

Unlocking economic insights: ESG integration, market dynamics and sustainable transitions[☆]

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ARTICLE INFO

Keywords:

ESG equity

Economic indicators

Financial markets

Energy and sustainability indicators

Time-frequency connectedness

ABSTRACT

The growing integration of ESG considerations into financial investments raises critical questions about the implications of ESG mainstreaming for economic activities. Our study examines ESG equity investments and their evolving relationships with future economic trends. By utilising wavelet coherence techniques on datasets spanning from 2011 to 2023 across both emerging and developed markets, we uncover significant interconnections between ESG investments and predictive economic indicators across medium- and long-term horizons. Our findings reveal that ESG investments exhibit a positive (inverse) correlation with favourable (adverse) economic indicators, playing a lagging role in forecasting long-term economic activity. The findings also underscore substantial regional disparities in the interaction between ESG equities and predictive indicators. Notably, the coherence between ESG investments and energy-sustainability indicators is less consistent and pronounced in emerging markets compared to developed markets. Our study provides strategic insights into optimal portfolio strategies for investors and delivers valuable guidance for market regulators and policymakers.

1. Introduction

The objective of our study is to investigate the relationship between ESG (Environmental, Social, and Governance) equity investments and predictive economic indicators. We address the following key research questions: (1) What is the nature and strength of the interconnection between ESG factors and economic indicators across varying markets? (2) Do ESG investments follow the movements of financial markets and economic indicators? (3) To what extent can ESG investments serve as reliable predictors of short-term and long-term economic growth, thereby identifying their potential role in shaping financial and economic dynamics?

ESG investments refer to financial assets or products offered by

companies that follow ESG investing strategies. The ESG paradigm has increasingly embraced by the corporate sector in its business practices and has gained popularity in recent years. This is evident in the substantial growth in ESG assets under management, which were estimated at \$35 trillion in 2020 and are expected to exceed \$50 trillion by 2025 (Global Sustainable Investment Alliance, 2020). According to the Bloomberg Intelligence, 2021 Midyear Outlook report, sustainable investments represent more than one-third of an estimated \$140.5 trillion in total global assets under management (Bloomberg, 2021).

Although the ESG industry has expanded globally, evidence on the relationship between ESG investments and macroeconomic conditions remains scarce. Few studies address whether ESG investments affect economic conditions or whether they contain any information about

[☆] We thank reviewers and participants from the 2023 International Conference on Sustainability, Environment, and Social Transition in Economics and Finance (SESTEF 2023) United Kingdom, 14–15–16 December 2023 and 3rd Annual Conference of the Academy of Sustainable Finance, Accounting, Accountability and Governance [ASFAAG], Valencia, Spain, 26th – 28th July 2023 for insightful comments. This publication is funded by University of Southampton Malaysia, the UoSM conference fund, project codes UoSM/CONF2023/1; UoSM/CONF2022/11 and is partially funded by the Faculty of Business and Economics, Universiti Malaya Special Publication Fund.

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future economic conditions. As ESG is a trending factor embraced by businesses and economies worldwide, financial markets and the corporate sector are incorporating ESG practices into their operations, environments, and business strategies. International industries and organisations are transitioning from conventional operational activities to environmental preservation and value-creation activities due to growing pressure from various stakeholders worldwide. However, the world currently faces several sustainability challenges. Many economies and industries are not well-prepared for a sustainable transition. Businesses are combating the challenges of meeting their sustainable development goals (SDGs) while achieving value creation and keeping their objectives of profit maximisation intact. As economies worldwide transform from trade proliferation to digitalisation and market interdependence, issues such as climate change, biodiversity, human rights, business ethics, and corporate governance are at the forefront of public and political attention. How companies and economies respond to these issues is becoming just as important as traditional financial metrics when evaluating their corporate and economic performance. This analysis plays a central role in investors' efforts to identify long-term opportunities and risks for decision-making.

The prior literature provides two important and well-established linkages between financial assets and economic activity. First, efficient asset markets optimise the allocation of resources for capital and economic growth. Second, financial efficiency and increased investment avenues increase capital productivity in the economy (Levine, 2005). Investment, financial markets, businesses, and economic growth are highly interconnected. Studies suggest that investors and asset managers consider economic policies and projections when making asset allocation decisions (Fama, 1990; Chatziantoniou, Duffy, and Filis, 2013). Additionally, understanding contemporary investment patterns and trends in financial markets helps gauge macroeconomic risk (Jank, 2012). As financial markets and industries transition from conventional business models to sustainable business practices, unexpected economic shocks are expected to significantly influence contemporary sustainable business policies and strategies. It is also plausible to expect that environmental sustainability and growing investments in sustainable projects may trigger expansion and growth, signalling positive developments for international investment, capital flows, business expansion, and economic growth.

With the recent emergence of sustainable finance and environmental protection, prior studies have investigated the risk, return performance, and diversification characteristics of ESG markets (Fatemi, Glaum, and Kaiser, 2018; Li, Gong, Zhang, and Koh, 2018; Cao, Duan, and Ibrahim, 2023; Liang, Zhang, and Li, 2024; Kim and Kim, 2024). In addition, some studies examine risk contagion among international ESG stock markets (Gao, Li, Zhao, and Wang, 2022; Umar, Kenourgios, and Papathanasiou, 2020). The findings suggest that ESG markets in developed economies are the primary sources of risk spillovers. However, few studies examine the impact of ESG securities on financial markets and economic growth. Despite the extensive literature on the risk and return performance of ESG, there is no empirical evidence on the linkage between ESG investments and predictive economic variables. Thus, to fill this gap, our study investigates the relationship between ESG and predictive economic indicators in both emerging and developed markets.

The study makes several significant contributions to the existing body of research. First, it provides the first empirical evidence on the linkage between ESG equity investments and predictive economic indicators, encompassing financial, energy, and sustainability metrics. To the best of our knowledge, this is the first study to explore these relationships comprehensively at the macro level. While prior literature has predominantly focused on assessing the return and risk profiles of sustainable securities at the firm or individual level (e.g., Pandey, Kumari, Palma, and Goodell, 2024; Ji and Nie, 2024; Abakah, Tiwari, Abdullah, Ji, and Sulong, 2024; Zhao, Yao, and Shen, 2024; Wang, Ali, and Ayaz, 2024), our research shifts the focus to broader macroeconomic interactions. This approach addresses the need to explore

“sustainability” beyond company-level ESG scoring frameworks, offering a more holistic perspective.

Second, our study adopts a time-varying connectedness approach using wavelet-based techniques to examine the dynamic relationships between ESG investments and predictive economic variables. Additionally, we employ partial wavelet coherence analysis to account for confounding factors such as market volatility and economic policy uncertainty. By incorporating a series of robustness tests and multiple coherence analyses, we expand the understanding of causality patterns and interactive relationships between ESG and economic indicators. Third, our research offers a comparative analysis of ESG investments in both emerging and developed economies, a perspective largely absent from previous studies. The emerging economies in our sample have made significant strides in adopting sustainable business practices and advancing ESG taxonomy development, as highlighted in the [Climate Bonds Initiative Report \(2022\)](#). Meanwhile, developed countries exhibit well-established ESG integration within their financial markets. Our study is the first to provide an in-depth comparative analysis of the interplay between ESG and predictive variables across these regions, offering critical insights into the dynamics of sustainability integration in different economic contexts.

