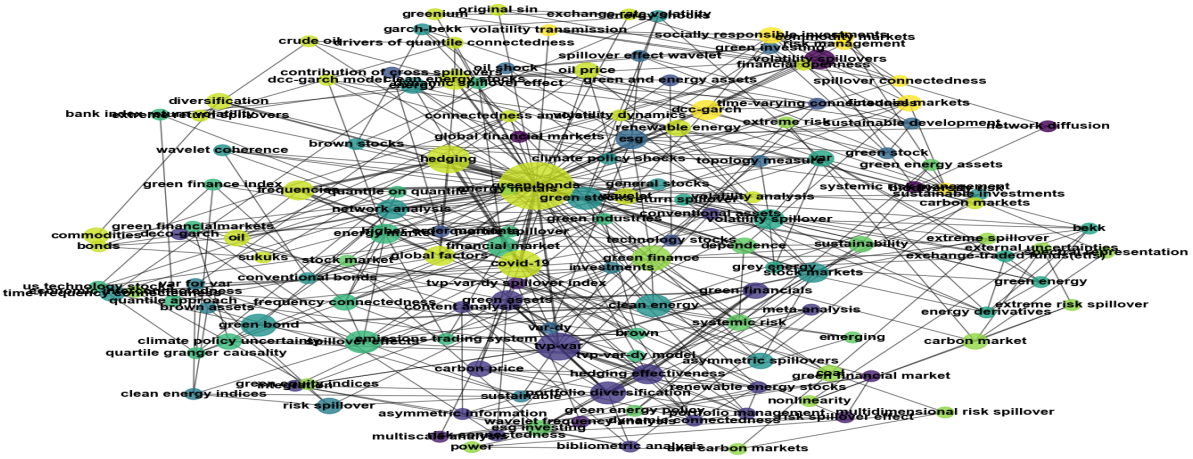

Figure 7. Cartography/Keywords analysis

Figure 7 demonstrates the major keywords used in the reviewed articles predominantly emphasize financial assets, energy, and environmental concerns, particularly via a lens of volatility, spillover and connectedness. The prominent themes consist of volatility spillovers and connectedness, primarily these association have examined among the various green and conventional financial assets. The essence of sustainable finance, green finance, impact investing,

and their market dynamisms are recurring contents. Furthermore, many keywords highlight the use of sophisticated tools for analysis, like time varying parameter (TVP), vector auto regression (VR), wavelet transform, network analysis, Diebold and Yilaz (DY), Barunik and Krehlik (BK) indices, dynamic conditional correlation (DCC), autoregressive conditional models to examine the complex associations. Similarly, the contents like risk spillover, transmission, portfolio diversification, economic shock and covid-19, are also common. The overall emphasizes is on understanding the interconnectedness within and across financial assets.

vii. Analysis Tools: Understanding the methodological landscape, offers the prompt locations of commonly applied techniques, robustness analysis tools, observe the shift in analytical approach over the time and methodological gaps. This visualization supports for logical methodological justifications for future research design and ensures the methodological transparency in SLR.

Figure 8. Analysis Tools

Based on the reviewed literatures, there are diverse set of advance econometric tools primarily focus on analyzing the time varying, spillovers and connectedness among the assets (Figure 8). A significant portion of tools revolves around to capture the dynamic associations over the periods. The prominent model used in the data analysis is time varying parameter vector autoregression (TVP-AR) to analyzing the varying value of parameter over the time. Similarly, generalized autoregressive conditional heteroskedasticity (GARCH) models, dynamic conditional correlation, and Baba, Engle, Kraft, and Kroner (BEKK) have used to capture the volatility spillovers and correlations. Further, Diebold-Yilmaz (DY) and Barunik-Krehlik (BK) spillover index methods are used to quantify the magnitude and direction among the financial assets. Additionally, some of the papers have used the Wavelet based models and Quantile regression models (QVAR, TVP-QQR) to examine the relationship across different frequencies and different parts of distribution.

viii. Data Points Analysis: Presenting the no of observations and their linkage with analysis tools offer to quickly convey the associations between data size and analysis tools. Sample size and their best fitted analysis model helps to generalize and replicate in the other research, thereby this visualization enhances methodological contribution in future research.

