GREEN ENERGY STOCKS & MARKET TRENDS: AN OVERVIEW OF CONTEMPORARY LITERATURE

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Abstract

The energy sector has gained increasing importance in recent years, playing a vital role in economic development at both national and global levels, especially in the shift towards a zero-carbon economy. This study provides a comprehensive overview, analysing green energy stocks and their trends from various perspectives and scenarios. The analysis is based on a thorough selection of academic sources sourced from scholarly databases, filtered using keywords related to climate change modelling and analysis. Key topics explored include the influence of green investments on oil prices, the effect of online environmental news on green industry stocks, the relationship between green energy indices and financial markets, the impact of spillovers between dirty and clean energy markets and global stock indices, and their effect on volatility transmission between green and conventional stocks. Additionally, the paper examines climate policy and the connection between green bonds and the green stock market. The central research question addressed is whether green energy stocks have a tangible impact on market trends. The future trajectory of the economy in the context of climate change is a critical issue with implications for both local and global economies. As such, this literature review covers various themes that, directly or indirectly, investigate the relationship between climate change and economic dynamics.

Keywords: investments, oil prices, energy indices, financial markets, clean energy, volatility, climate policy, stock exchange

JEL Classification: G10, G12, Q40, Q42, Q50

DOI: https://doi.org/10.65672/fs.2025.4.6

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1. Introduction

With the increasing recognition of sustainability's importance (Zhou et al, 2025), investors are progressively reallocating capital toward green investments (Wang et al, 2022a; Liu et al., 2024). In particular, there is a growing tendency to construct portfolios that incorporate environmentally responsible firms. These companies are gaining prominence for their production of, and support for, sustainable goods and services. Schaeffer et al. (2012), for example, contend that eco-friendly firms have garnered significant attention from investors, policymakers, and society at large due to their provision of environmentally sustainable services. Overall, green investments—also referred to as environmental assets—have become a focal point of interest among market participants.

Among other factors, this study also explores whether green investments exhibit a significant response to oil price shocks. This analysis could be crucial for policymakers in understanding the broader impact of oil price fluctuations on environmental investments and crafting suitable strategies to encourage the growth of eco-friendly businesses. For instance, during a downturn in the oil market, the incentives for environmentally conscious investors may diminish, potentially leading to a decline in the prices of environmental assets. Conversely, when oil prices rise, incentives for green investments tend to increase, which could drive up the equity prices of eco-friendly firms.

Several studies (Bondia et al., 2016; Dutta, 2017; Xia et al., 2019) suggest that an increase in oil prices fosters green investments. For example, Bondia et al. (2016) demonstrate that rising energy prices incentivise investors to shift towards green energy companies, as the potential rewards for such investments grow. Similarly, Dutta (2017) argues that oil price volatility (OVX) exerts an inverse effect on clean energy stocks, indicating that they tend to move in the same direction.

Undoubtedly, global economic growth generates a sustained demand for energy. As a result, countries strive to secure a reliable energy supply while maintaining reasonable energy prices. Both objectives must be pursued concurrently through the development of an integrated energy market. At the same time, there is a growing recognition that fossil fuel resources are becoming increasingly scarce, and renewable energy has emerged as both an alternative source and a sustainable solution for many nations.

The unforeseen Russian invasion of Ukraine on February 24, 2022, introduced increased uncertainty regarding access to fossil fuel commodities. However, it may have also opened new opportunities for alternative energy sources and investment in the green energy market. As a result, investors may be motivated to rebalance their portfolios by shifting towards alternative assets, thereby diversifying their exposure to risks in financial markets. However, the overall effect of the war on the global economy, as seen in the rising energy prices and the reactions of international financial markets, is still challenging to evaluate (Adekoya et al., 2022; Lo et al., 2022).

Considering the significant reliance on non-renewable energy resources from Russia by many countries, the Russia-Ukraine conflict could serve as a turning point for energy policy in Europe. Amid the global transition to renewable energy and the ongoing uncertainty surrounding the war, investments in green energy could pose challenges for market participants. The diverse impacts of energy commodity price shocks on other asset prices shape the decisions of various economic agents, such as companies, investors, and policymakers. However, it remains unclear how to mitigate portfolio risk with clean energy stocks and how the risk of the renewable energy market compares to that of traditional assets. In order to bridge this gap, one of the objectives of this study is to explore how the Russian-Ukrainian war affects financial interconnectedness, focusing on the volatility spillovers between energy markets and stock indices.

The global recognition of the pressing issue of climate change has led to an increased emphasis on environmental sustainability and carbon reduction (Ding et al 2020; Khurshid et al. (2022)). As a result, investors are showing greater interest in companies that specialize in green technologies or renewable energy. The 2022 report from the International Development Finance Club (IDFC) highlights a record-breaking total of USD 288 billion in green financing commitments, marking a 29% increase compared to 2021. Since the adoption of the Paris Agreement in 2015, cumulative green finance commitments from IDFC members have surpassed USD 1.5 trillion.

