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# GREEN BOND MARKET-RELATED DYNAMIC CORRELATIONS AND VOLATILITY SPILLOVERS: SYSTEMATIC LITERATURE REVIEW

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***Abstract:*** *Given the green bond universe's expansion, grasping the evolvement of empirical investigations on green bond market-related dynamic correlations and volatility spillovers is paramount. The research aims to generate a systematic literature review considering these investigations' evidence, delineate dominant green bond-correlated markets and volatility transmissions, ascertain prevalent econometric models employed, and unveil recurring patterns in research findings. To attain the research aim, the academic literature databases' – Web of Science, Scopus, and Google Scholar – collections were scrutinized, and the PRISMA systematic literature review methodology's recommended phases – identification, screening, eligibility, and inclusion – were followed. Articles' selection criteria included the article's content validity, relevance to the research question, evidence robustness, and recency of publication. Finally, the research was built on the latest (2019-2024 period) empirical knowledge, extracted from a total of 30*

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*pertinent articles published in 18 reputable academic journals. The research findings documented a solid knowledge foundation and spawned recommendations valuable for both academic and non-academic actors.*

***Keywords**: green bonds, dynamic correlation, volatility spillover, systematic literature review.*

## INTRODUCTORY CONSIDERATIONS

Green bonds herald the economy's and the environment's reconciliation – these bonds' aptitude to comply with both economic and environmental goals positions them not only as a financing mechanism of the moment, but of the future. Namely, issuers' strategic intents to tackle the challenges of environmental preservation "one bond at a time", by financing or re-financing, partially or fully, new or existing green projects, as well as investors' portfolio hedging aspirations, coupled with growing climate awareness, led to the green bond universe's amplification – as per the latest reported figures, green bonds 2024 issuance volume (688 billion U.S. dollars) outpaced that of 2023 (588 billion U.S. dollars) by 17%, and matched its 2021's record-high issuance volume (594 billion U.S. dollars) (Skandinaviska Enskilda Banken, 2025; Statista, 2024). The expectations are that these bonds' issuance volume will continue to reach new highs (Ferrer, Shahzad & Soriano, 2021; Han & Li, 2022; Joksimović & Stoimenov, 2024; Jolović & Jolović, 2021; Mensi, Naeem, Vo & Kang, 2022; Park, Park & Ryu, 2020) and attain an impressive value of 1.02 trillion U.S. dollars by 2030 (TechSci Research, 2025).

Nevertheless, as the mounting body of research (Elsayed, Naifar, Nasreen & Tiwari, 2022; Jolović, Sinoi & Focaracci, 2025; Liu, Liu, Da, Zhang & Guan, 2021) documents, even a market of this magnitude cannot be independent, nor immune to cross-market volatility spillovers. Understanding green bond market connectedness and movements with various markets is, therefore, of paramount importance. Since the academic community placed a strong emphasis on this issue in the past several years, the central question posed by this research is: "What are the specificities and findings of current (2019-2024 period) empirical literature on green bond market-related dynamic correlations and volatility spillovers?". In alignment with the research question posed, the aim of the research is, finally, articulated as the development of a systematic literature review that provides insight into dominant green

bond-correlated markets and volatility transmissions, prevalent econometric models used, and recurring patterns observed in the research findings.

## RESEARCH METHODOLOGY

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology's recommended phases – identification, screening, eligibility, and inclusion (Moher, Liberati, Tetzlaff & Altman, 2009) – academic literature databases, including Web of Science, Scopus, and Google Scholar, were searched in pursuit of articles addressing the research's central question. In this endeavour, the combinations of the following keywords were employed: "green bond(s)", "green bond(s) market(s)", "dynamic correlation(s)", "dynamic connectedness", "volatility", "volatility spillover(s)", "financial market(s)", "hedging". Onward, the selection criterion – recency of article's publication – was applied, considering the research's contemporaneity aspiration (2019-2024 interval), as well as aspiration of embracing recent global instability events' (COVID-19 crisis, Brexit, Russia-Ukraine war, etc.) escalations. Furthermore, critical selection criteria – article's content validity, relevance to the research question, and evidence robustness – were applied. Articles that failed to meet the aforementioned criteria, along with linguistically incomprehensible/repetitive/unavailable ones, were declared redundant and excluded from further research. Finally, after the filtering processes' completion, the research encompassed a total of 30 pertinent, high-quality and readily accessible academic articles that empirically discussed the research's central topic. The aforementioned articles were extracted from 18 reputable academic journals of the following publishers: AIMS Press, Elsevier, Emerald Publishing, MDPI, Springer, Taylor & Francis, and Wiley.