Fourth, we provide interesting and insightful findings that are useful for asset allocation, portfolio management, and forecasting strategies. We detect strong connectivity between ESG and predictive economic variables in the medium- and long-term. ESG securities are positively (negatively) associated with the stock market (foreign exchange market and credit default swaps) and lag behind economic indicators over medium- to long-term horizons. The positive correlation between ESG and stock market indicates that ESG securities are favourable investments during periods of financial market growth. Our analysis reveals significant regional differences in examining the ESG equity relationships with financial and economic indicators. ESG shows strong coherence with stock markets in developed economies, reflecting alignment with equity dynamics, while its coherence with exchange rates and credit default swaps is negative, highlighting sensitivity to currency fluctuations. In emerging markets, ESG coherence with energy and sustainability predictors is weaker and sporadic due to regulatory and market instability, with ESG investments mainly reacting to financial market signals rather than predicting economic conditions. Moreover, we find that while ESG investments may not immediately predict economic changes in the long run, their performance can be a leading indicator in the short term.

The remainder of this paper is organised as follows: Section 2 provides a comprehensive literature review, theoretical framework, and hypothesis development. Sections 3 and 4 provide an overview of the data, variables, and methodologies. Section 5 discusses the results, analysis, discussion, and policy implications. The conclusions are presented in Section 6.

2. Literature review

We comprehensively review the existing literature on the interconnections between ESG investments, financial markets and clean energy. Our focus extends to exploring the relationship between ESG and macroeconomic fundamentals, highlighting the broader dynamics that influence these interactions. Furthermore, the literature emphasises the critical nexus between financial markets and economic fundamentals, underscoring the interconnected nature of these domains.

2.1. Theoretical framework

The theoretical foundation of this study is grounded in Arbitrage Pricing Theory (APT), which establishes the relationship between macroeconomic indicators and investment returns (Ross, 1976). APT posits that asset returns are influenced by multiple macroeconomic factors, such as inflation, interest rates, and GDP growth. When asset

prices deviate from their fair values due to these factors, arbitrageurs exploit the discrepancies, thereby restoring market equilibrium. This process ensures that asset prices reflect prevailing economic conditions. In essence, APT suggests that an asset's returns can be forecasted based on its sensitivity to macroeconomic variables, under the assumption that efficient markets correct mispricing and eliminate arbitrage opportunities.

Similarly, the Finance and Growth theory highlights the critical role of financial assets in influencing economic activity (Levine, 2005). Financial policies and reforms promote economic development by fostering savings, optimising capital allocation, and facilitating international trade. Enhanced financial efficiency and diversified investment avenues contribute to increased capital productivity. Research shows that economic policies and projections significantly shape asset allocation decisions (Fama, 1990; Chatziantoniou, Duffy, and Filis, 2013). Economic news exerts a multiplier effect, influencing households, industries, businesses, and financial markets. Within the finance-growth literature, McKinnon (1973) and Shaw (1973) introduced the supply-leading theory, which posits that financial asset growth drives economic growth, suggesting that financial market development has positive implications for economic development. Conversely, the demand-driven hypothesis proposed by Friedman and Schwartz (1963) argues that economic growth enhances the development of financial markets, implying an endogenous relationship between economic growth and financial development. Jank (2012) extended this perspective with the information response theory, which states that when investors and financial markets react simultaneously to economic information, these reactions can provide valuable insights into future economic conditions.

Building on these theories, Fama (1990) identified a significant impact of macroeconomic variables on stock market return volatility. Specifically, shifts in inflation and interest rates directly contribute to increased market uncertainty, particularly during periods of economic stress. Unexpected economic shocks, such as abrupt changes in GDP growth or inflation expectations, further exacerbate this volatility. Additionally, investor behaviour plays a pivotal role: during periods of economic uncertainty, heightened risk aversion among investors amplifies stock price fluctuations as portfolios are realigned to adapt to changing economic conditions.

The relationship between financial markets, volatility and macroeconomic indicators has been further advanced in subsequent research. Schwert (1989) demonstrated the substantial effect of macroeconomic conditions on stock market fluctuations, supported by later studies (Adrian and Shin, 2010; Ludvigson and Ng, 2007; Mittnik, Robinzonov, and Spindler, 2015; Park, Ryu, and Song, 2017). Schwert's analysis highlighted the time-varying nature of volatility, shaped by macroeconomic indicators, financial market conditions, and investor sentiment. Dixit and Pindyck (1994) argued that financial market uncertainty, arising from shifts in firms' investment behaviour during periods of high uncertainty, adversely impacts economic activity.

The countercyclical behaviour of stock market volatility has also been widely explored. Mele (2007) noted that asymmetric variability in risk premiums is influenced by economic conditions, driving countercyclical return volatility through the discount rate channel. Veronesi (1999) introduced the "learning effect" from behavioural economics, suggesting that investors overreact to adverse news during economic booms and underreact to positive news during recessions, further amplifying volatility. Financing liquidity and dividend yields are additional contributors, as discussed by Bansal and Yaron (2004) and Brunnermeier and Pedersen (2009).

Empirical studies have identified various predictor variables for stock market volatility, including macroeconomic uncertainty, economic policy uncertainty, geopolitical risks, credit conditions, dividend-price ratios, book-to-market ratios, stock-price variance, long-term returns, default yield spreads, Treasury bill rates, inflation rates, oil prices, and investor sentiment (Fama and Schwert, 1977; Campbell and

Shiller, 1988; Fama and French, 1989; Guo, 2006; Bomfim, 2003; Liu, Ma, and Wang, 2015; Cai, Chen, Hong, and Jiang, 2017; Ma, Wang, Lu, and Wahab, 2021; Salisu, Lasini, and Tchankam, 2022; Chen, Ma, Qiu, and Li, 2023). Recent research continues to explore these dynamics, emphasising the interconnectedness between stock market volatility and macroeconomic indicators (Giacomini and White, 2006; Clark and West, 2007; Pierdzioch, Döpke, and Hartmann, 2008; Paye, 2012; Corradi, Distaso, and Mele, 2013; Chun, Cho, and Ryu, 2020; Ghani, Guo, Ma, and Li, 2022; Li et al., 2023a, b; Song, Tang, Wang, and Ma, 2023; Li et al., 2024).

2.2. ESG and macroeconomic fundamentals

Economic indicators play an undeniably significant role in assessing the economic situation, guiding policy decisions, and serving as mechanisms to address economic challenges. However, the relationship between ESG performance and economic indicators remains underexplored, with the existing literature offering mixed and often contradictory findings. Some studies highlight a positive association between ESG performance and GDP growth (Zhu, Tian, and Wang, 2024; Diaye, Ho, and Oueghlissi, 2022). These studies suggest that regions with strong ESG performance tend to achieve higher economic growth through efficient resource utilisation and the effective implementation of economic policies. This perspective aligns with the principles of green growth theory, which posits that environmental, social, and governance initiatives contribute positively to economic growth by fostering sustainability and resource efficiency (North, 1990; Stern, 2008; Jacobs, 2013).

Conversely, a competing strand of literature raises concerns about the potential trade-offs between ESG performance and economic growth. Scholars supporting the degrowth theory argue that prioritising ESG policies may reduce consumption and production levels, ultimately slowing economic growth (Schneider, Kallis, and Martinez-Alier, 2010; Howarth, 2012). This perspective posits that the allocation of resources towards ESG objectives may detract from short-term economic priorities. For example, firms often redirect funds away from ESG proposals to align with government-driven economic goals, focusing instead on projects that promise rapid economic improvements (Zhang, Zhao, and Qu, 2021; Diaye, Ho, and Oueghlissi, 2022). Governments, too, frequently prioritise sectors that yield short-term economic gains, overlooking the long-term investments required for sustainable ESG development. These dynamics create significant funding challenges for companies attempting to pursue ESG initiatives.