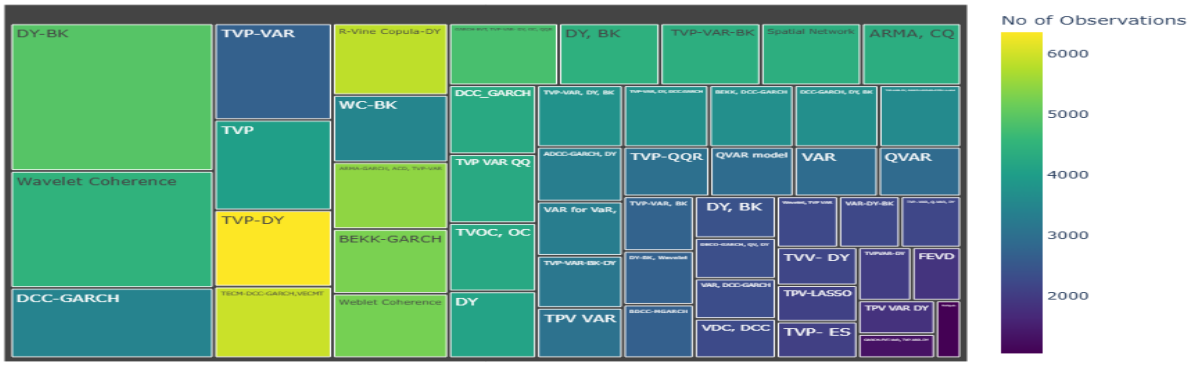

Figure 9. Data Points and Analysis Tools

Figure 9 illustrates the application of analysis tools according to data point based on the reviewed literatures. The size of rectangles corresponds to the observation point; a larger rectangle indicates that a tool was applied for large dataset. Each of the rectangle is labeled with an acronym for analysis tool. The models like TVP-VAR, DY-BK, and Wavelet coherence are using for the large set of data. Similarly, FEVD, TPL-LASSO, TPV-ES, VDC are used less often and with smaller dataset.

ix. Geographical Database: This assessment examines the key countries involved in research within these areas, highlighting their contributions to the existing knowledge base. Additionally, it explores patterns of international collaboration, regional research strengths, and identifies potential gaps in global academic participation.

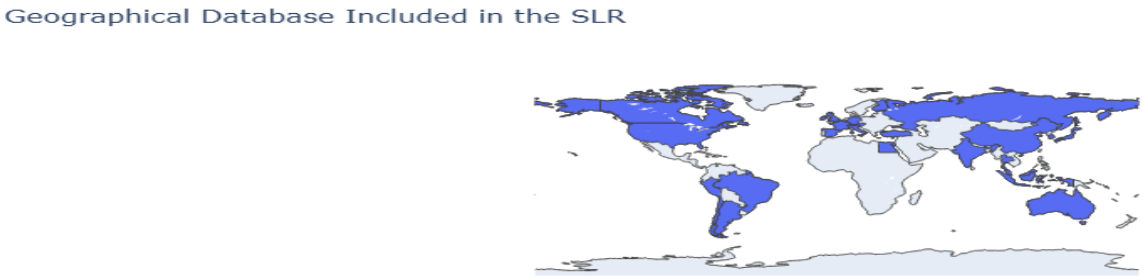

Figure 10. Geographical Database

Figure 10 illustrates the geographic focus of reviewed papers. The most frequently mentioned countries are China and the USA, indicating that the substantial portion of literatures are centered on these two major economies. Similarly, there are few literatures covering the multi-country analysis. Additionally, there are other European countries. There are also many examples where a diverse set of countries from different continents are includes, suggesting a broad, international perspective. The data reflects a repeating trend of research concerning on a few dominant economies, a wide-ranging global scale and specific regional block.

3.2 Thematic Analysis

In this section, we have presented and assessed the major themes emerged from the reviewed journal topics. Following Creswell and Creswell (2018), we used the thematic analysis to detect and codes the emergent themes in existing body of knowledge. Themes were emerged from the identifications, analyzing and reporting the repeated patterns in research objectives of reviewed literatures (Braun and Clarke 2006). Based on the Contagion and Spillover theory, we have generated the four major themes: i. Volatility and Risk Spillover, ii. Dynamic Connectedness and Tail Risk Analysis, iii. External Shocks and Crisis Events, and iv. Network Diffusion and Systematic Risk among the brown and green assets (Dornbusch et al., 2000; Forbes and Rigobon, 2002). All the themes are analyzed below.