## THE MAIN FINDINGS OF THE SYSTEMATIC LITERATURE REVIEW

The main findings of the systematic review of the empirical literature on green bond market-related dynamic correlations and volatility spillovers, spanning the years 2019 –2024, are outlined below:

1. Reboredo (2019) performed an extensive study considering the setting of the global market, utilising Copula models on daily data (October 14, 2014 –August 31, 2017), with the aspiration to

investigate co-movements in the "green bond market–financial markets" (corporate bond market, treasury bond market, stock market, energy commodity market) relation (Reboredo, 2019). In finer detail, as stated by Reboredo (2019, p. 38): "*We examine co-movement between the green bond and financial markets, finding that the green bond market couples with corporate and treasury bond markets and weakly co-moves with stock and energy commodity markets. We also find that green bonds have negligible diversification benefits for investors in corporate and treasury markets, whereas diversification benefits are sizeable for investors in stock and energy markets. We further confirm that green bonds are affected by substantial price spillovers from corporate and treasury fixed-income markets and that large price swings in stock and energy markets have a negligible impact on green bond prices.*" (Reboredo, 2019, p. 38);

2. Park et al. (2020) executed a comprehensive study considering the setting of the global market, utilising Baba-Engle-Kraft-Kroner (BEKK) model, as well as Dynamic Conditional Correlation-Generalised Autoregressive Conditional Heteroscedasticity (DCC-GARCH) model on daily data (January 1, 2010 –January 1, 2020), with the aspiration to analyse the volatility dynamics and spillovers between the equity and green bond markets (Park et al., 2020). In finer detail, as stated by Park et al. (2020, p. 10): "*We test whether green bonds exhibit asymmetric volatility and confirm that although green bonds do exhibit asymmetrical volatility, they have the unique characteristic that their volatility is sensitive to positive shocks, unlike other financial instruments. We also analyze the association between the green bond and equity markets and confirm that the two markets have some volatility spillover effects but that neither responds significantly to negative shocks in the other market.*" (Park et al., 2020, p. 10);

3. Reboredo & Ugolini (2020) conducted a broad study considering the setting of the global market, utilising Structural Vector Autoregressive (SVAR) model on daily data (October 14, 2014 –June 25, 2019), with the aspiration to examine price connectedness between the green bond and financial markets (fixed-income markets (treasury bond market, corporate bond market, high-yield corporate bond market), currency market, stock market, energy commodity market) (Reboredo & Ugolini, 2020). As stated by Reboredo & Ugolini (2020, p. 25): "*Our empirical findings reveal that the green bond market is closely linked to the fixed-income and currency markets, receiving sizeable price spillovers from those markets and transmitting negligible reverse effects. We also show that, in*

*contrast, the green bond market is weakly tied to the stock, energy and high-yield corporate bond markets.*" (Reboredo & Ugolini, 2020, p. 25);

4. Reboredo, Ugolini & Aiube (2020) undertook an extensive study considering the setting of the European Union (EU) and the United States (U.S.) markets, utilising Wavelet-based methods, as well as Vector Autoregressive (VAR) models on daily data (October 12, 2014 –December 20, 2018), with the aspiration to explore co-movement and network price connectedness between the green bond and different asset classes markets (energy market, financial markets (fixed-income markets (treasury bond market, corporate bond market, high-yield corporate bond market), stock market)) over a few investment horizons (Reboredo et al., 2020). As stated by Reboredo et al. (2020, p. 1): "*Our empirical evidence reveals strong connectedness between green bonds and treasury and corporate bonds in the short and long run and in both the EU and the USA, with green bonds receiving sizeable spillovers from treasury and corporate bond prices and transmitting negligible effects. Likewise, we find that green bonds are weakly connected with high-yield corporate bond, stock and energy assets over different time scales.*" (Reboredo et al., 2020, p. 1);

5. Ferrer et al. (2021) performed a comprehensive study considering the setting of the global market, utilising 2018's Baruník and Křehlík (BK-18) method on daily data (October 14, 2014 –December 19, 2019), with the aspiration to investigate time-frequency connectedness between the green bond and financial markets (treasury bond market, corporate bond market, equity market, currency market), as well as energy market (crude oil market) (Ferrer et al., 2021). As stated by Ferrer et al. (2021, p. 1): "*The empirical results indicate that connectedness between the global green bond market and the conventional financial and energy markets mainly occurs at shorter time horizons, suggesting that shocks are rapidly transmitted across markets with an effect lasting less than a week. A strong connectedness in return and volatility is found between green bonds and Treasury and investment-grade corporate bonds, principally because of the numerous characteristics they share. This finding implies that green fixed-income securities are not a different asset class, but they closely mirror the performance of government and high-quality corporate bonds. In contrast, there is a quite limited connectedness between the green bond market and the general stock market, the renewable energy equity sector and the crude oil market regardless of the time horizon considered.*" (Ferrer et al., 2021, p. 1);

6. Le, Abakah & Tiwari (2021) executed an extensive study considering the setting of the U.S. market, utilising 2012's Diebold and Yilmaz (DY-12) time-domain spillover index model, as well as BK-18 frequency-domain spillover method on daily data (November 28, 2018 –June 29, 2020), with the aspiration to examine the time- and frequency-domains connectedness and spillover among the fintech, green bond, and cryptocurrency markets (Le et al., 2021). As stated by Le et al. (2021, p. 1): "*The results of DY suggest that, first, the total connectedness of 21st century technology assets and traditional common stocks is very high, and hence in the turbulent economy, there is a high probability of contemporaneous losses. Second, Bitcoin, MSCIW, MSCI US, and KFTX are net contributors of volatility shocks whereas US dollar, oil, gold, VIX, green bond and green bond select are net receivers. Therefore, Fintech and common equities are not good hedging instruments in the same portfolio. Third, the short-term witnesses higher volatility transmission than the long-term. That is, holding assets for a long-term is likely to mitigate risks whereas trading financial assets in the short-term can increase risk because of higher volatility. Fourth, the traditional assets, gold and oil, as well as modern assets, green bonds, are useful as good hedgers compared with other assets because shock transmissions from them to Fintech, KFTX are below 0.1% and, more importantly, the total volatility spillover of all assets in the sample is moderately average, accounting for 44.39%.*" (Le et al., 2021, p. 1);