Furthermore, the manipulation of economic indicators by governments and firms exacerbates these challenges, undermining both the quality of information and corporate transparency. The pressure on firms to meet government objectives often leads to distorted reporting practices, where environmental disclosures are unverifiable, and critical ESG developments are sidelined in favour of short-term profit goals (Cai, Li, Lin, and Luo, 2022). Such distortions negatively affect the credibility of economic indicators and reduce the quality of ESG-related reporting. This erosion of transparency diminishes stakeholders' trust in government policies and deters investors from allocating capital to ESG initiatives. As a result, reduced investment in ESG-related projects limits progress on sustainable development, while inaccurate economic signals hinder informed decision-making (Yao, Zhang, and Lin, 2023).

Overall, while the interaction between ESG performance and economic indicators holds significant potential, the existing evidence underscores the complexity of this relationship. The dual perspectives of green growth theory and degrowth theory reveal both opportunities for synergies and the risks of conflict between sustainability and economic growth objectives. To reconcile these competing dynamics, further research and policy efforts are needed to ensure that ESG integration does not come at the expense of either long-term sustainability or economic development.

2.3. ESG and financial markets

The existing literature increasingly investigates the dynamic interactions between ESG assets and traditional equities, highlighting significant interconnections and their implications for financial markets. Notable studies, such as [Almansour, Alshater, Marashdeh, Dhiaf, and Atayah \(2022\)](#) and [Sharma, Sarker, Rao, Talan, and Jain \(2022\)](#), provide valuable insights into this relationship. [Sharma, Sarker, Rao, Talan, and Jain \(2022\)](#) focused on the NASDAQ clean energy indexes, revealing heightened connectivity with conventional indexes in the post-COVID-19 period. Similarly, [Almansour, Alshater, Marashdeh, Dhiaf, and Atayah \(2022\)](#) observed substantial interconnectedness between the Dow Jones and S&P indexes with sustainability indexes, both during and prior to the pandemic, underscoring the growing relevance of ESG in mainstream financial markets.

Another strand of research examines the interactions between sustainable/ESG assets and commodities, offering nuanced insights into their dynamics with traditional financial benchmarks. [Sadorsky \(2014\)](#) finds that the Dow Jones Sustainability Index exhibits volatility and correlation patterns with gold and oil similar to those observed with the S&P 500. [Andersson, Hoque, Rahman, Uddin, and Jayasekera \(2022\)](#) confirm a bidirectional causality between conventional indexes and ESG assets, although they report a weaker causal association between commodity returns and ESG investments. Similarly, [Díaz, Esparcia, and López \(2022\)](#) emphasise the performance-enhancing potential of socially responsible investment (SRI) assets in portfolio construction, particularly highlighting the role of renewable energy-linked exchange traded funds (ETFs). [Çagli, Mandaci, and Taşkın \(2023\)](#) further note that ESG indexes generally act as net volatility transmitters, which contrasts with the behaviour of most commodities. [Jabeur, Khalfaoui, and Arfi \(2021\)](#), utilising machine learning techniques, demonstrate that elevated ESG index levels and clean energy adoption are correlated with reduced crude oil prices during the pandemic, underscoring the inverse relationship between sustainable energy and traditional fossil fuel markets. Additionally, [Umar, Kenourgios, and Papathanasiou \(2020\)](#) explored the dynamics between bonds, VIX, oil, MSCI ESG Leaders indexes, and economic policy uncertainty in emerging and developed markets. They concluded that, during periods of market turmoil, ESG indexes exhibit risk contagion and provide limited diversification benefits compared to their developed-market counterparts.

Further, [de Boyrie and Pavlova \(2024\)](#) investigate the connectedness between traditional equity indexes and ESG leader commodities across developing markets in Asia, Europe, and Latin America. Their findings reveal that shock transmission is predominantly concentrated within equity indexes, with limited spillovers from commodities. Additionally, they note significant regional variations in connectedness, highlighting the heterogeneous nature of ESG-financial market relationships across regions. Interestingly, the study finds no substantial differences in the diversification benefits of combining conventional developing market indexes or ESG leaders indexes with commodities in investment portfolios.

Overall, the reviewed literature points to a growing body of research examining the relationships between ESG assets and traditional financial indicators. However, most studies focus on firm- or industry-level analysis, and there remains a noticeable gap in macro-level research exploring ESG stocks and their predictive variables collectively. Additionally, comparative studies on ESG dynamics in developed and developing markets are largely absent. These gaps underscore the need for comprehensive investigations into the role of ESG investments in forecasting economic conditions and assessing a country's economic health. Moreover, the connections between ESG assets, energy, commodities, and sustainability indicators further highlight the multifaceted impact of ESG on financial markets.

2.4. ESG, clean energy and economy

Green finance has emerged as a vital tool for advancing the SDGs and ensuring energy security in both contexts ([Sun, Duru, Razzaq, and Dinca, 2021](#)). However, global investment in energy efficiency and renewable energy saw a 3 % decline in 2017, threatening environmental sustainability ([Sun, Duru, Razzaq, and Dinca, 2021](#)). Additionally, financial institutions often favour fossil fuel projects over green initiatives, citing the risks and lower returns associated with new technologies. The existing literature highlights the critical role of clean energy in achieving sustainable goals and ESG-driven development across both emerging and developed countries ([Gu, Renwick, and Xue, 2018](#); [Razzaq, Wang, Chupradit, Suksatan, and Shahzad, 2021](#)). [Gu, Renwick, and Xue \(2018\)](#) analysed the BRICS approach to sustainable development, green economic growth, and renewable energy adoption in Africa, underscoring the need for policy synchronisation between emerging economies and their global partners.

Recent policy initiatives in emerging economies, particularly within BRICS nations, have stressed the need to scale up renewable energy investments for sustainable development. [Paramati et al. \(2018\)](#) found a long-term positive relationship between renewable energy consumption and economic activity in G20 countries, highlighting its potential to reduce carbon emissions. In Africa, [Bugaje \(2006\)](#) emphasised renewable energy adoption as a solution to energy crises and environmental challenges. Conversely, [Khan, Ali, Dong, and Li \(2021\)](#) demonstrated that decentralisation significantly improves environmental quality by reducing carbon emissions in OECD countries, while [Ma, Wang, Lu, and Wahab \(2021\)](#) revealed that provincial economic growth in China—an emerging economy—exacerbates carbon emissions, posing environmental risks.

Several studies further establish the relationship between renewable energy and ESG practices, reflecting distinct dynamics in developed and emerging economies. [Yang, Du, Razzaq, and Shang \(2022\)](#) analysed G7 economies, confirming that green financing, clean energy, and green economy development significantly contribute to sustainable practices. Individually, green bonds, clean energy investments, and green economic development positively influence sustainability in these countries. [Fu et al. \(2024\)](#) examined China's economy using a time-frequency-quantile framework and found that, in the short term, clean energy equities play a critical role, while energy commodities provide the most benefits. Over the long term, ESG investments dominate as key contributors, followed by solar energy and coke investments.