To reduce the carbon footprint of energy within the overall energy mix, it is essential to increase the share of clean energy by promoting green investments and discouraging investments in non-renewable energy sources (Khan, Razzaq, Yu, & Miller, 2021; Sohag, Hassan, Bakhteyev, & Mariev, 2023). Moreover, supporters argue that green investment plays a vital and irreplaceable role in driving a

market-based shift toward sustainable energy alternatives. To improve the cost competitiveness of renewables over fossil fuels, numerous governments have introduced carbon pricing policies and extended subsidies to promote the production of green energy (Intergovernmental Panel on Climate Change [IPCC], 2023; Reboredo & Ugolini, 2020).

Consequently, there has been a surge in investor interest in the renewable energy sector. Simultaneously, greater attention is being directed toward the role of the financial system as a catalyst for broader sectoral transformation. Nevertheless, there remains a noticeable gap in the literature regarding the relationship between green and conventional asset markets during periods of geopolitical and economic instability, particularly in the context of developing countries.

The green transformation presents significant opportunities for advancing global sustainable development. At present, there is broad international consensus on the importance of this transition, accompanied by tangible policy actions. As of 2022, over 120 countries had established or were in the process of establishing carbon neutrality targets, collectively representing 88% of global carbon emissions. Green bonds play a dual role by supporting the low-carbon transition and fostering economic growth (Reboredo et al., 2020).

The issuance of green bonds can facilitate the mobilization of greater social capital toward achieving carbon neutrality objectives. However, as an emerging asset class, green bonds embody both financial and environmental characteristics. Given the common exposure to macroeconomic conditions across green financial markets, there is potential for risk contagion among these assets—particularly during periods of crisis (Dai et al., 2022; Wei et al., 2023). Consequently, in the pursuit of carbon neutrality, examining the complex relationship between green bonds and green equity markets has emerged as a pressing concern.

Building on the preceding discussion, this article undertakes a comprehensive review of the literature examining the relationship between green energy stocks and evolving market dynamics. The primary focus is on how green investments respond to oil price shocks. The analysis then considers the influence of online environmental news on green industry stock performance. Further, the study explores the interplay between green energy indices and broader financial markets. It also addresses the effects of the Russia–Ukraine conflict on both dirty and clean energy markets, in comparison with global

indices. Finally, the review investigates the role of volatility transmission, hedging strategies across green and conventional stocks, and the uncertainty surrounding the correlation between green bonds and green stocks—particularly from the perspective of climate policy.

The remainder of this paper is organised as follows: Section Two outlines the data and methodology, detailing the primary approaches used in conducting the study. Section Three presents the key findings and discussions, while Section Four offers the conclusion.

2. Data and methodology

In order to evaluate the influence of green energy stocks on market trends, we carried out an extensive literature review, utilising academic research published from the early 2000s to the present. Pertinent studies were gathered from reputable scholarly databases, including Elsevier Ebooks, SpringerLink Journals, Wiley Ebooks, SciVal, ProQuest Central and Sage Journal Collection, through targeted searches using terms associated with green energy dynamics and current market movements.

The central research question addressed in this paper is whether green energy stocks have a tangible impact on market trends. The future trajectory of the economy in the context of climate change is a critical issue with implications for both local and global economies. As such, the analysis is based on six scholarly references that address the subject from various perspectives within the specialised literature. Those six dimensions are investigated further in the paper.

3. Results and discussion

3.1. Green investments and oil price shocks

This study distinguishes itself from previous research in two key ways. First, it investigates the relationship between crude oil and green investments across various economic regimes using the Markov Regime Switching (MRS) approach. In contrast, most existing studies on the relationship between ethical investments and other financial assets typically rely on ordinary least squares (OLS) regression. However, these studies often overlook the fact that the connections between financial markets are subject to frequent shifts due to events such as recessions, terrorist attacks, and natural disasters (Dutta et. al., 2020).

Consequently, the fixed parameter assumption inherent in the least squares method is overly restrictive, potentially leading to model misspecification. In this context, employing the MRS regression proves advantageous, as it enables the coefficients to vary across different economic states (Uddin et al., 2018). For example, by using this approach, it can be examined how green assets respond to oil price shocks in both high and low volatility states.

Secondly, this study incorporates newly introduced environmental indices that comprise companies engaged in eco-friendly production and green infrastructure development. Notably, it includes the MSCI Global Environment Index and the MSCI Global Green Building Index. According to MSCI.com, these indices are designed to enhance exposure to clean technologies, featuring companies that derive the majority of their revenue from products and services contributing to environmental sustainability. The index construction employs MSCI ESG Sustainable Impact Metrics. To the best of the authors' knowledge, this is the first study to analyze these specific green assets, whereas prior research has primarily focused on the relationship between oil prices and broader clean energy stock indices (Dutta et. al., 2020).

Henriques and Sadorsky (2008) utilize a vector autoregression (VAR) model to explore the relationship between oil prices, alternative energy, and other macroeconomic variables, finding that movements in clean energy stock prices are partially influenced by these factors. Sadorsky (2012a) argues that rising oil prices increase the risk associated with clean energy equities, while Sadorsky (2012b) further demonstrates that oil price volatility spills over into clean energy stock markets. Focusing on firm-level dynamics, Kumar et al. (2012) examine the sensitivity of renewable energy stock prices to oil price shocks. Wen et al. (2014) analyze the mean and volatility transmission between Chinese renewable energy and fossil fuel firms. Additionally, Reboredo (2015), using a copula approach, provides empirical evidence of a time-varying dynamic dependence between oil prices and clean energy stocks.