7. Liu et al. (2021) conducted a broad study considering the setting of the global market, utilising binary Copula models, as well as Conditional Value-at-Risk (CoVaR) methods on daily data (July 5, 2011 –February 24, 2020), with the aspiration to investigate the dynamic dependency structure and risk spillover among the green bond market and six clean energy markets (Liu et al., 2021). As stated by Liu et al. (2021, p. 1): "*Our empirical analysis shows that there is positive time-varying average and tail dependence between GBs and CE stock markets. Moreover, extreme downward or upward movements in the CE stock market have a spillover effect on the GB market, and vice versa. Furthermore, the risk spillover between these markets is asymmetric.*" (Liu et al., 2021, p. 1);

8. Naeem, Adekoya & Oliyide (2021) undertook a thorough study considering the setting of the global market, utilising 2014's Diebold and Yilmaz (DY-14) method, as well as BK-18 method on daily data (December 1, 2008 –December 31, 2020), with the aspiration to examine the asymmetric connectedness between the green bond and

commodity markets (gold market, silver market, crude oil market, natural gas market, wheat market, corn market) in the time- and frequency-domains (Naeem, Adekoya & Oliyide, 2021). As stated by Naeem, Adekoya & Oliyide (2021, p. 1): "*Findings reveal the evidence of asymmetric spillovers among the assets across time and different frequency cycles. While the spillover is stronger for commodities within the same class, gold and silver have the strongest connectedness with green bonds regardless of the periods. However, crude oil observes a strong connection with green bonds in the long-run. Additionally, the asymmetric spillover results show that positive returns spillover is stronger in the short-run, while negative returns spillover substantially holds in both periods but is more pronounced in the short-run.*" (Naeem, Adekoya & Oliyide, 2021, p. 1);

9. Naeem, Nguyen, Nepal, Ngo & Taghizadeh-Hesary (2021) performed an extensive study considering the setting of the global market, utilising Cross-Quantilogram (CQ) approach on daily data (December 1, 2008 –December 31, 2019), with the aspiration to investigate the asymmetric behaviour of green bonds in correlation to commodity markets (energy market, metals (precious and industrial) market, agriculture commodities market) (Naeem, Nguyen, Nepal, Ngo & Taghizadeh-Hesary, 2021). As stated by Naeem, Nguyen, Nepal, Ngo & Taghizadeh-Hesary (2021, p. 1): "*The empirical evidence highlights the asymmetric behaviors of green bonds in response to diverse groups of commodities. Further, the hedging and diversification benefit of including green bonds to commodity portfolio is revealed. Defined by the uncorrelation or negative correlation with commodities in the periods of high volatility, we found the strongest hedging benefit of green bonds against the fluctuation of natural gas, some industrial metals, and agricultural commodities.*" (Naeem, Nguyen, Nepal, Ngo & Taghizadeh-Hesary, 2021, p. 1);
10. Nguyen, Naeem, Balli, Balli & Vo (2021) executed a comprehensive study considering the setting of the global market, utilising Rolling Window Wavelet Correlation (RWWC) approach, as well as Wavelet Coherence approach on daily data (December 1, 2008 –December 1, 2019), with the aspiration to examine the interrelationship between the green bond and other asset markets (stock market, commodity market, clean energy market, conventional bond market) (Nguyen et al., 2021). As stated by Nguyen et al. (2021, p. 1): "*We find strong evidence that most correlation emerged and reached a peak in the aftermath of GFC 2007-2009. While comovement among stocks,*

*commodities, and clean energy is found relatively high, the diversification benefit of green bonds is significantly revealed due to its low or negative correlation with stocks and commodities.*" (Nguyen et al., 2021, p. 1);

11 Pham (2021) conducted an extensive study considering the setting of the global market, utilising DY-14 method, BK-18 method, as well as CQ approach on daily data (August 1, 2014 –August 1, 2020), with the aspiration to investigate the frequency connectedness and cross-quantile dependence between the green bond and green equity markets (Pham, 2021). As stated by Pham (2021, p. 1): "*Our empirical results suggest that after controlling for movements in the general stock, energy and fixed-income markets, the dependence between green bond and green equity during normal market conditions is relatively small. On the other hand, green bond and green equity are more connected during extreme market movements, where they boom and bust together. We also find that across all market conditions, the spillover effects between green bond and green equity are short-lived, as the degree of connectedness dissipates in the medium- and long-term investment horizons.*" (Pham, 2021, p. 1);