[Sević, Nerantzidis, Tampakoudis, and Tzeremes \(2024\)](#) explore the interconnectedness and spillover effects among key sustainability indices—the Global Clean Energy Index, the Green Economy Index, the World ESG Index, and the Global Environment Index—using daily data. The study identifies the World ESG Index and the Green Economy Index as significant contributors, particularly during and after the pandemic. Meanwhile, the Global Environment Index served as a net receiver, and the Global Clean Energy Index transitioned to a net-receiving role post-2022. In addition, [Işık, Ongan, Islam, Balsalobre-Lorente, and Sharif \(2024\)](#) investigate the impact of economic and ESG factors on energy efficiency aligned with the SDGs in G7 countries, revealing that while economic factors negatively influence energy efficiency, environmental factors have a positive impact. These findings offer critical insights into the varying trajectories of sustainable development in emerging and developed economies, emphasising the importance of tailored approaches to address energy and environmental challenges.

2.5. ESG and predictive variables

[Jank \(2012\)](#) introduced the information response theory, which posits that the simultaneous reactions of investors and financial markets to economic information can serve as reliable indicators of future economic conditions. He further elaborates that certain economic predictor variables are more effective in forecasting fluctuations in investor

behaviour than in predicting market returns. Key financial and economic predictive variables discussed in the literature include stock market movements (Pan and Mishra, 2018), forex market fluctuations (Haddad, Lim, Pancaro, and Saborowski, 2013), credit default swap (CDS) spreads (Fama and French, 1989), and treasury bond (TB) rates (Hodrick, 1992; Caballero, Fernández, and Park, 2019).

In the realm of predictive economic variables, the role of ESG factors has received limited attention. For instance, evidence suggests that high-ranked ESG firms often operate in multinational environments, where currency market movements are significantly influenced by governance-related issues. Research further indicates that ESG factors can provide valuable insights into future currency valuations and affect the risk premiums associated with currencies. As a result, exchange rate fluctuations may have a greater impact on the stock prices of ESG firms compared to conventional firms. Filippou and Taylor (2021) find that ESG factors negatively predict currency returns, while Andersson et al. (2022) observe short-run causality from ESG portfolio returns to currency returns, highlighting the intricate link between ESG performance and currency markets.

Despite the critical importance of interest rates in valuing a wide range of financial instruments, limited research has explored their relationship with ESG. Since ESG investments typically have lower exposure to social, climate, and governance risks compared to non-ESG stocks, they often outperform during periods of crisis (Albuquerque, Koskinen, Yang, and Zhang, 2020). Consequently, it is plausible to anticipate that the interest rate exposure of ESG indices differs from that of traditional financial indices. Iqbal, Umar, Ruman, and Jiang (2024), in their examination of the return and volatility interconnectedness between the US Treasury term structure and ESG indices, conclude that the return and volatility spillovers of yield curve components shifted significantly during periods of turmoil, such as the COVID-19 pandemic and the Global Financial Crisis (GFC). Their findings emphasise the role of long-term interest rates as dominant shock transmitters during periods of economic distress.

The impact of CDS trading on firms' ESG performance is another underexplored yet compelling area of research. Extensive literature suggests that CDS trading reduces lenders' incentives to monitor a company's investment decisions, as credit risks are effectively transferred to CDS sellers (Pennacchi, 1988; Carlstrom and Samolyk, 1995; Morrison, 2005; Parlour and Winton, 2013; Arping, 2014; Zhao and Zhu, 2024). This dynamic often leads to more conservative decision-making and lower levels of investment in ESG projects (Bolton and Oehmke, 2011; Subrahmanyam, Tang, and Wang, 2017). Moreover, Barth, Hübel, and Scholz (2022) analyse the influence of ESG factors on CDS spreads and find that firms with strong ESG scores generally experience reduced credit spreads. However, the magnitude of this effect is modest and varies across sectors, highlighting the nuanced relationship between ESG and credit risk. Based on the above literature, we hypothesise the following:

H1. : There is a significant association between ESG equity and predictive economic variables.

H2. : Predictive economic variables have a significant influence on ESG equity.

H3. : ESG equity leads predictive economic variables and serves as a reliable indicator for forecasting future economic conditions.

3. Data and methodology

3.1. ESG data

This study examines the interrelationships between ESG equity and predictive economic indicators. Table 1 provides an overview of the variables, their definitions, and data sources utilised in the analysis. The ESG equity index for each country serves as the primary measure for

Table 1
Variable Description.

Variable	Abbreviations	Definition	Source
Environmental, Social and Governance Equity Index	ESG	MSCI ESG Leaders Index for emerging markets	MSCI Website
Financial and Economic predictive variables			
Stock Market Indices (Brazil, China, India, Indonesia, Malaysia, Thailand and South Africa)*	Stock	Sao Paulo SE Bovespa Index	Refinitiv Eikon
		Shanghai Shenzhen CSI 300 Index	
		S&P BSE Sensex Index	
		Jakarta Stock Exchange Composite index, FTSE Bursa Malaysia KLCI Index, SET Index	
		FTSE/JSE SA Top 40 Companies Index	
Exchange rate	EX	Exchange rate Home/USD	Refinitiv Eikon
Credit default swap	CDS	Credit Default Swap spread is the CDS premium at the end of each period.	Refinitiv Eikon
Treasury Bill	TB	Treasury bill rate taken at the end of each period.	Refinitiv Eikon
Energy and sustainable predictive variables			
Brent Crude oil	BCO	Reflect the market value of crude oil	Bloomberg
Green Energy Index	GE	Tracks the performance of companies primarily engaged in renewable energy sectors, such as wind, solar, and hydro.	Bloomberg
S&P Clean Energy Index	CE	Focuses on companies developing and producing clean technologies, such as energy storage, electric vehicles, and carbon capture.	Bloomberg
DJ Sustainability Index	SI	Tracks companies meeting Environmental, Social, and Governance (ESG) criteria. It reflects corporate commitment to sustainable practices and societal impact.	Bloomberg
Control Variables			
Fear/Volatility Index	VIX	measures the expected volatility of the stock market over the next 30 days. Index measures the uncertainty in economic policies based on media coverage, policy documents, and disagreement among economic forecasters.	Bloomberg and Investing.com
Economic policy uncertainty index	EPU		Bloomberg and https://www.policyuncertainty.com/

The Table 1 describes the variables, definition, sample and data sources. The initial sample includes developing countries: Brazil, China, India, Indonesia, Malaysia, Thailand and South Africa.

* The sample is then extended to include developed countries: Australia, Canada, Japan, Sweden, Switzerland, United Kingdom, United States of America. The stock market indices for these developed countries are as follows: S&P/ASX 200 Index (Australia), S&P/TSX Composite Index (Canada), Nikkei 225 Index (Japan), OMXS All-Share Index (Sweden), SMI PR Index (Switzerland), FTSE 100 Index (United Kingdom), and NASDAQ 100 Index (United States).

investigating this relationship. ESG data were sourced from the official Morgan Stanley Capital International (MSCI) Index website, ensuring the accuracy and reliability of insights into ESG performance. Among leading ESG stock indexes—such as the S&P 500 ESG Index, and the Nasdaq-100 ESG Index—MSCI is recognised as the largest global provider, offering a comprehensive suite of over 1500 equity and fixed-income ESG indexes (Wan, Yin, and Wu, 2024).