Bondia et al. (2016) identify a significant relationship between energy equities and oil markets, further establishing that movements in the commodity market Granger-cause those in the stock market, but not the reverse. Using wavelet analysis, Reboredo et al. (2017) observe weak short-term comovements between clean energy and conventional energy stock prices; however, this relationship becomes

more pronounced over the long term. Similarly, Ahmad (2017) confirms a co-movement between renewable energy stock returns and oil prices.

These findings suggest that rising energy prices may serve as a catalyst for increases in green energy stock prices. Dutta et al. (2018a, 2018b) demonstrate that clean energy stocks can be effectively hedged using information derived from carbon emission prices. Bouri et al. (2019) identify crude oil and gold as safe-haven assets for clean energy stocks during periods of heightened market volatility. Additionally, Xia et al. (2019) highlight that fluctuations in electricity, oil, and coal prices are key determinants of clean energy stock returns.

Recent research by Kocaarslan and Soytas (2019) reveals that the appreciation of the US dollar is a significant factor influencing the time-varying relationship between clean energy stock prices and oil prices. Another strand of the literature focuses on the Oil Volatility Index (OVX) to assess its impact on clean energy stock indices. In this context, Dutta (2017) identifies a positive relationship between the OVX and the realized volatility of renewable energy stocks. Conversely, Ahmad et al. (2018) find a negative correlation between clean energy equities and the OVX, suggesting that incorporating OVX into investment portfolios may help mitigate risks associated with clean energy stocks.

Dutta (2019) examines the influence of implied volatility indices for oil, gold, and silver on the equity prices of solar energy firms. The results indicate that oil market volatility, measured by the OVX, transmits greater risk to alternative energy stocks compared to the volatility indices of silver and gold. Additionally, Dutta et al. (2018a) suggest that the OVX serves as an effective instrument for hedging downside risk associated with clean energy stock prices.

The literature review indicates that many of the referenced studies address time-series data characterised by structural breaks. However, the majority rely on conventional OLS regression models to examine the relationship between oil prices and clean energy stock prices. As noted by Kim et al. (2008), the results derived from such models may be misleading in the presence of structural shifts. In contrast, regime-switching models—such as those proposed by Hamilton (1990), Fong and See (2002), and Lee and Chen (2006)—are better suited for capturing regime-dependent dynamics and may offer more accurate insights.

3.2. Online environmental news on green industry stock

Growing awareness of the detrimental effects of environmental pollution has led to increased public concern and policy attention in China. Both the government and the public have come to recognise the critical importance of environmental protection. In 2017, China committed to advancing green development, addressing major environmental challenges, and enhancing ecosystem conservation. In line with this commitment, the government introduced a green economic strategy aimed at simultaneously fostering economic growth and mitigating environmental degradation. To support this transition, a range of legal and economic policy instruments have been implemented to stimulate investment in emerging green industries, including renewable and clean energy, electric vehicles, clean production technologies, and environmental management technologies (Wang et al., 2021).

Also, many companies have begun to increase investments in renewable and clean energy and environmental protection technologies. Due to the importance of green industries in future developments, these green companies, as well as their environmental strategies, will receive increased attention from the public, and from media agencies, individual investors, and institutional investors. Evidence has been mounting recently to suggest that this greater attention should affect asset pricing and lead to a violation of market efficiency (Chen, 2017).

The news media serve as a primary source of public information for investors (Aman et al., 2018), and empirical evidence suggests that heightened media coverage can significantly influence investor attention, subsequently impacting trading volumes, stock prices, and returns (Yang et al., 2017; Seng & Yang, 2017). Prior research indicates that news impacts stock market movements not only through information dissemination but also by shaping investor sentiment. Various forms of news—such as macroeconomic updates, business events, corporate disclosures, and announcements related to technological innovation—can alter investor sentiment, which in turn influences stock returns and trading volumes (Gan et al., 2020).

While the relationship between news media, investor attention, sentiment, and stock returns has been extensively examined, the findings remain inconclusive—particularly regarding the extent to which environmental news influences investor sentiment and the stock performance of companies within the green industry. In the digital age,

nearly all mainstream news organizations publish reports via their official websites and social media platforms. Furthermore, specialised web portals such as Eastmoney (www.eastmoney.com) continuously monitor, aggregate, and disseminate a wide array of commercial, technological, economic, and financial news, providing investors with streamlined and immediate access to relevant market information (Wang et al., 2021).

The literature relevant to this analysis encompasses two key areas: the impact of news media coverage on stock returns and the influence of investor sentiment on stock market performance. Regarding the first area, an increasing body of research highlights the significant role that news media reporting plays in financial markets, with particular emphasis on online and social media platforms, which have become primary sources of information for investors (Zhang et al., 2018). Prior research on the influence of news media on stock returns can be understood through two theoretical frameworks. The first is the Efficient Market Hypothesis (EMH), which posits that stock prices fully reflect all available information—past, present, and anticipated future events—thus adjusting as new information emerges through news media. The second is the Attention Hypothesis (AH), which contends that investors are cognitively constrained and often react only to information that captures their attention. Within this framework, mainstream news coverage can significantly shape investor sentiment and, consequently, affect trading behavior (Aman et al., 2018; Yang et al., 2017).