12 Elsayed et al. (2022) undertook a broad study considering the setting of the global market, utilising Multivariate Wavelet approach, Ensemble Empirical Mode Decomposition (EEMD) method, as well as DY-12 method on daily data (September 30, 2014 –June 30, 2020), with the aspiration to inspect the interdependence between the green bond and financial markets (treasury market, corporate bond market, stock market, energy market, clean energy market) in the time- and frequency-domains (Elsayed et al., 2022). As stated by Elsayed et al. (2022, p. 1): "*The findings of wavelet multiple correlations indicate that the benefits of diversification opportunities are more evident in the short run. The evidence of wavelet multiple cross-correlations reveals that green bonds and financial markets are highly integrated in the long run. The results of the static connectedness framework explain that the direction and magnitude of spillover behave differently across markets. The world stock market is the net spillover transmitter, while the corporate bond market is the net spillover receiver among the selected markets. The green bond market is receiving more but transmitted less volatility in the present study. The evidence on dynamic connectedness measured by the rolling window approach shows that the interconnection between green bonds and financial markets is volatile over time.*" (Elsayed et al., 2022, p. 1);

13 Gyamerah, Bright & Akwaa-Sekyi (2022) performed a thorough study considering the setting of the global market, utilising Unrestricted Trivariate VAR-BEKK-GARCH model on daily data (November 2, 2011 –August 31, 2021), with the aspiration to explore the mean and volatility spillover between the green bond's price and the renewable energy stock's price (Gyamerah et al., 2022). As stated by Gyamerah et al. (2022, p. 310): "*The results from the VAR-BEKK-GARCH model indicate that there exists a unidirectional Granger causality from renewable energy stock prices to green bond prices. While the price of green bonds is positively influenced by its own lagged values and the lagged values of renewable energy stock prices, only the past price value of renewable energy stocks has a positive effect on the current price value. We identified a uni-directional volatility spillover from renewable energy stock prices to green bond prices. However, there was no shock spillover from both sides of the market.*" (Gyamerah et al., 2022, p. 310);

14 Mensi et al. (2022) executed a comprehensive study considering the setting of the Group of Seven (G7) countries' (Canada, France, Germany, Italy, Japan, United Kingdom (UK), U.S.) markets, utilising BK-18 method, as well as Wavelet Coherence approach on daily data (January 1, 2014 –May 11, 2021), with the aspiration to explore the dynamic and frequency spillovers between the green bond, West Texas Intermediate (WTI) oil and G7 stock markets (Mensi et al., 2022). As stated by Mensi et al. (2022, p. 331): "*The results show that the spillovers is dynamic and crisis-sensitive. Furthermore, adding GBs and oil futures to stock portfolio reduces the spillover size during turmoil periods. The short-term spillovers (up to five trading days) represent the largest proportion of the total spillovers. A significant jump in spillovers is observed in the early of COVID-19 outbreak (March–April 2020). Interestingly, Canada, France, Germany, Italy, and UK are the net transmitters of spillovers, whereas Japan and GBs are the net recipients of the spillovers, irrespective of time horizons. Oil and US stock market shift from net contributors in short term to net receipts in medium and long terms. Wavelet coherence analysis reveals significant co-movements between G7 stock markets and both oil and GBs. The co-movements are more pronounced in both medium and long terms and during COVID-19 spread where both oil and GBs lead stock markets. GBs provide higher diversification benefits to G7 investors than oil in the short-term. The hedging is expensive at the long term for GBs and intermediate term for WTI oil. Finally, the hedge effectiveness of crude oil is higher than GBs, irrespective of time horizons.*" (Mensi et al., 2022, p. 331);

15 Rao, Gupta, Sharma, Mahendru & Agrawal (2022) conducted an extensive study considering the setting of the global market, utilising Time-Varying Parameter-Vector Autoregressive (TVP-VAR) model, as well as Quantile Regression approach on daily data (August 1, 2011 – July 1, 2021), with the aspiration to examine the nexus and the connectedness between the green bond market and the cryptocurrency and commodity markets, before, throughout, and after the COVID-19 era (Rao et al., 2022). As stated by Rao et al. (2022, p. 725): "*Findings show that these markets are strongly linked, which will only expand in the post-pandemic future. Before the pandemic, the MSCI World and Emerging Markets indices contributed the most shocks to the remaining market variables. Green bond index shows a greater correlation and shock transmission with gold. Bitcoin can no longer be used as a good hedging instrument.*" (Rao et al., 2022, p. 725);

16 Yadav, Tandon, Singh, Shore & Gaur (2022) undertook an extensive study considering the setting of the global market, utilising DCC model, DY-12 method, as well as BK-18 method on daily data (October 3, 2016 –February 23, 2021), with the aspiration to investigate the dynamic linkages of the green bond market with the energy and cryptocurrency markets (Yadav et al., 2022). As stated by Yadav et al. (2022, p. 1): "*The DCC reveals no dynamic linkages of volatility from the green bond to the energy and crypto market in the short run. Referring to Diebold and Yilmaz (2012), it dictates that the green bond (RSPGB) is a net receiver while the energy market (RIGW) and cryptocurrency (RETHER) are the largest and least contributors to the transmission of the volatility. Additionally, the Baruník and Křehlík (2018) model confirmed that the magnitude of the total spillover is high in more prolonged than shorter periods, suggesting reduced diversification opportunities.*" (Yadav et al., 2022, p. 1);

17 Dai, Zhang & Yin (2023) performed a thorough study considering the setting of the Chinese market, utilising Quantile Regression model, as well as TVP-VAR model on daily data (April 21, 2010 –March 25, 2022), with the aspiration to investigate the extreme spillover effects considering the high carbon emission stock, green bond and WTI crude oil markets (Dai et al., 2023). As stated by Dai et al. (2023, p. 1): "*The results display a static total spillover index of approximately 49% at the conditional mean and conditional median estimates; while about 83% under the left tail and right tail estimates. The quantile-based spillover model is better than the mean-based one, because the former better captures the risk contagion mechanism under extreme market*