Following the methodology of Wan, Yin, and Wu (2024), we utilise the MSCI ESG Index, which covers major countries and regions worldwide. Furthermore, we employ the MSCI ESG Leaders Index, which includes firms with the highest ESG scores within their respective sectors, to capture the nuances of ESG stock market dynamics effectively. Investing in ESG stocks aligns with supporting companies that demonstrate superior ESG performance (Chen and Lin, 2022). For emerging markets, the MSCI ESG Leaders Index covers seven countries: Brazil, China, India, Indonesia, Malaysia, Thailand, and South Africa. To provide a comparative perspective, we also analyse the relationship using the MSCI ESG Index for developed markets. The MSCI ESG Leaders Index for developed markets comprises seven countries: Australia, Canada, Japan, Sweden, Switzerland, the United Kingdom, and the United States. The selection of these countries was based on data availability from the MSCI database. The dataset includes monthly observations spanning from 2011 to 2023, chosen according to the available data from the MSCI website.

3.2. Predictive variables (baseline economic and financial predictors)

For predictive indicators, we utilise stock market indices (stock) for each country, exchange rates (EX), credit default swap (CDS) spreads, and treasury bill rates (TB), as suggested by Jank (2012), Pan and Mishra (2018), Haddad, Lim, Pancaro, and Saborowski (2013), and Caballero, Fernández, and Park (2019). These studies confirm that stock market variables, exchange rate fluctuations, T-bill rates, and CDS movements are essential economic indicators that provide forecasting information critical for investment planning and decision-making.

Movements in the stock market are strongly correlated with economic conditions, making them a robust gauge of economic growth and stability (Pan and Mishra, 2018). Additionally, fluctuations in the foreign exchange market offer valuable insights into anticipated macroeconomic changes (Haddad, Lim, Pancaro, and Saborowski, 2013). Caballero, Fernández, and Park (2019) utilised CDS spreads and T-bill rates as predictive indicators for future economic conditions. Fama and French (1989) found that CDS spreads reflect credit risk, signalling increased business and economic fluctuations. Furthermore, Hodrick (1992) and Shanken (1990) argued that T-bill rates reflect changes in monetary policy, which influence institutional investors' decisions. Qureshi, Qureshi, Shah, Rehman, and Shahzad (2020) and Qureshi (2022) indicated that greater volatility in exchange rates and CDS spreads suggests turbulent economic conditions, which have significant implications for investors.

3.3. Predictive variables (energy and sustainability predictors)

In addition to traditional financial indicators, we incorporate energy-related and sustainability variables into our research model. These variables include Brent Crude Oil (BCO), the Green Energy Index (GE), the Clean Energy Index (CE), and the Sustainability Index (SI). BCO serves as a key energy-related economic indicator, following the methodology of Yang, Agyei, Bossman, Gubareva, and Marfo-Yiadom (2024).

Their research investigates the interplay between oil, gold, and other macroeconomic indicators in predictive modelling. Furthermore, we utilise renewable energy market indicators — including the Green Energy Index (GE), Clean Energy Index (CE), and Sustainability Index (SI) — as additional predictors. These measures are inspired by studies from Lorente, Mohammed, Cifuentes-Faura, and Shahzad (2023), Mohsin and Jamaani (2023), and Younis, Shah, Missaoui, and Tang (2024). These studies demonstrate that renewable energy indicators are significantly connected to financial markets and economic risks, highlighting their potential as predictors for economic events.¹

Lins, Servaes, and Tamayo (2017) conclude that Sustainability Index (SI) serve as predictors of long-term economic growth, reflecting how firms' and corporations' strategies align with sustainability. Engle, Rangel, and Sun (2020) identify that the Green Energy Index (GE) exhibits positive correlations with increased capital flows and robust economic growth. The study by Kose, Ohnsorge, and Stocker (2020) suggests that Clean Energy (CE) movements are often followed by reduced inflationary pressures and economic adjustments. Finally, Campiglio, Monnin, and von Jagow (2018) highlight that renewable energy indices often presage financial market trends and future economic growth potential.

By examining these interrelations, we aim to provide a comprehensive understanding of how ESG equity interacts with various economic indicators and how these relationships can inform investment strategies and policy decisions. Tables 2 and 3 show descriptive statistics of all the variables in emerging and developed countries. Most indices display positive skewness with kurtosis values indicating flatter distributions in many cases. Furthermore, the JB statistics revealed that the series was not normally distributed with rare exceptions. The ARCH-LM test confirms the presence of ARCH effects in this series.

4. Methodology

4.1. Main estimation technique: Continuous Wavelet Transformation (CWT)

The wavelet method analyses the association among variables across different investment horizons by utilising dimensions such as time and frequency scales. Heterogeneous risk perceptions and expectations cause traders and investors to react differently to investment prospects. Thus, wavelet methods provide insights into varying cycle trends and interactions at multitude scales. Furthermore, unlike traditional time-series techniques, wavelets are effective in detecting lead and lag relations between nonlinear time series (Gallegati, 2012). In addition, this method does not require the assumption of conventional data generation procedures.

Our study utilises the continuous wavelet transforms, illustrated as $Na(p, q)$, which depict the projection of a wavelet $\psi(\cdot)$ onto the time sequence $a(t) \in k^2(\mathbb{R})$, i.e.

$$Na(p, q) = \int_{-\infty}^{\infty} a(t) \frac{1}{\sqrt{q}} \psi\left(\frac{t-p}{M}\right) dt \quad (1)$$

The important characteristic of this technique is its ability to decompose and subsequently reconstruct a time series $a(t) \in k^2(\mathbb{R})$ perfectly:

$$a(t) = \frac{1}{C_{\psi}} \int_0^{\infty} \left[\int_{-\infty}^{\infty} Na(p, q) \psi_{p,q}(t) du \right] \frac{dq}{M^2}, M > 0 \quad (2)$$

In addition, this technique conserves the potential of the detected

¹ We extend our gratitude to the anonymous reviewers for their valuable suggestions on incorporating energy and sustainability-based variables into our model. While additional variables, such as gold prices and the Climate Change Index, were considered for further analysis, they yielded insignificant results in most cases and have therefore been excluded from the reported findings.

Table 2
Descriptive statistics.