Extensive empirical research has demonstrated that news reports can have both direct and indirect effects on stock returns. (Tetlock, 2007) showed that the content of news media could predict movements in broad stock market indicators. (Seng & Yang, 2017) provided evidence that financial news influenced stock returns in the Taiwanese market. (Vanstone et al., 2019) found that incorporating predictors such as the number of news articles and “X” posts could significantly enhance the accuracy of stock price predictions. (Su et al., 2019) examined the impact of news reporting in the United States on Chinese stock market returns, revealing that news-induced volatility (NVIX) had a negative effect on Chinese stock returns over the long term.

(Mo et al., 2019) explored the relationship between news-induced volatility (NVIX) and stock market volatility in the United States from a multiscale perspective. They found that the correlation between

NVIX and market volatility was weak in the short term but significantly stronger in the long term. (Huang, 2018) demonstrated that macroeconomic news had a notable effect on the expected future stock returns of energy companies. (Robinson et al., 2018) examined the impact of news media on the stock market performance of green companies, revealing that the stock returns of green companies in emerging markets were less influenced by daily news and were instead more driven by long-term factors.

Regarding the second area, the influence of investor sentiment on market returns has long been acknowledged in financial literature. However, measuring investor sentiment remains challenging due to factors such as differences in sampling methods, time horizons, and other variables, leading to inconsistent conclusions regarding its relationship with stock returns. A review of the existing literature reveals that investor sentiment has been measured through various approaches, including direct indicators, indirect indicators, and online-based metrics.

Direct indicators measure investor sentiment based on their expectations about current and future market trends, typically gathered through survey data. Common examples include bullish and bearish sentiment indexes (Waggle et al., 2015; Renault, 2017), investor confidence indexes (Fisher et al., 2000; Wu et al., 2018), and consumer confidence indexes (Shen et al., 2017; Meier, 2018). For instance, Frugier et al. (2016) used the State Street Investor Confidence Index to proxy for investor sentiment and found that it significantly influenced stock returns under certain market conditions. Indirect indicators refer to financial market-based measures such as trading volume, turnover rate, the number of newly opened accounts, and the discount on closed-end funds. Building on the approach by Baker and Wurgler (2006), Aboody et al. (2018) utilised overnight returns as a proxy for gauging investor sentiment.

3.3. The relationship between green energy indices and financial markets

Green financial assets are part of the broader category of green investments—investments directed toward sectors that enhance the environmental sustainability of the economic system (Campiglio, 2016). As such, understanding the features of green stocks requires examining the broader trends in green energy investment. For instance, how are green energy investments progressing? Are green

financial assets becoming central to funding sustainable projects? And who are the major players driving this shift? This section provides a descriptive analysis to address these questions.

Historically, investments in fossil fuels have consistently outpaced those in green energy. However, since 2014, oil and gas investments have declined—largely due to falling oil prices—while global investments in green energy have steadily increased. This upward trend in green investment is encouraging, yet more substantial efforts are needed to advance toward low-carbon economies. During the COVID-19 pandemic, investments in both sectors saw significant declines. Between 2019 and 2020, fossil energy investments dropped by 32.09%, while green energy investments fell even more sharply by 51%. The dramatic decrease in oil demand during the Great Lockdown, coupled with storage capacity issues, played a major role in this downturn. This situation triggered panic in the West Texas Intermediate (WTI) crude oil futures market, driving prices into negative territory for the first time—plummeting from $18 to –$37 per barrel (Mignon, 2020).

In summary, green investments have shown a steady upward trend over time. Companies typically finance green projects through internal funding mechanisms, such as loans or equity issuance. To further promote green lending, various macroprudential policies can be implemented—for instance, introducing a brown-penalizing factor that compels banks to hold additional capital against carbon-intensive assets, or applying differentiated reserve requirements that adapt to green lending needs based on whether a country is developed or developing (D'Orazio and Popoyan, 2019). Although this topic is gaining attention in the literature, green stocks remain underexplored. As highlighted earlier, fostering investor participation in green firms via mutual funds or exchange-traded funds (ETFs) that track green indices demands greater transparency. This section underscores the importance of aligning green indices with green investment trends, given their strong interconnection. The next section outlines the criteria for selecting an appropriate green benchmark.

Choosing an appropriate green financial index is a complex task due to the varied definitions of green assets and the diversity of Sustainable and Responsible Investment (SRI) strategies. To begin, we examine the various SRI strategies and justify our preference for the exclusionary approach. Next, we present the specific criteria that informed our selection of the WilderHill New Energy Global Innovation

Index (NEX) as our green benchmark. Finally, we conduct a descriptive analysis of this green energy stock index to provide further context and support for its selection (Nobletz, 2022).

Green financial products vary widely in their Sustainable and Responsible Investment (SRI) strategies. The primary and contrasting approaches for company selection in portfolios include positive and negative screening, represented by the best-in-class and exclusion methods, respectively. The best-in-class strategy selects companies with the highest ESG (Environmental, Social, and Governance) scores within each industry, promoting leaders across sectors. On the other hand, the exclusion strategy—one of the oldest SRI approaches—removes companies that fail to meet specific ethical, social, or environmental standards, such as those involved in tobacco, alcohol, or nuclear energy.