*conditions. In addition, under extreme market conditions, green bond and WTI crude oil are net receivers of systemic shocks, while the remaining markets analyzed are net transmitters. The connectedness is time-varying in all cases, but the tail is less volatile. The analysis of relative tail dependence suggests the existence of asymmetric behavior, which implies different spillover effects in bullish and bearish markets.*" (Dai et al., 2023, p. 1);

18 Mensi, Vo, Ko & Kang (2023) executed an extensive study considering the setting of the U.S. market, utilising DY-12 method, BK-18 method, TVP-VAR model, as well as Quantile-on-Quantile Regression method on daily data (January 3, 2011 –September 9, 2022), with the aspiration to explore the frequency dynamic spillovers in return and volatility, as well as the hedging ability of green bonds, gold, silver, Brent crude oil, the U.S. dollar index, and the volatility index (VIX) against the downside U.S. stock prices, prior to the inception and throughout the COVID-19 era, and in the short- and long-term (Mensi et al., 2023). As stated by Mensi et al. (2023, p. 558): "*We show that the short-term volatility spillovers dominate their long-term counterparts. Green Bond is net transmitters of spillovers in the system at the short term and net receivers at the long term. S&P500 and silver (USDX and oil) are net transmitters (receivers) of short- and long-term spillovers. Gold and VIX are net receivers of short-term spillovers and net transmitters of long-term spillovers. COVID-19 crisis has more effects on the short-term spillover, which reaches its highest level early 2020. COVID-19 and time horizons lead the direction and the magnitude of spillovers. The Quantile-on-Quantile regression analysis shows significant nonlinear relationships between markets under study. More interestingly, we show that green bonds and gold are safe haven assets for US equity investors during COVID-19. On the other hand, a mixed portfolio offers higher diversification benefits. Finally, hedging effectiveness is dependent on COVID-19 and time horizon.*" (Mensi et al., 2023, p. 558);

19 Peng, Ding, Zhou & Zhu (2023) conducted a thorough study considering the setting of the Chinese market, utilising VAR model, DCC-GARCH model, as well as Copula-CoVaR model on daily data (May 9, 2016 – May 6, 2022), with the aspiration to investigate the spillover effect between the green bond market and the traditional bond markets (corporate bond market, enterprise bond market, conventional bond market) (Peng et al., 2023). As stated by Peng et al. (2023, p. 538): "*The research findings of this paper are as follows: (1) There are three*

*spillover effects of mean value, volatility and extreme risk among the green bond market, corporate bond market, enterprise bond market and conventional bond market. (2) From the perspective of mean spillover between markets, only the mean spillover between the conventional bond market and the green bond market is bidirectional, and there is the profoundest impact of spillover from the green bond market to the conventional bond market. (3) As far as the volatility spillover between markets is concerned, the volatility spillover between the three traditional bond market and the green bond markets are all positive. The volatility spillover between the conventional bond market and the green bond market is the largest, which is particularly obvious in the first half of 2018 and the first half of 2020. (4) In terms of inter-market extreme risk spillover, the risk spillover between the green bond market and the traditional bond market is positive. The green bond market contributes more to the risk spillover of the enterprise bond market, and it has a time-varying risk spillover effect on the traditional bond market.*" (Peng et al., 2023, p. 538);

20 Tang, Aruga & Hu (2023) undertook an extensive study considering the setting of the U.S. market, utilising Bayesian Dynamic Conditional Correlation-Multivariate Generalised Autoregressive Conditional Heteroscedasticity (DCC-MGARCH) model, as well as BK-18 method on daily data (June 30, 2014 –October 18, 2021), with the aspiration to investigate the dynamic correlation and volatility spillover between the green bond, clean energy, and fossil fuel markets (Tang et al., 2023). As stated by Tang et al. (2023, p. 1): "*Three findings arose from our results: First, the green bond market has a weak negative correlation with the fossil fuel (WTI oil, Brent oil, natural gas, heating oil, and gasoline) and clean energy markets, which means that green bonds play a critical hedging role against fossil fuel and clean energy. Second, the green bond and clean energy are net volatility receivers from WTI crude oil and heating oil for the short term, indicating that investors and policymakers need to pay attention to the WTI oil volatility spillover risk when promoting green bonds and clean energy. Third, the correlation and volatility spillover from WTI crude oil to green bonds and clean energy is stronger than that of Brent oil, which implies that investors and policymakers need to consider the price movements of WTI crude oil more than Brent oil when investing in the green bond market.*" (Tang et al., 2023, p. 1);

21 Umar, Abrar, Hadhri & Sokolova (2023) performed an extensive study considering the setting of the global market, utilising Network

Dynamic Connectedness framework on daily data (May 1, 2009 – March 1, 2022), with the aspiration to analyse the influence of oil price shocks on conventional bonds, Islamic bonds (sukuks) and green bonds (Umar et al., 2023). As stated by Umar et al. (2023, p. 1): "*We document a sizable connectedness between oil price shocks and the three fixed income market segments namely conventional bonds, sukuks and green bonds. Among the oil shocks, we find that demand and risk shocks are the main transmitters of spillover, whereas conventional bonds appear to be an influential transmitter of spillover among the fixed income segments.*" (Umar et al., 2023, p. 1);