Theme I. Volatility and Spillover: We emerged the theme spillover and volatility concerns on how shocks in one assets spillover other, explaining the interconnected risk behavior in the financial market (Balele, 2005). Following Bensaida et al. (2019), we have primarily emphasized on the papers related to transmission of risk, return, and volatility spillovers between green instruments such as (green bond, clean energy stock, ESG indices) and conventional markets (Oil, fossil fuels, traditional bonds, and stocks) (Table 2).

Table 2. Volatility and Risk Spillover

Paper Titles	References	SJI	Methods	Result	Data Point
Volatility transmission and hedging strategies across green and conventional stocks in global markets	*Karkowska and Urjasz (2024)*	*Q1*	*TVP-VAR*	*Positive*	*June-2016 to Dec-2023*
Volatility spillovers between equity and green bond markets	*Park et al. (2020)*	*Q1*	*GARCH*	*Positive*	*Jan-2010 to Jan-2020*
Is green investment different from grey? Return and volatility spillovers between green and grey energy EFTs	*Rizvi et al. (2022)*	*Q1*	*BEKK*	*Mixed*	*Oct-20015 to Oct-2020*
Asymmetry in the returns and volatility between green financial assets, sustainable investments, clean energy, and international stock markets	*Dogan et al. (2025)*	*Q1*	*DY-BK*	*Mixed*	*June-2009 to June-2022*
Dynamic volatility among fossil energy, clean energy and major assets: evidence from DCC-GARCH	*Ozkan et al. (2024)*	*Q2*	*DCC-GARCH*	*Positive*	*Sep-2014 to Oct-2022*
Spillover effects between fossil energy and green markets: Evidence from international inefficiency	*Ren et al. (2024)*	*Q1*	*TVP-VAR*	*Positive*	*Nov-2017 to Nov-2022*
The contagion of extreme risks between fossil and green energy markets: evidence from China	*Ren et al. (2024)*	*Q1*	*DY, GARCH-EVT-VAR*	*Positive*	*Jan-2019 to Aug-2022*
Dynamic and frequency spillovers between green bonds, oil and G7 stock markets: Implications for risk management	*Mensi et al. (2022)*	*Q1*	*BK-GFEVD*	*Positive*	*Jan-2014 to May-2021*
Risk connectedness between green and conventional assets with portfolio implications	*Naeem et al. (2023)*	*Q2*	*DECO-GARCH*	*Positive*	*Aug-2014 t0 Dec-2020*
Risk spillovers and network connectedness between clean energy stocks, green bonds, and other financial assets: Evidence from China	*Chen et al. (2023)*	*Q1*	*DY-FEVD*	*Mixed*	*Jan-2015 to June-2022*

Karkowska and Urjasz (2024) presents an evidence of transmitting the volatility from developed countries in to emerging countries and substantial benefits from hedging and portfolio diversification strategies. Park et al (2024) green bonds show asymmetric volatility and volatility is also sensitive to positive price shock. Rizvi et al. (2022) concludes that shocks originating in green financial market have a more impact on other market. Ozkan et al. (2024) asserts that the interconnectedness reaches peak during the market stress like Covid-19, Russia-Ukraine war and conventional assets transmits the spillover to other assets. Dogan et al. (2025) highlight that green stocks and developed stock market has the significance difference in return and spillover in short and long-time horizon. Ren et al. (2024a) spot that the market inefficiency and ripple effects vary over the period and influenced by extreme events. Ren et al. (2024b) green energy is more variable to severe risks than fossil fuels and are less stable and developing. Mensi et al. (2022) shows that green bond has more diversification benefits and co-movement is more pronounced in medium and long time. Naeem et al. (2023) confirms that both green and conventional bonds have time varying characteristics over the time periods. Chen et al. (2023) presents that clean energy markets vary in transmitting the risks and global market shocks alters the risk spillovers.

Theme II. Dynamic Connectedness and Tail Risk Analysis: We materialized the theme dynamic connectedness and tail risk frequency analysis in response to capture evolving and extreme co-movement of financial assets, how tail risks and frequency decomposition matters in the financial market (Massacci, 2017; Guo et al., 2021). In this theme, following Barunik and Krehlik (2018), we have included the papers: modeling of advance tail risk, time-frequency analysis, and multi-scale spillover using the wavelet, quantile regression, DCC-GARCH for examining the connectedness and risk under extreme shocks (Table 3).