Additionally, thematic investing focuses on specific environmental issues or sectors. Engagement and voting strategies use shareholder influence to encourage better ESG integration within firms. Lastly, impact investing targets primarily private companies aiming to generate measurable social and environmental benefits, often prioritising purpose over profit (Eurosif, 2018).

We select green indices based on several key criteria. First, the index should offer broad coverage of the environmental sector and adopt the exclusion strategy to ensure it aligns with sustainable investment principles. Second, it must use an equal-weighting approach to prevent a few large companies from dominating the index and skewing its representation. Lastly, it is essential that the index provides a complete and accessible list of its constituent companies for each year to ensure transparency and support long-term analysis. Two green energy indices satisfy the established criteria: the WilderHill Green Energy Index (ECO) and the WilderHill New Energy Global Innovation Index (NEX).

The ECO index concentrates on the U.S. market, while the NEX index has a broader global focus. Both indices emphasize environmental sectors, apply exclusion-based screening, use equal weighting to prevent overrepresentation by large firms, and provide publicly available constituent lists annually—making them suitable benchmarks for tracking green financial performance. We select the WilderHill New Energy Global Innovation Index (NEX) as our benchmark green index due to its comprehensive global coverage. This broader perspective allows for an international analysis of green

financial trends before narrowing the focus to more localised or sector-specific dynamics.

The NEX index comprises companies specialising in innovative clean energy solutions, energy conservation, efficiency, and advanced renewable technologies. It is calculated by Solactive using a modified equal-weighting methodology, is rebalanced quarterly, and ensures that no individual stock holds more than 5% of the total index weight (Nobletz, 2022).

For the selected green index, we choose a financial benchmark that offers both global and sectoral coverage of the world stock market. This allows for a meaningful comparison between the components of the green energy index and those of the benchmark index, helping to better understand the unique characteristics of green markets.

We adopt the market-oriented classification approach, as it offers a more accurate depiction of sectoral concentration (Hrazdil & Zhang, 2012) and is effective in capturing comovements in stock returns (Bhojraj et al., 2003). Within this framework, we choose the Global Industry Classification Standard (GICS) due to its suitability for global analysis. Developed by Standard & Poor's (S&P) and MSCI, the GICS is the first market-oriented classification system, updated annually, and structured into four hierarchical levels—11 sectors, 24 industry groups, 69 industries, and 158 sub-industries. For our analysis, we focus on the sector level to avoid losing critical insights that might be diluted at more granular levels.

3.4. Volatility spillovers between the dirty and clean energy markets and global stock indices during periods of escalating geopolitical risk

There is a growing global interest in renewable energy, driven by the increasing economic and societal impacts of climate change. International bodies and various stakeholders are actively working to establish targets and develop frameworks for managing environmental and climate-related risks, aiming to promote environmentally responsible practices in the coming decades. Fahmy (2022) emphasizes the rising awareness among investors about climate risks and the importance of green investments, particularly following the Paris Agreement. This heightened awareness has influenced the dynamics between clean energy prices and traditional sectors like oil and technology. Zhang et al. (2020), employing wavelet quantile-on-quantile analysis, revealed that oil price shocks affect clean energy

stocks differently depending on investment horizons and quantiles, with long-term asymmetry. Similarly, Yahya et al. (2021) found non-linear and long-term interconnections between oil prices and clean energy stocks, highlighting that clean energy has emerged as a leading factor influencing oil prices in the post-financial crisis period.

However, the impact of the Russian invasion on the global shift toward renewable energy remains uncertain. Amid the COVID-19 pandemic, the real options theory suggests that heightened uncertainty led many investors to delay investment decisions, which in turn negatively impacted stock returns. As the world continued grappling with the pandemic's economic fallout, a new shock arose with the onset of the Russia–Ukraine war on February 24, 2022. This conflict has had significant repercussions, especially for European nations heavily dependent on Russian oil and gas. The disruption in supply chains caused a sharp increase in global oil prices, reaching their highest point in eight years. This geopolitical development carries substantial weight for the global economy. Lo et al. (2022) assessed the war's effects on financial markets across a panel of 73 countries, finding that the impact varies depending on each country’s reliance on Russian commodity exports.

The authors identified heightened volatility and reduced asset returns in financial markets as a consequence of the war. Their findings indicate that the Ukraine conflict exerts a negative influence on stock markets and elevates volatility levels, irrespective of a country's reliance on Russian commodities. In a related study, Adekoya et al. (2022) explored whether oil behaves differently in relation to key financial assets during wartime. Their analysis revealed significant variation in asset connectedness prior to the conflict and a pronounced spillover effect from oil to all assets during the war. Further, Adekoya et al. (2023) examined cross-correlations between oil prices and major European and non-European stock markets before and during the Russia–Ukraine war. Their results demonstrate that the conflict has intensified the persistence of relationships between oil prices and European stock markets more than with non-European ones.

Steffen and Patt (2022) offer early insights showing that the Russia–Ukraine war has influenced public policy preferences, notably increasing public backing for phasing out fossil fuels and promoting clean energy alternatives. Their study found strong support among the Swiss public for clean energy initiatives, though they emphasize that such support must be matched by concrete political action. While past

research has explored the relationship between energy markets and financial markets during turbulent times, there is still a gap in comparative studies assessing the differing impacts of the Russia–Ukraine war and the COVID-19 pandemic on the interconnectedness between dirty and green energy sectors and financial markets.