22 Yadav, Pandey, Taghizadeh-Hesary, Arya & Mishra (2023) executed a thorough study considering the setting of the global market, utilising DCC-GARCH model on daily data (October 1, 2015 –February 24, 2022), with the aspiration to explore volatility spillovers among the green bond market and the renewable energy and cryptocurrency markets (Yadav et al., 2023). As stated by Yadav et al. (2023, p. 928): "*The results reveal the presence of spillovers from green bonds to renewable energy and the cryptocurrency market in the long run.*" (Yadav et al., 2023, p. 928);

23 Zhang & Umair (2023) conducted an extensive study considering the setting of the global market, utilising VAR model, as well as TVP-VAR model on daily data (January 1, 2010 –December 31, 2020), with the aspiration to explore dynamic spillover effects between the green bond, renewable energy stock and carbon markets (Zhang & Umair, 2023). As stated by Zhang & Umair (2023, p. 77605): "*The results reveal significant dynamic spillover effects between green bonds and renewable energy stocks, as well as between carbon markets and renewable energy stocks. Additionally, the findings suggest a complementary relationship between green bonds and carbon markets.*" (Zhang & Umair, 2023, p. 77605);

24 Chen, Shi & Hou (2024) undertook a comprehensive study considering the setting of the Chinese market, utilising TVP-VAR model, BK-18 frequency connectedness method, as well as Network Visualization techniques on daily data (January 4, 2012 –December 31, 2022), with the aspiration to investigate the dynamic evolution and volatility spillovers between the green bond and conventional financial markets (conventional bond market, stock market, commodity market, foreign exchange market) (Chen et al., 2024). As stated by Chen et al. (2024, p. 1): "*The empirical findings are as follows: firstly, there is a significant*

*volatility spillover effect between the green bond market and other traditional financial markets, with the spillover effect showing clear time-varying characteristics. The total spillover effects among all markets increase notably during extreme market conditions. Secondly, the green bond market primarily acts as a net risk spillover transmitter in most periods. Thirdly, compared to the stock, foreign exchange, and commodity markets, the green bond market has a more significant spillover effect on the traditional fixed-income market. Finally, the volatility spillover effect of the green bond market on other markets exhibits a time-frequency evolution, predominantly driven by short-term factors. However, as market maturity increases, the influencing factors of the spillover effect gradually shift from short-term to medium and long-term factors.*" (Chen et al., 2024, p. 1);

25 Gao & Liu (2024) performed a thorough study considering the setting of the global market, utilising DY-14 method, BK-18 method, as well as Glosten-Jagannathan-Runkle-Generalised Autoregressive Conditional Heteroscedasticity (GJR-GARCH) model on daily data, with the aspiration to analyse the time and frequency return and volatility spillover relation between the rare earth market and the oil, clean energy, gold, base metals, green bond, Environmental, Social and Governance (ESG), and agricultural markets (Gao & Liu, 2024). As stated by Gao & Liu (2024, p. 1): "*The empirical results suggest that the rare earth metals (REM) market is a net spillover receiver from the base metal, clean energy, and ESG markets, which are the top three net risk emitters. The network connectedness results shed light on the connections and strengths at different time horizons throughout the sample. The regression results indicate that financial condition and investor sentiment play the most significant roles in driving connectedness and have different effects at different frequencies. Furthermore, severe financial stress may increase short-term risk spillover, which indicates that investors sell out risky assets in stressful times. However, financial stress decreases long-term spillover, which implies that it damages the long-term operation of the financial market.*" (Gao & Liu, 2024, p. 1);

26 Joof, Adaoglu & Taspinar (2024) executed an extensive study considering the setting of the global market, utilising DY-12 method, TVP-VAR model, as well as DCC-GARCH model on daily data (2012 – 2022), with the aspiration to investigate the volatility spillovers and the hedging between the green bond, clean energy stock, and fossil fuel markets (Joof et al., 2024). As stated by Joof et al. (2024, p. 1): "*The*

*dynamic volatility spillovers reach their peak points during the onset period of COVID-19 pandemic, the Russia-Ukraine crisis/war, the oil price plunge, and the negative oil price in descending order of magnitude, respectively. Furthermore, the results show that during the turmoils not caused by the fossil fuel markets, crude oil and coal are better instruments for hedging due to their negative correlations with green bonds and clean energy stocks. However, during turmoils caused by fossil fuel markets, the hedging and the diversification power of crude oil against green bonds and clean energy stocks is weaker as the dynamic correlations become more positive.*" (Joof et al., 2024, p. 1);