Table 3. Dynamic Connectedness and Tail Risk Analysis

Paper Title	References	SJI	Methods	Result	Data Point
Tail risk contagion and multiscale spillovers in the green finance index and large US technology stocks	*Zeng et al (2025)*	*Q1*	*QVAR,GC, TVPVAR, QQR*	*Positive*	*Jan-2015 to Mar-2023*
Clean energy indices and brown assets: an analysis of tail risk spillovers through the VAR for Var model	*Angelini et al. (2022)*	*Q1*	*VAR for VAR, GC*	*Positive*	*Sep-2011 to May-2019*
Extreme spillovers among green finance, energy, and energy metals markets in China: Evidence under the dilemma of energy transition	*Lin and Zhang (2025)*	*Q1*	*QVAR*	*Positive*	*Jan-2016 to Dec-2023*
Asymmetric spillovers between green bonds and commodities	*Naeem et al. (2021)*	*Q1*	*DY-BK*	*Mixed*	*Dec-2008 to dec-2020*
Time-frequency comovement among green bonds, stocks, commodities, clean energy, and conventional bonds	*Nguyen et al. (2021)*	*Q1*	*Wavelet Coherence*	*Positive*	*2008 to 2019*
The green sin: how exchange rate volatility and financial openness affect green premia	*Moro and Zaghini(2025)*	*Q1*	*CRSE*	*Positive*	*Jan-2014 to Dec-2021*
Extreme risk connectedness and its determinants between carbon, green finance and energy markets	*Jin (2025)*	*Q3*	*GAS/GARCH-BK*	*Positive*	*Jul-2013 to Dec-2021*
Frequency spillovers between green bonds, global factors and stock market before and during Covid-19 crisis	*Mensi and Kang (2023)*	*Q1*	*DY-BK, TVP, QQR*	*Positive*	*Jan-2011 to Sep-2022*
Dynamic risk spillover in green financial markets: A wavelet frequency analysis from China	*Wang et al. (2025)*	*Q1*	*TVP-VAR-DY*	*Positive*	*2018 to 2024*

Zeng et al. (2025) presents that volatility connectedness is more pronounced at extreme tail and dynamic spillover intensifies during bullish period. Angelini et al. (2022) concludes that extreme events exert a significant spillover effect. Lin and Zhang (2025) asserts that total spillovers fluctuate over time and peaking at the time of extreme market scenario. Naeem et al. (2021) highlight for asymmetric spillovers among the financial assets across times and frequency circles. Nguyen et al. (2021) show the high correlation aftermath global financial crisis and weak correlation with commodities. Moro and Zaghini (2025) demonstrate that effect is high in developing countries than developed countries. Jin (2025) spots that extreme volatility intensify during the sudden external shocks. Mensi and Kang (2023) note that green bond as transmitters in short-run volatility dominates the long run as receiver. Wang et al (2025) state that risk transmission follows the cyclical patters and affected by external shocks in the green financial market.

Theme III. External Shocks and Crisis Events: In this theme, following Kenourgios and Padhi (2012), we evolved this theme concerning on how geopolitical risks, environmental policy uncertainties, and exogenous crisis like Covid-19, Russia-Ukraine war affects in the financial markets. In this theme, we have incorporated papers related to macro financial factor, interventions and global shocks affects volatility in the financial assets (Caldara et al., 2016) (Table 4).

Table 4. External Shocks and Crisis Events

Paper Title	Reference	SJI	Methods	Result	Data Point
Ripple effects of climate policy uncertainty: risk spillovers between traditional energy and green financial markets	*Liu et al. (2025)*	*Q1*	*TVP-VAR-DY*	*Positive*	*Mar-2014 to Dec-2023*
The role of uncertainty in return spillovers among digital assets: new insights from the shock of unprecedented events	*Zhou et al. (2024)*	*Q1*	*TPV-VAR*	*Positive*	*July-2016 to Oct-2023*
Climate policies, energy shock and spillovers between green and brown stock price indices	*Albanese et al. (2025)*			*Mixed*	*Mar-2009 to Dec-2023*
How does the volatility of ESG stock indices spillover in times if high geopolitical risk? New insights form emerging and developed markets	*Karkowska and Urjasz (2025)*	*Q1*	*ADCC-GARCH*	*Positive*	*May-2014 to May-2023*
Time-frequency connectedness among traditional/new energy, green finance, and ESG in pre-and post-Russia Ukraine war periods	*Jiang et al. (2023)*	*Q1*	*DY-BK*	*Positive*	*Sep-2020 to Nov-2022*
The time-frequency connectedness among carbon, traditional/new energy and material markets of China in pre-and post-Covid-19 outbreak periods	*Jiang and Chen (2022)*	*Q1*	*DY-BK*	*Positive*	*Jan-2015 to July-2021*
Extreme spillover effects of Covid-19 pandemic-related news and cryptocurrencies on green bond markets: a quantile connectedness analysis	*Khalfaoui et al. (2023)*	*Q1*	*DY-Quantile Reg.*	*Positive*	*Jan-2020 to Jan-2022*
Green shocks: the spillover effects of green equity indices on global market dynamics	*Trancoso and Gomes (2024)*	*Q2*	*TVP-VAR*	*Positive*	*Aug-2013 to July-2023*
Global factors and the transmission between United States and emerging stock markets	*Naeem et al. (2023)*	*Q2*	*DY-BK*	*Mixed*	*Jan-1996 to Dec-2018*