Brazil		Emerging/Developing Countries					
Variables	Mean	Max	Min	SD	Skew	Kurt	JB
ESG	6.6072	7.0700	6.0700	0.2572	−0.3014	−1.0607	20.066
Stock index	11.216	11.807	10.607	0.3294	0.1140	−1.4400	30.852
EX	1.1995	1.7500	0.4400	0.3893	−0.3390	−1.1101	25.142
CDS	5.2519	6.1900	4.6000	0.3443	0.3818	−0.0909	4.7233
T-Bills	2.1633	2.7473	0.7701	0.4702	−1.1491	0.7406	71.968
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	5.1895	6.5176	3.2908	0.4683	−0.2800	1.1820	9.8007
VIX	2.8607	3.9804	2.2523	0.3196	0.7739	0.4610	20.094
China							
ESG	7.1206	7.8500	6.5100	0.3298	0.2303	−0.8258	9.1221
Stock index	6.2525	6.7300	5.8400	0.2279	0.1178	−0.6692	3.6645
EX	1.8810	1.9910	1.8010	0.0491	0.3460	−0.9486	18.678
CDS	4.2685	5.2320	3.3710	0.3867	−0.1688	−0.5627	3.1887
T-Bills	2.7016	4.1200	1.1430	0.5862	0.2629	−0.4904	4.5481
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	5.7706	6.8782	3.2636	0.8031	−0.6518	−0.2943	24.958
VIX	2.8607	3.9804	2.2523	0.3196	0.7739	0.4610	20.094
India							
ESG	7.2990	7.8600	6.7300	0.3142	0.1763	−1.0602	13.825
Stock index	6.1846	6.7670	5.6470	0.2891	0.2634	−0.9962	15.379
EX	4.1822	4.4230	3.7870	0.1572	−0.7366	0.0908	23.766
CDS	4.5453	5.0270	4.2110	0.2339	0.8610	−0.6384	89.138
T-Bills	6.5821	11.180	2.9300	1.7841	−0.3783	−0.3368	6.6871
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	4.4440	5.6479	3.1507	0.4810	0.1689	−0.1941	0.9126
VIX	2.8450	4.1652	2.3430	0.2771	0.9624	2.1846	19.572
Indonesia							
ESG	7.0820	7.2900	6.6900	0.1132	−1.0273	1.0009	37.548
Stock index	0.4225	0.5180	0.2780	0.0449	−0.7114	0.5277	14.702
EX	9.4493	9.7000	9.0460	0.1789	−1.0197	−0.3368	116.72
CDS	4.8563	5.6620	4.1490	0.3585	0.0599	−0.8618	6.1913
T-Bills	5.1033	7.0000	2.1500	1.2339	−0.4754	−0.8762	27.086
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	5.2217	6.0803	4.4542	0.3819	−0.0140	−1.0350	10.114
VIX	2.8607	3.9804	2.2523	0.3196	0.7739	0.4610	20.094
Malaysia							
ESG	6.6178	6.9400	6.2000	0.2081	−0.1001	−0.9765	9.3662
Stock index	6.0514	6.3842	5.6873	0.1854	0.0686	−1.0329	10.475
EX	1.3426	1.5623	1.0852	0.1431	−0.5518	−1.2411	66.825
CDS	1.3182	1.4873	0.9651	0.1132	−1.2749	1.4030	72.558
T-Bills	2.8432	3.3200	1.7500	0.4731	−1.3899	0.5478	207.78
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.52254	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	5.2217	6.0803	4.4542	0.3819	−0.0014	−1.0350	10.114
VIX	2.8607	3.9804	2.2523	0.3196	0.7739	0.4610	20.094
South Africa							
ESG	7.1815	7.5500	6.7400	0.1336	−0.2257	0.8111	5.9437
Stock index	8.2102	8.4534	7.7335	0.1239	−0.8300	0.9267	18.525
EX	2.5337	2.9800	1.8800	0.2820	−0.7031	−0.4277	36.594
CDS	5.3312	6.0300	4.7600	0.2505	0.2261	−0.0564	1.4258
T-Bills	6.1319	9.1000	3.0000	1.2339	−0.0817	0.3840	2.1729

(continued on next page)

Table 2 (continued)

Brazil	Emerging/Developing Countries						
	Mean	Max	Min	SD	Skew	Kurt	JB
Variables							
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	5.2217	6.0803	4.4542	0.3819	−0.0014	−1.0350	10.114
VIX	2.8607	3.9804	2.2523	0.3196	0.7739	0.4610	20.094
Thailand							
ESG	7.2927	7.6300	6.9400	0.1383	0.1732	−0.3029	1.3113
Stock index	3.7983	4.0650	3.3810	0.1417	−0.5177	−0.1802	11.440
EX	3.4839	3.6390	3.3750	0.0591	0.3660	−0.7281	13.122
CDS	0.9385	1.4610	0.0720	0.3279	−0.6876	−0.1894	25.829
T-Bills	0.4585	1.2750	−1.2040	0.5669	−0.9641	0.3353	48.847
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	5.2217	6.0803	4.4542	0.3819	−0.0014	−1.0350	10.114
VIX	2.8607	3.9804	2.2523	0.3196	0.7739	0.4610	20.094

Note: The table provides descriptive statistics. ESG equity refers to Environmental, social and governance equity index price, Ex stands for Exchange rate, CDS refers to Credit default swap, T-Bills stands for Treasury Bill rate, GE is Green Energy Index, CE represents Clean Energy Index, BCO stands for Brent Crude Oil, SI is Sustainability Index, VIX for Volatility Index and EPU is Economic policy uncertainty index. Further, SD, Skew, Kurt, and JB stands for standard deviation, skewness, kurtosis and Jarque-Bera test of normality.

time series.

$$\|a\|^2 = \frac{1}{C_\psi} \int_0^\infty \left[\int_{-\infty}^\infty |Na(p, q)|^2 dp \right] \frac{d_q}{M^2} \quad (3)$$

The current study considers the abovementioned method in the form of wavelet coherence, which specifies the structure between two-time sequences in a bivariate archetype.

4.2. Wavelet Coherence (WC)

Wavelet coherence is a supportive tool that measures the magnitude of correlation between two series, considering both time intervals and frequency space. It helps to distinguish potential relationships between the two-time series. In particular, wavelet coherence strengthens correlation analysis by unveiling infrequent, periodic correlations between series without losing time-scale information. To examine the multiscale interrelations between ESG equity and economic indicators, we use wavelet coherence is used which is also considered a popular and widely applied time series methodology.

Torrence and Compo (1998) defined the cross-wavelet power and transform (CWT), explaining that the cross-wavelet transform can be specified by two time series $a(t)$ and $b(t)$ as

$$N_{ab}(p, q) = N_a(p, q)N_b^*(p, q) \quad (4)$$

where $Na(p, q)$ and $Nb(p, q)$ represent the continuous transfigures of $a(t)$ and $b(t)$, respectively; p denotes the location index; q is the estimate; and the combined joint is depicted by $(*)$. A cross-wavelet transform is used to compute the wavelet power using $|Na(p, q)|$. The cross-wavelet power spectra segregate the area in which a significant cluster is unveiled in the time-frequency domain compared to the time sequence under observation. The WC technique can assess particular parts of the time-frequency domain where unknown and important fluctuations occur in the correlation between the time sequence under consideration. Torrence and Webster (1999) demonstrated the adjusted wavelet coherence equation, which is formulated as follows:

$$W^2[p, q] = \frac{|M(M^{-1}Nab(p, q)|^2}{|M(M^{-1}N_a(p, q)|^2|M(M^{-1}N_b(p, q)|^2)} \quad (5)$$

M denotes the smoothing mechanism. The squared wavelet

coherence coefficient, $0 \leq W^2(p, q) \leq 1$, represents the range of wavelet coherence. A value close to zero indicates a low or negligible correlation, whereas a value near 1 signifies a high correlation. The Monte Carlo method was applied to ascertain the hypothetical allocation of the wavelet coherence (WC).

4.3. Partial Wavelet Coherence (PWC)

One limitation of continuous wavelet coherence is that it only captures the co-movements between two variables without accounting for external or third-party influences. Since external variables play a crucial role in shaping the relationship between variables, we apply Partial Wavelet Coherence (PWC) to control for these external impacts. Following Naeem, Husain, Bossman, and Karim (2024), we incorporate two external variables—VIX (Volatility Index) and the EPU (Economic Policy Uncertainty Index)—which are likely to influence the relationship among our primary variables. This approach allows us to isolate the direct relationship between the variables of interest while accounting for potential external shocks or confounding factors.