27 Mensi, Selmi, Al-Kharusi, Belghouthi & Kang (2024) conducted a broad study considering the setting of the U.S. market, utilising DY-12 method, as well as Quantile Connectedness approach on daily data (April 1, 2013 –April 4, 2023), with the aspiration to explore the spillovers among the green bond market and the non-green bond (10-year U.S. treasuries) and energy markets (WTI crude oil market, heating oil market, natural gas market, petrol market) amidst the bear and bull market conditions (Mensi et al., 2024). As stated by Mensi et al. (2024, p. 1): "*The main results show a strong time-varying connectedness between focal asset classes during major crisis periods, including the oil price crash, the China-US trade conflict, the coronavirus crisis and the war between Russia and Ukraine. The network analysis reveals that WTI, heating oil and green bonds act as net transmitters of risk, while the other asset classes serve as net receivers of spillovers. In extreme conditions, spillovers between energy commodities, green bonds and non-green bonds are asymmetric, given that they are not equal in the upper and lower quantiles. Green bonds offer greater diversification benefits when coupled with WTI, heating oil, gasoline, and natural gas, though with varying portfolio weights.*" (Mensi et al., 2024, p. 1);

28 Umar, Hadhri, Abakah, Usman & Umar (2024) undertook a thorough study considering the setting of the developed markets worldwide (Australia, Canada, Denmark, EU, Hong Kong, Japan, New Zealand, Norway, Switzerland, Sweden, UK, U.S.), utilising DY-14 Generalised VAR framework on daily data (December 1, 2008 –June 1, 2022), with the aspiration to inspect the spillover effects among oil price shocks and green bonds issued in 12 aforementioned economies (Umar et al., 2024). As stated by Umar et al. (2024, p. 1): "*Our results show the dominance of the US and the European green bond markets as the main contributors to return and volatility spillovers among international green bonds, respectively. The degree of connectedness among markets*

*varies over time with a more pronounced effect on returns during turbulent periods. Oil shocks exhibit a relatively low degree of connectedness with green bonds implying potential diversification attributes. This result is, particularly, supported in the case of green bond markets of USA, Euro, Denmark and Hong-Kong.*" (Umar et al., 2024, p. 1);

29 Wu & Qin (2024) performed an extensive study considering the setting of the Chinese market, utilising Asymmetric DCC-GARCH model on daily data, with the aspiration to analyse asymmetric dynamic volatility spillovers between the new energy, ESG, green bond and carbon markets (Wu & Qin, 2024). As stated by Wu & Qin (2024, p. 1): "*Our results show that (i) the persistence of asymmetric volatility shock transmission between new energy and ESG stock markets is about 40 days, which is higher than that of carbon or green bond markets; (ii) bad total volatility spillovers dominate good total volatility spillovers after the COVID-19 outbreak; (iii) for both good and bad volatility, ESG and green bond markets are mainly net transmitters, while new energy and carbon markets are mainly net receivers; and (iv) the bad volatility spillovers to new energy and ESG stock markets from other markets in the green finance system are higher than good volatility spillovers. However, the good volatility spillovers to carbon and green bond markets from other markets are higher than bad volatility spillovers.*" (Wu & Qin, 2024, p. 1);

30 Yousaf, Mensi, Vo & Kang (2024) executed a comprehensive study considering the setting of the global market, utilising BK-18 method, DCC-GARCH model, BEKK-GJR-GARCH model, as well as Wavelet Coherence analysis on daily data, with the aspiration to explore dynamic frequency spillovers, co-movements and volatility transmission between crude oil and green bond yields (Yousaf et al., 2024). As stated by Yousaf et al. (2024, p. 1): "*The results of BK-18 show that the spillover between green bonds is higher in short-term horizons than in intermediate- and long-term horizons. Furthermore, Industrial and Securitized ABS bonds are weakly connected with other green bonds. The findings of BEKK-GJR-GARCH model shows the negative unidirectional volatility spillover from oil to Global GB markets, indicating the hedging ability of green bonds against the oil. The dynamic conditional correlations are negative between oil and Industrial and Securitized ABS over sample period, suggesting them as strong hedge and safe haven against the oil. The Wavelet Coherence analysis reveals that the connectedness is weak between crude oil and green bonds in most of the short and long run.*" (Yousaf et al., 2024, p. 1).

## CONCLUDING CONSIDERATIONS

Research findings divulged that erratic markets represent suitable ground for volatility spillovers, i.e., transmissions of shocks across various markets – several studies (Chen et al., 2024; Elsayed et al., 2022; Ferrer et al., 2021; Nguyen et al., 2021; Peng et al., 2023; Reboredo, 2019; Reboredo & Ugolini, 2020; Reboredo et al., 2020; Umar et al., 2023) provided evidence on dynamic connectedness and transmissions of shocks on relation green bond market–conventional bond market; dozen studies (Chen et al., 2024; Dai et al., 2023; Elsayed et al., 2022; Ferrer et al., 2021; Mensi et al., 2022; Mensi et al., 2023; Nguyen et al., 2021; Park et al., 2020; Pham, 2021; Reboredo, 2019; Reboredo & Ugolini, 2020; Reboredo et al., 2020) evidence on green bond market–stock market dynamic connectedness and volatility spillovers; a good many of authors (Chen et al., 2024; Dai et al., 2023; Ferrer et al., 2021; Gao & Liu, 2024; Joof et al., 2024; Mensi et al., 2022; Mensi et al., 2023; Naeem, Adekoya & Oliyide, 2021; Naeem, Nguyen, Nepal, Ngo & Taghizadeh-Hesary, 2021; Nguyen et al., 2021; Rao et al., 2022; Reboredo et al., 2020; Tang et al., 2023; Umar et al., 2023; Umar et al., 2024; Yousaf et al., 2024) evidence on green bond market–commodity market dynamic connectedness and volatility spillovers; a plethora of authors (Elsayed et al., 2022; Gao & Liu, 2024; Gyamerah et al., 2022; Joof et al., 2024; Liu et al., 2021; Mensi et al., 2024; Naeem, Adekoya & Oliyide, 2021; Naeem, Nguyen, Nepal, Ngo & Taghizadeh-Hesary, 2021; Nguyen et al., 2021; Reboredo, 2019; Reboredo & Ugolini, 2020; Tang et al., 2023; Wu & Qin, 2024; Yadav et al., 2022; Yadav et al., 2023; Zhang & Umair, 2023) evidence on green bond market–energy market dynamic connectedness and volatility spillovers; a number of authors (Chen et al., 2024; Ferrer et al., 2021; Mensi et al., 2023; Reboredo & Ugolini, 2020; Reboredo et al., 2020) evidence on green bond market–foreign exchange market dynamic connectedness and volatility spillovers; whilst a handful of studies (Le et al., 2021; Rao et al., 2022; Yadav et al., 2022; Yadav et al., 2023) supplied evidence on dynamic connectedness and spread of volatility shocks on relation green bond market–fintech/cryptocurrency market.