Spillover effects between climate policy uncertainty, energy markets, and food markets: a time frequency analysis	*Zhang et al. (2025)*	*Q1*	*DY-BK*	*Mixed*	*Jan-2012 to Dec-2023*

Liu et al. (2025) concludes that there are substantial risk spillovers with sharp shift during the policy shocks, primarily in short run than medium and long run. Zhou et al. (2024) highlight the information shock and more effect in digital assets than other assets. Albanese et al (2025) shows the climate policy and energy shock are more influential and energy shock has uniform effects. Karkowska and Urjasz (2025) concludes that geopolitics and climate shocks affect global financial market, shaping the stability. Jiang et al. (2023) note that overall connectedness rise noticeably with a stronger increase in the short run. Jiang and Chen (2022) asserts that told connectedness is high in shot run and increased following the Covid-19 outbreak. Khalfaoui et al. (2025) presets the strong net information shock among the markets during the bearish conditions. Trancoso and Gomes (2024) concludes the global market moves from being a shock transmitter to a shock receiver as green finance gains influence. Naeem et al. (2023) presents the heterogeneous impact of global factors on connectedness across markets. Zhang et al. (2025) demonstrate that the climate policy shock is contributor of return shock in short run and a net recipient in medium and long run.

Theme IV. Network Diffusion and Systematic Risk: The theme network diffusion and systematic risk appeared in assessment on how the systematic linkage, architecture, and risk propagation cause effects in financial markets (Summer, 2013; Jackson and Pernoud, 2021). In this theme, following Chen (2021), we have reviewed the journals that explore the network structure of financial assets, their interconnectedness and uncontrollable risks transmission among the financial assets (Table 5).

Table 5. Network Diffusion and Systematic Risk

Paper Title	References	SJI	Methods	Result	Data Point
Market volatility spillover, network diffusion, and financial system risk management; financial modeling and empirical study	*Meng and Chen (2023)*	*Q2*	*R-Vine Copula and DY*	*Mixed*	*2007 to 2022*
Network analysis of volatility spillovers between environmental, social and governance ratings stocks: evidence from China	*Tian et al. (2025)*	*Q2*	*VAR-DY*	*Positive*	*2013 to 2023*
Examining the interconnectedness of green finance: an analysis of dynamic spillover effects among green bonds, renewable energy, and carbon markets	*Zhang and Umair (2023)*	*Q1*	*DCC-GARCH*	*Positive*	*Oct-2013 to Jan-2020*
Dynamic linkage and spillover effects of biodiversity risk in socially responsible investment and commodity market	*Kalhoro and Ahmed (2025)*	*Q1*	*DCC-GARCH*	*Mixed*	*Dec-2014, to Dec-2022*
Interdependence between green financial instruments and major conventional assets: a wavelet based network analysis	*Ferrer et al. (2021)*	*Q2*	*Wavelet Coherence*	*Mixed*	*Oct-2010 to Nov-2020*
Dynamic spillovers and asymmetric connectedness between fossil energy and green financial markets: Evidence from China	*Deng et al. (2022)*	*Q2*	*DY Spillover Index*	*Positive*	*Mar-2018 to Nov-2021*
The connectedness of oil shocks, green bonds, sukuks and conventional bonds	*Umar et al. (2023)*	*Q1*	*GEVD*	*Postive*	*May-2009 to Mar-2022*
Information linkage, dynamic spillovers in prices and volatility between the carbon and energy markets	*Ji et al. (2018)*		*VAR-DR*	*Positive*	*July-2006 to Oct-2017*
Risk spillover in the carbon-stock system and sustainability transition: empirical evidence from China's ETS pilots and a share emission regulated firms	*Wang et al. (2025)*	*Q1*	*TVP-VAR-BK-DY*	*Mixed*	*May-2014 to Dec-2022*
Spatial spillover effect of green finance on economic development, environmental pollution, and clean energy production across China	*Li et al. (2022)*	*Q1*	*Spatial Durbin model*	*Positive*	*2009 to 2019*