Understanding these linkages is critical not only for shaping effective investment strategies but also for guiding governmental and regulatory responses to market instability. This issue becomes even more pertinent when viewed in the context of emerging policy instruments like the Market Stability Reserve, which seeks to regulate the volume of CO_2 allowances auctioned annually.

In light of rising concerns over energy security and climate change, renewable energy presents promising investment opportunities for market participants. Analyzing the interconnectedness between energy sectors and financial markets can provide valuable insights for risk diversification and optimal asset allocation. However, there is limited research examining the dynamic relationships between price movements in clean and fossil energy and equity market volatility across U.S., Asian, and European markets. Existing empirical studies mainly serve to guide investors in developing effective hedging strategies when navigating both stock and international energy markets (Karkowsca & Urjasz, 2023).

An increasing number of investors are incorporating energy assets into their portfolios, leading to stronger linkages between energy and equity markets (Jiang & Yoon, 2020; Kilian & Murphy, 2014; Kilian & Park, 2009; Managi & Okimoto, 2013; Nandha & Faff, 2008). For instance, Managi and Okimoto (2013) identify a positive correlation between non-renewable and clean energy prices, and highlight how clean energy and technology stock prices respond similarly to market changes. He (2020) further explores the implications for risk management, demonstrating the diversification and hedging benefits of including non-renewable energy assets in investment portfolios.

The findings provide strong evidence of a time-varying and asymmetric relationship between oil prices and East Asian equity markets. Ahmad (2017) highlights that dynamic hedging strategies suggest clean energy indices may offer more effective and profitable hedging opportunities when paired with oil futures, compared to technology indices. Similarly, Papathanasiou et al. (2022) examine the interactions between hedge arbitrage funds and traditional asset classes such as equities, bonds, gold, oil, currencies, commodities,

and real estate. They estimate hedging ratios and optimal portfolio weights to evaluate the hedging effectiveness of these funds, concluding that such funds exhibit the lowest sensitivity to shocks from stocks, oil, gold, and currency markets.

The existing literature review does not adequately address critical questions regarding the significance of the relationship between dirty and clean energy markets and global financial indices during the Russian invasion of Ukraine. Overall, the body of research exploring the link between energy and financial markets under the influence of geopolitical risk—as an external and destabilising factor—remains limited. Therefore, this study aims to bridge that gap, offering valuable insights for both investors and market regulators (Karkowsca & Urjasz, 2023).

3.5. Volatility transmission between green and conventional stocks

Understanding the interconnections and dynamics between various markets is crucial for asset managers aiming to manage portfolio risk effectively, as well as for policymakers who need to identify strategic sectors for targeted financial regulation. Extensive academic research has examined the significance of incorporating both green and traditional assets—such as crude oil, commodities, gold, and fossil fuels—into diversified investment portfolios. This strategy supports objectives related to asset allocation, risk mitigation, and hedging (Huang, Zhu, Hau, & Deng, 2023; Mensi, Naeem, Vo, & Kang, 2022; Nguyen, Naeem, Balli, Balli, & Vo, 2021; Reboredo et al., 2022; Umar et al., 2023; Vogl, Kojić, & Mitić, 2024; Yadav, Pandey, Taghizadeh-Hesary, Arya, & Mishra, 2023a). However, most of these studies are conducted within specific markets and concentrate on particular analytical aspects—such as examining volatility dynamics and persistence, spillover effects, or the influence of policy and regulatory shifts on the volatility of green assets. The findings on volatility behaviour, especially its dynamics and persistence, remain mixed and inconclusive.

The green equity market seeks to promote environmental sustainability, yet its financial viability is closely tied to market efficiency. The effectiveness of low-carbon equity in financing green initiatives hinges on understanding the mechanisms of risk transmission—particularly among oil prices, indices of high carbon-emitting sectors, and green equity indices aligned with "dual carbon" goals (Dai, Zhang, & Yin, 2023). Findings related to volatility dynamics

and persistence vary widely. For instance, Chakrabarti and Sen (2021) analysed time-varying market risks in green equity investments across the Asia-Pacific, U.S., and European markets, revealing significant volatility contagion from local markets to green equities in the U.S. and Europe.

Analysing the spillover effects between conventional and green assets provides critical insight into the transition risks financial markets may encounter as economies shift aggressively toward low-carbon models. According to Li, Li, and Zhang (2023), comprehending these spillover dynamics is essential for developing effective risk management strategies in energy markets. This understanding can help investors, policymakers, and regulators anticipate and mitigate volatility and instability during the transition to sustainable energy systems.

Liu, Lu, and Shi (2023) analyse the interaction between oil shocks and both conventional and green assets, uncovering heterogeneous spillover effects. They find that instruments like WTI crude oil futures and heating oil futures are particularly sensitive to both demand- and supply-side oil shocks. Their findings underscore the importance of shielding conventional and green assets from such risks. However, the study falls short in addressing the broader implications for a wider range of green and traditional financial instruments, limiting its applicability for comprehensive portfolio or policy-level decisions.