Furthermore, research produced the following conclusions: commodity market and energy market demonstrate dominance in the realm of connectedness and transmissions of volatility attained with green bond market; green bond market predominantly holds the position of net volatility receiver; Diebold and Yilmaz (DY) and Baruník and Křehlík (BK) methods, as well as Generalised Autoregressive Conditional

Heteroscedasticity (GARCH) family models, are detected as the most attractive econometric modelling choices; a number of authors of the examined articles are united in the stance that green bonds can serve as an ultimate portfolio hedge. Additionally, spatially and temporally viewed, the following conclusions arose: the majority of the articles address global green bond market-related dynamic correlations and volatility spillovers; academia's curiosity surrounding this topic intensifies in the years drawing closer to 2024 (the growth in articles' corpus volume related to this topic can be attributed to the green bond phenomenon's topicality, as well as to the sharp volatility spillover events triggered by the recent public health-endangering and geopolitical events, such as COVID-19, Brexit, Russia-Ukraine war, etc.).

Contribution to the latest knowledge could be recognised in the innovative scrutiny of the research itself, since a systematic literature review on this niche topic has not been carried out to the best of the authors' knowledge. Recommendations for academic actors include guidance regarding further investigations of the scarce topic of green bond market–fintech/cryptocurrency market dynamic connectedness and volatility spillovers, due to lacking/contradicting findings of the examined articles; whilst recommendations for non-academic actors (investors, portfolio managers, policymakers, etc.) include recognition of hedging evidence (regarding green bonds' inclusion into investment portfolios) provided in 14 scrutinised studies (Elsayed et al., 2022; Joof et al., 2024; Le et al., 2021; Mensi et al., 2022; Mensi et al., 2023; Naeem, Adekoya & Oliyide, 2021; Naeem, Nguyen, Nepal, Ngo & Taghizadeh-Hesary, 2021; Nguyen et al., 2021; Pham, 2021; Reboredo et al., 2020; Tang et al., 2023; Yadav et al., 2022; Yousaf et al., 2024; Zhang & Umair, 2023). Ultimately, research limitations can be found in the main empirical research part's exclusivity of conference articles, master's/PhD theses, institutional/industry reports, etc., that is, in reliance on only peer-reviewed articles published in academic journals.

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# DINAMIČKE KORELACIJE I PRELIVANJA VOLATILNOSTI U KONTEKSTU TRŽIŠTA ZELENIH OBVEZNICA: SISTEMATSKI PREGLED LITERATURE

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***Sažetak:*** *Usled ekspanzije univerzuma zelenih obveznica, razumevanje evolucije empirijskih studija o dinamičkim korelacijama i prelivanjima volatilnosti u kontekstu tržišta zelenih obveznica od izuzetne je važnosti. Istraživanje ima za cilj da generiše sistematski pregled literature uvažavajući dokaze pomenutih studija, istakne dominantno korelisana tržišta i transmisije volatilnosti u kontekstu zelenih obveznica, detektuje preovlađujuće ekonometrijske modele, te identifikuje repetitivnost u istraživačkim nalazima. Zarad dostizanja cilja istraživanja, kolekcije baza koje integrišu akademsku literaturu – Web of Science, Scopus i Google Scholar – pažljivo su pregledane, a preporučene faze PRISMA metodologije za sistematski pregled literature – identifikacija, skrining, ocena podobnosti i uključivanje – uvažene. Kriterijumi za odabir članaka uključivali su: validnost sadržaja članka, relevantnost za postavljeno istraživačko pitanje, robusnost dokaza i datum objave. Konačno, istraživanje je izgrađeno na najnovijim (interval od 2019-2024. godine) empirijskim saznanjima, ekstrahovanim iz 30 relevantnih članaka objavljenih u 18 renomiranih akademskih časopisa. Rezultati istraživanja dokumentovali su solidnu bazu znanja, te iznedrili preporuke dragocene kako za akademske, tako i za neakademske aktere.*

***Ključne reči:*** *zelene obveznice, dinamička korelacija, prelivanje volatilnosti, sistematski pregled literature.*