Given the high levels of financial market integration and the occurrence of various financial crises, the inclusion of the CBOE Volatility Index (VIX) and Economic Policy Uncertainty (EPU) is a justifiable choice (Naeem, Husain, Bossman, and Karim, 2024). Both variables have significant impacts on financial markets and serve as reliable indicators for assessing economic uncertainties and capturing market reactions, making them crucial for examining the dynamics among our primary variables. Following Aguiar-Conraria and Soares (2014), we apply the partial wavelet which is represented as:

$$R^2_{\left(\frac{ab}{c}\right)}(x, y) = \frac{|R_{ab}(x, y) - R_{ac}(x, y)R_{bc}(x, y)|}{\left|(1 - R_{ac}(x, y))^2 \parallel 1 - R_{bc}(x, y)\right|^2} \quad (6)$$

where $R_{ab}(x, y)$ and $R_{bc}(x, y)$ represent the wavelet coherence between the time series $a(t)$, $b(t)$ and $b(t)$, $c(t)$, respectively.

4.4. Vector Wavelet Coherence (VWC)

We employ the vector-wavelet methodology as a robustness measure to assess the overall coherence between variables in the model, following Bossman and Agyei (2022) and Oygur and Unal (2021). The

Table 3
Descriptive statistics.

Australia	Developed Countries						
	Mean	Max	Min	SD	Skew	Kurt	JB
ESG	6.7302	6.9700	6.3300	0.1011	−0.4986	0.8841	7.4177
Stock index	8.4262	8.6300	8.0400	0.1046	−0.5397	0.5861	7.3706
EX	0.8020	1.1000	0.6100	0.1326	0.8594	−0.6235	86.940
CDS	3.3692	4.5800	2.2600	0.4948	0.3162	−0.6799	9.4400
T-Bills	2.1035	4.8900	0.0000	1.2403	0.2101	−0.3802	2.3281
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	4.7389	5.8202	3.6134	0.4321	0.2397	−0.2529	2.1398
VIX	2.7007	3.6159	2.2691	0.2526	1.0460	1.0086	40.118
Canada							
ESG	6.9878	7.3400	6.6800	0.1392	0.4999	0.0685	7.8527
Stock index	9.4555	9.7700	9.1200	0.1319	0.2169	−0.1633	1.4546
EX	1.1223	1.4100	0.9400	0.1356	−0.7502	−0.9838	92.997
CDS	3.6118	3.7700	3.4000	0.1095	−0.4267	−0.9838	27.034
T-Bills	1.4315	5.3000	0.1200	1.2731	1.7705	2.2811	239.74
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	5.4985	6.5204	4.7111	0.3738	0.1179	−0.5642	2.4365
VIX	2.7132	3.4895	2.2865	0.2277	0.7116	0.2803	17.823
Japan							
ESG	6.8425	7.1800	6.4600	0.1794	−0.2606	−0.6449	6.6232
Stock index	2.5926	2.9000	2.2200	0.1756	−0.3524	−0.7573	13.084
EX	4.6777	5.0200	4.3300	0.1616	−0.3728	0.0454	3.9188
CDS	3.5637	4.9600	2.7400	0.5814	0.6101	−0.7083	36.048
T-Bills	−0.0611	0.1900	−0.3200	0.1264	0.1285	−1.0366	11.666
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	4.7056	5.4436	4.1584	0.2362	0.4774	0.4506	5.8987
VIX	3.0655	3.9108	2.6304	0.2365	0.5733	0.3400	9.1326
Sweden							
ESG	7.4719	7.7800	7.1300	0.1302	0.1790	−0.1629	0.9677
Stock index	5.2329	5.6206	4.8875	0.1439	0.5590	0.4090	8.2699
EX	2.1118	2.4131	1.7968	0.1651	−0.2595	−1.0300	16.371
CDS	2.9483	4.7080	2.1960	0.6212	1.1719	0.6814	82.024
T-Bills	1.1102	99.792	−0.8640	8.0285	11.903	143.32	18,189
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−2.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	4.6478	5.2105	4.1299	0.1673	0.2086	0.6981	4.8863
VIX	2.9986	3.7808	2.5688	0.2315	0.3938	−0.2847	6.7189
Switzerland							
ESG	7.3924	7.9200	6.8200	0.2675	−0.3016	−0.4216	4.9297
Stock index	9.1508	9.5500	8.7000	0.1990	−0.0994	−0.5337	1.9443
EX	0.9435	1.0300	0.7900	0.0438	−0.4831	0.2625	6.2816
CDS	3.6185	5.3700	2.7100	0.6647	0.9998	0.2352	61.363
T-Bills	−0.1564	1.9500	−1.0500	0.7860	1.2130	0.5734	104.05
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	5.3742	6.0714	4.7167	0.2913	0.1465	−0.3673	1.2850
VIX	2.9986	3.7808	2.5688	0.2315	0.3938	−0.2847	6.7189
UK							
ESG	6.5532	6.8000	6.2700	0.1084	0.1965	0.0116	1.1116
Stock index	9.1522	9.3500	8.8600	0.0926	−0.4837	0.8041	6.8834
EX	1.4106	1.7100	1.1200	0.1534	0.2911	−1.2995	32.099
CDS	3.3332	4.5600	2.3600	0.5033	0.2799	−0.2295	2.8365
T-Bills	0.8576	5.3500	0.0100	1.2569	2.4546	4.8096	630.18

(continued on next page)

Table 3 (continued)

Australia	Developed Countries						
	Mean	Max	Min	SD	Skew	Kurt	JB
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	4.9670	6.3248	4.1325	0.3957	0.5739	0.5490	8.3704
VIX	6.1204	13.538	−3.9120	4.2184	−0.4266	−0.5309	12.713
US							
ESG	4.9267	5.6000	4.1900	0.3888	0.0428	−1.0536	10.834
Stock index	8.6956	9.7300	7.6700	0.6151	0.0740	−1.2305	17.758
EX	1.1879	1.4800	0.9800	0.1125	0.6477	−0.5841	35.474
CDS	2.7867	4.1500	1.7000	0.5017	0.0960	−0.2869	0.4855
T-Bills	1.1945	5.4700	0.0400	1.5257	1.5289	1.2985	192.54
GE	5.6974	6.9500	4.7400	0.6009	0.6120	−0.7269	37.287
CE	6.6298	7.5500	6.0100	0.3759	0.6419	−0.7785	45.209
BCO	4.3004	4.8400	3.1200	0.3610	−0.5225	−0.2585	12.995
SI	7.2553	7.7100	6.7900	0.2420	0.2275	−1.0055	13.990
EPU	5.0219	6.2225	4.1570	0.3699	0.5215	0.4210	7.0373
VIX	2.8607	3.9804	2.2523	0.3196	0.7739	0.4610	20.094

Note: The table provides descriptive statistics. ESG equity refers to Environmental, social and governance equity index price, Ex stands for Exchange rate, CDS refers to Credit default swap, T-Bills stands for Treasury Bill rate, GE is Green Energy Index, CE represents Clean Energy Index, BCO stands for Brent Crude Oil, SI is Sustainability Index, VIX for Volatility Index and EPU is Economic policy uncertainty index. Further, SD, Skew, Kurt, and JB stands for standard deviation, skewness, kurtosis and Jarque-Bera test of normality.

methodology of Vector Wavelet Coherence (VWC) can be defined as follows:

$$VR_{a(b_1, b_2, b_3, \dots, b_n)}^2 \quad (7)$$

If a represents the return series for ESG equity, and the return series for Stock, EX, CDS, TB, BCO, GE, CE, SI, or uncertainty measures (such as the VIX and Economic Policy Uncertainty Index) are denoted as $b_1, b_2, b_3, \dots, b_n$, the squared n -dimensional Vector Wavelet Coherence (VWC) among them is formulated as²:

This can be rewritten as $VR_{b(q)}^2$ with the corresponding dimensions:

$$VR_{1(q)}^2 = 1 - \frac{C_d}{C_1^d} \quad (8)$$

5. Main empirical results and discussion

5.1. Preliminary analysis using dynamic conditional correlations (DCC)-GARCH model

We begin with a preliminary analysis to examine the correlations between ESG indices and baseline financial and economic indicators (Stock, EX, CDS, TB) in our initial sample,³ using the DCC-GARCH model (Engle, 2002).⁴ This analysis aims to determine the presence of time-varying correlations between ESG indices and economic indicators over time. Fig. 1 displays the plots of all variables, revealing significant correlations between ESG indices and economic indicators. However, the overall trend exhibits substantial fluctuations, with correlations turning negative during crisis periods such as the European debt crisis (2015–2016), the Sino-US trade war (2018–2019), and the COVID-19 pandemic (2020). Notably, the markets were severely impacted during COVID-19 crisis, with a downward trend in both regional ESG markets

and economic indicators. We observe significant volatility in ESG equity markets, CDS spreads, and stock indices across different regions, especially during these periods of market turmoil.