Naeem, Ashraf, Karim, and Moussa (2024) conducted a comprehensive investigation into the risk mitigation potential of green assets across various financial instruments, including green stocks, bonds, cryptocurrencies, and carbon markets. Their findings revealed strong intra-class connectedness—indicating that assets within the same class are tightly linked—while cross-market interconnectedness remained limited. Furthermore, by examining dynamic NET spillovers, they identified which markets served as key transmitters and recipients of risk before and after the COVID-19 pandemic. The study highlighted persistent and significant risk spillovers throughout the observation period, underscoring the complexity of managing environmental financial risks in turbulent times.

Dai et al. (2023) analysed extreme spillover effects among high carbon emission stocks, green bonds, and WTI crude oil over the period from 2010 to 2022. Their study reported a static total spillover index of 49%, highlighting substantial interconnectedness across these asset classes. Using a quantile-based approach, they effectively

captured risk contagion under extreme market conditions. However, a key limitation of their work is the absence of a dynamic analysis, which would reveal how these relationships shift over time, particularly in response to varying market regimes. Additionally, the study found that green bonds and WTI crude oil generally acted as net receivers of systemic shocks, exhibiting asymmetric behaviours in bullish versus bearish markets.

Arif, Naeem, Farid, Nepal, and Jamasb (2022) explored the potential of green bonds as a hedging tool and safe haven for conventional investments across commodities, foreign exchange, fixed income, and equities. Their findings suggest that the green bond index can serve as a diversified asset for long-term and medium-term equity investors, providing stability in diversified portfolios. However, these results slightly contrast with those of Tiwari et al. (2022), who, based on hedging effectiveness, found that two-dimensional and multi-dimensional portfolios significantly reduce the risk associated with investing in individual assets.

However, this remains unclear with regard to green bond strategies, suggesting that further research into the return transmission process is needed. Such an investigation is crucial, considering its potential for enhancing portfolio construction and optimising risk management.

Climate policy and the link between green bond and green stock market

In recent years, extreme climate events have been occurring more frequently around the world. However, the combined impacts of the COVID-19 pandemic and geopolitical conflicts seem to have weakened global commitments to climate action. For instance, some G7 nations have decided to reopen previously decommissioned coal-fired power plants in response to the Russia-Ukraine conflict. The ongoing changes and implementations of policies have increased climate policy uncertainty, which could potentially slow down the progress of the green low-carbon transition in financial markets (Gong et al., 2022; Huang, 2023; Sun et al., 2024).

Recent studies have revealed significant differences in how traditional and green energy sectors respond to climate risks (Kong, 2024; Ren et al., 2023; Siddique et al., 2023). Therefore, when examining the green financial market, it is essential to take climate policy uncertainty (CPU) shocks into account. On one hand, existing research on climate policy uncertainty (CPU) has primarily

concentrated on its effects on individual markets, with limited studies exploring its influence on asset correlations (Syed et al., 2023; Xi et al., 2023). In the context of carbon neutrality, financial integration, and the rising levels of CPU, there should be increased focus on addressing systemic risks in the green financial market.

On the other hand, much of the existing literature on the impact of climate risks on financial markets relies on a linear framework (Gong, Song, Fu, & Li, 2023; Gong & Liao, 2024). In reality, many economic variables interact in a multi-channel manner (Cui et al., 2024; Shahbaz et al., 2017). The effect of climate policy uncertainty (CPU) on the relationship between the green bond and green stock markets may involve multiple interconnected channels. For instance, the asset substitution channel posits that as CPU rises, investors might shift their investments by buying green bonds and selling green stocks to hedge against risks, which could result in a negative impact. On the other hand, the financial contagion channel suggests that an increase in CPU could strengthen the interconnections between markets, leading to a positive impact. These factors could cause the impact of CPU on asset correlations to be non-linear and asymmetric.

In conclusion, the interrelationship between financial asset correlations, portfolio construction, and risk management is fundamental. Analysing the dynamic evolution of green financial markets provides insight into the mechanisms behind their price interlinkages, enabling investors to develop effective hedging strategies for mitigating market risks. Furthermore, investigating the nonlinear effects of climate policy uncertainty (CPU) on long-term correlations enhances our understanding of the alignment between different segments of the green financial market and supports regulators in refining risk control strategies (Chen et al., 2025).

The rapid growth of the green bond market has sparked interest in its risk-return profile. Compared to conventional bonds, green bonds often yield higher returns but also demonstrate greater price volatility (Flaherty et al., 2017). Amid rising financial integration and growing uncertainty, researchers have begun to explore the price linkages and risk spillover dynamics between green bonds and other financial markets. For instance, Dai et al. (2023) found that within the broader system involving green bonds and carbon-intensive (“brown”) stocks, green bonds predominantly act as recipients of systemic risk.

Asl et al. (2023) utilized quantile cross-spectral analysis and non-linear Granger causality techniques to reveal that the interactions

between green bonds and Islamic bonds are inherently nonlinear. Similarly, Wei et al. (2023) applied a time-varying parameter vector autoregression (TVP-VAR) model to examine the transmission of risk between green bonds and conventional financial markets. While this body of research has substantially advanced our understanding of green bonds' connections with traditional asset classes—such as equities, fixed income instruments, and commodities—the internal dynamics among green financial sub-markets, particularly among green instruments like green bonds and green equities, remain notably underexplored.