Meng and Chen (2023) concludes that there are certain aggregation characteristics and clustered volatility spillovers centered in developed European countries. Tian et al. (2025) suggest that traditional risk management should integrate ESG factors to better manage risk contagion in extreme markets. Zhang and Umair (2023) shows an evidence that points to a complementary connection between green bonds and carbon markets. Kalhoro and Ahmed (2025) concludes that raising biodiversity risk strengthens market connectedness, amplifying risk transmission across them. Ferrer et al. (2021) highlight that the green financial instruments have the weak connection with high-yield corporate bond and fossil fuel. Deng et al. (2022) note that green bond as the safe heaven characteristics receives fewer shocks from the energy shocks. Umar et al. (2023) documents the energy price shocks acts as key spillover transmitter. Ji et

al (2018) shows that conventional energy price has the spillovers effects across other assets. Wang et al. (2025) present that the market maturity has the minimal level of overall risk spillovers, however dynamic spillovers have the upwards pattern. Li et al. (2022) also supports to the geographical factors have spillover risks.

4. Findings and Future Research

4.1. Major Findings: The literatures conclude there is dynamic interconnection of volatility spillovers between the green and conventional assets. The time-frequency dynamics analysis in the literatures highlights that the impacts can be very over the different time periods and market scenario. Based on the advance econometrical analysis like TVP-VAR, DCC, DY, SK, GARCH etc. the effect is not in same direction, they often from conventional to green, however there is also evidence that their reverse spillovers during market turmoil. The reviewed literatures present the several macro factors such as monetary policy, fiscal policy, geopolitical concerns, policy uncertainty, Covid-19, Russia-Ukraine war for analyzing the degree and direction of association and spillovers among the green and conventional financial assets. The major findings reveals that during the turmoil period, there is strong connectedness between the different asset's classes. Furthermore, carbon climate policies and environmental regulations have pertinent role in shaping the volatility dynamism. The core theme in the papers is to analyze the role of green assets in portfolio diversification, whether the inclusion of green assets in the portfolio optimizes the risk-return paradox against the conventional assets-based portfolio. The evidence is mixed, however, generally suggest that the inclusion offers diversification benefit in investment decision and are time varying with multiple market scenario. The findings shows that it's important to know the details of green and brown assets, as they can behave differently, different momentum of movement, different sensitive of effect and carry the different level of risk.

4.2. Future Research: Based on the reviewed literatures, several directions for future research have emerged to deepen the clear grasp of green finance and its interconnections with other financial asset, policies, risk. Expanding the analytical scope by incorporating the broader markets, longer time horizons, more contextual based attributes, geopolitical tensions, uncertainties and new regulatory environment. Another promising research direction involves capturing the high order connectedness such as skewness, kurtosis and jumps between the green and conventional financial assets, focusing the heterogeneous market behavior in developed and developing economics with multiple time and turmoil. The presence of green finance in carbon market volatility and the spillover between emission trading systems (ETS) and emission-regulated firms also demands further exploration. More robust models are needed to measure tail risk spillovers, asymmetries, and joint dynamics of returns, volatility, and extreme risk across green bonds, green stocks, and conventional financial assets.A multi frequency analysis for detecting the short-, medium- and long-term volatility transmission analysis for creating the optimal portfolio and risk management strategies. Similarly, a comparative analysis across the counties, industries including the high, medium and low ESG aligned stocks, to assess their hedging effectiveness and diversification benefits. Similarly, a methodological robustness and innovative techniques like generalized models, Quantile models, Copula and Bayesian models incorporating the sentiment-based data. Furthermore, areas of explore are in the impact of technological innovations, transition risks, and investors'' sentiment beyond the financial industries. Additionally, a rich area of investigation is in case of past and expected global shocks. In nutshell, a multidisciplinary research agenda is advance modeling, broad dataset, nuance policy adjustment, and cross comparison with some sustainability parameters.

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