The green bond not only mobilises capital for environmentally sustainable initiatives but also functions as a hedge against financial market disruptions (Zhong et al., 2023). For instance, Jin et al. (2020) demonstrated that green bonds offer a cost-efficient means of hedging against risks in the carbon market. Similarly, Guo and Zhou (2021) explored the protective roles of both Chinese and U.S. green bonds during the COVID-19 crisis. Xia et al. (2023) further showed that green financial instruments, including green bonds, can effectively hedge against economic policy uncertainty (EPU). Importantly, recent findings by Xiao and Liu (2023) highlight that the impact of climate policy uncertainty (CPU) on market volatility is distinct from that of other uncertainty types.

On one hand, geopolitical tensions have caused some countries to scale back their climate commitments. On the other hand, the rising frequency of extreme climate events has reinforced global efforts to combat climate change. These opposing forces have collectively heightened climate policy uncertainty (CPU). As a result, when analysing optimal hedge ratios and portfolio allocations, it is crucial to assess whether green bonds can function as a safe haven for green stock markets during periods of elevated CPU.

There is a noticeable degree of co-movement among green financial markets, including green bonds. From a corporate resource allocation perspective, one of the primary objectives behind the development of the green bond market is to channel financial resources into the green sector, thereby easing the financing constraints faced by environmentally focused industries (Wang et al., 2022b).

This underlying purpose establishes an intrinsic link between green financial instruments. From a policy standpoint, both green bonds and green stocks fall within the broader green finance

ecosystem and are influenced by similar macroeconomic conditions. As such, their co-movements may signal channels for risk transmission across markets (Wang et al., 2023). Consequently, it is essential to investigate the underlying drivers of these cross-market co-movements to better understand and mitigate potential systemic risks within the green financial landscape.

Recent research on cross-asset correlations has increasingly considered factors like economic policy uncertainty (Guo et al., 2023), market volatility (Nakagawa & Sakemoto, 2022), geopolitical risks (Babaei et al., 2023), and investor attention allocation (Hu et al., 2023). However, with the recent and significant rise in climate policy uncertainty (CPU), it becomes crucial to investigate how CPU influences correlations within green financial markets. This examination can offer deeper insights into risk transmission and portfolio management under environmental policy volatility.

4. Conclusions

This paper aims to examine and analyse the evolving relationship between green energy stocks and market tendencies and dynamics within the context of the transition to a zero-carbon economy. The analysis is based on six scholarly references that address the subject from various perspectives within the specialised literature.

The first topic of the study explores whether green investments are connected to oil price shocks. One key finding from the empirical analysis is that green assets exhibit greater sensitivity to oil market volatility than to changes in oil prices themselves. This has important implications for portfolio managers. Since investors primarily aim to secure strong returns, even environmentally conscious investors are likely to include assets in their portfolios that not only align with sustainability goals but also offer competitive financial performance.

The transition was then to the impact of online environmental news on the stock returns of green industry companies in China. The empirical findings indicated that environmental news significantly impacted the stock returns of green companies in China, with investor sentiment partially mediating this effect. These results are likely to be of considerable interest to both policymakers and investors.

Next on the list was the duo of green energy indices and financial markets. Focusing on the global green energy index, the NEX monitors trends in the green energy market, with its composition

highlighting the dynamic and volatile nature of environmental markets, particularly in terms of inflows and outflows of index companies. To deepen the analysis, we selected a financial benchmark, traced its constituents over time, and compared them with the green index components. Our findings reveal limited overlap between the green and financial indices. This outcome is twofold, as it underscores that the index selection methodology excluded many companies that could potentially be involved in pollution.

The fourth topic of the analysis focused on the relationship between renewable and non-renewable energy markets and stock markets. The analysis could be extended to examine the long-term effects of the Russian invasion of Ukraine on investment and policy decisions. Encouraging a shift towards a more renewable and sustainable energy system may spur innovation within individual energy sectors, potentially increasing the stock market's dependence on fluctuations in renewable energy prices.

Moreover, the study aimed to rigorously analyze the volatility transmission between green and conventional equities across major financial markets in the United States, Europe, and China, covering the period from June 1, 2016, to December 31, 2023. To the best knowledge, no prior study has undertaken this specific analysis.

Last but not least, the latest topic that was tackled was the link between climate policy and green bond / stock market. The correlations between the green bond and green stock markets are relatively weak and display time-varying characteristics across different time scales, the cost of using green bonds to hedge green stock markets is relatively high, we observe that, in the event of extreme shocks to the CPU, green bonds do not appear to serve as a strong safe-haven asset for green stocks and ultimately, CPU shows an asymmetric, nonlinear positive effect on long-term relationships. On average, the long-term correlation between green bonds and the clean energy market is the most responsive to CPU, while the correlation with the green transportation market is the least affected by CPU.

The limitations of this study arise from the broad scope of the research topic. Each area explored in this literature review represents a separate field of study, and therefore, the goal was not to provide an exhaustive analysis or conduct a citation count or document frequency analysis. Future research could focus on these topics individually, providing a more detailed analysis with a greater emphasis on their implications for policy development.

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