Post-2020, the ESG indices exhibited a gradual upward trend with smaller fluctuations, although this movement is observed to decline by 2021. Extreme peaks in ESG-stock, ESG-EX, and ESG-TB correlations, ranging from 10 % to 90 %, were observed in Brazil. In India, the ESG-stock and ESG-CDS plots displayed relative consistency compared to the continuous fluctuations observed in other countries. These plots showed extreme peaks ranging from 50 to 95 % and 10–30 %, respectively. Similarly, Malaysia's plots revealed relative stability and persistence. The ESG-EX correlation in China showed weak and short-lived correlations, indicating potential hedging opportunities for investors and portfolio managers.

Overall, the patterns of the variables across countries are highly volatile and unstable, with extreme values observed between 2015 and 2020. The post-pandemic recovery phase has been gradual. Additionally, before 2017, positive relationships between variables were observed; however, after 2017, the trends show a decline, and instability. The correlation patterns between ESG indices and predictive economic variables were predominantly negative after 2017, with varying magnitudes. This negative association confirms the hedging characteristics of ESG investments. Furthermore, high and sharp peaks are evident for most pairs, followed by a significant decline in 2021 and a subsequent reversal. In summary, our findings show the dynamic correlations between ESG indices and economic indicators, which are influenced by economic events and crises.

5.2. Main estimation: Continuous Wavelet Transform (CWT) in developing countries

To provide a broader analysis, this study examines the extent and direction of pairwise dependence between ESG equity and predictive economic indicators in both time and frequency domains. Fig. 2 presents wavelet coherence plots for ESG equity and predictive economic indicators. The horizontal axis represents time, while the vertical axis depicts frequency scales. Monte Carlo simulations were employed to estimate the results using a phase-based surrogate series, with a 5 % significance level denoted by the thick black contour. The cone of influence is represented by a thin curved white line, while power ranges

² Refer to Bossman and Agyei (2022) and Oygur and Unal (2021) for details on the VWC methodology.

³ Our initial sample focused on emerging markets; however, following constructive feedback from an anonymous reviewer, the scope was subsequently extended to include developed markets. We are grateful for this valuable suggestion, which has enriched the comprehensiveness of our analysis.

⁴ Refer to Engle (2002) for details on the DCC-GARCH methodology.

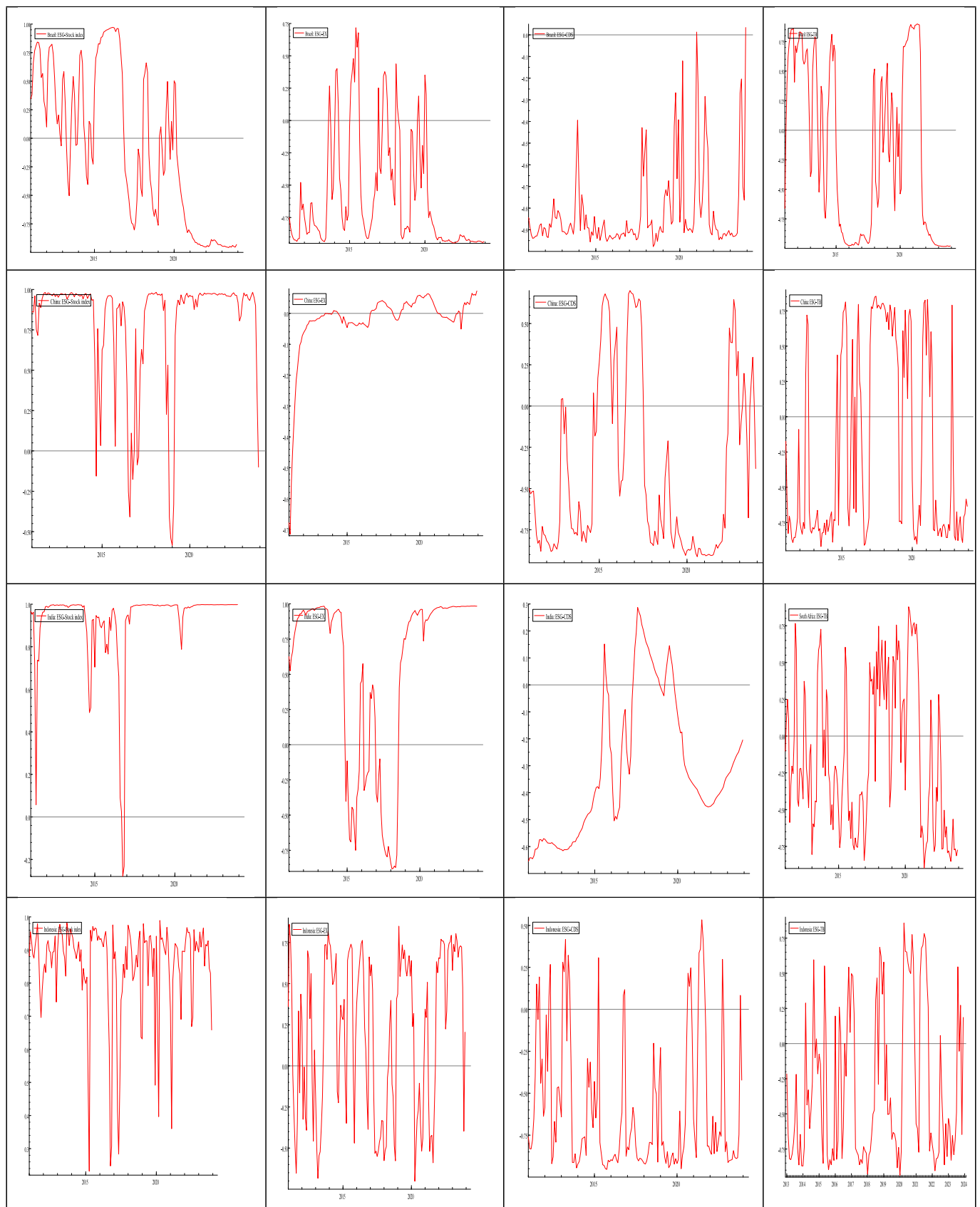


Fig. 1. shows Dynamic conditional correlation plots of ESG and economic indicator. ESG stands for Environment Social and Governance equity index, Stock stands for Stock indices, EX stands for Exchange rate, CDS stands for Credit Default Swaps and TB stands for Treasury bill. Source: Authors' own estimations.

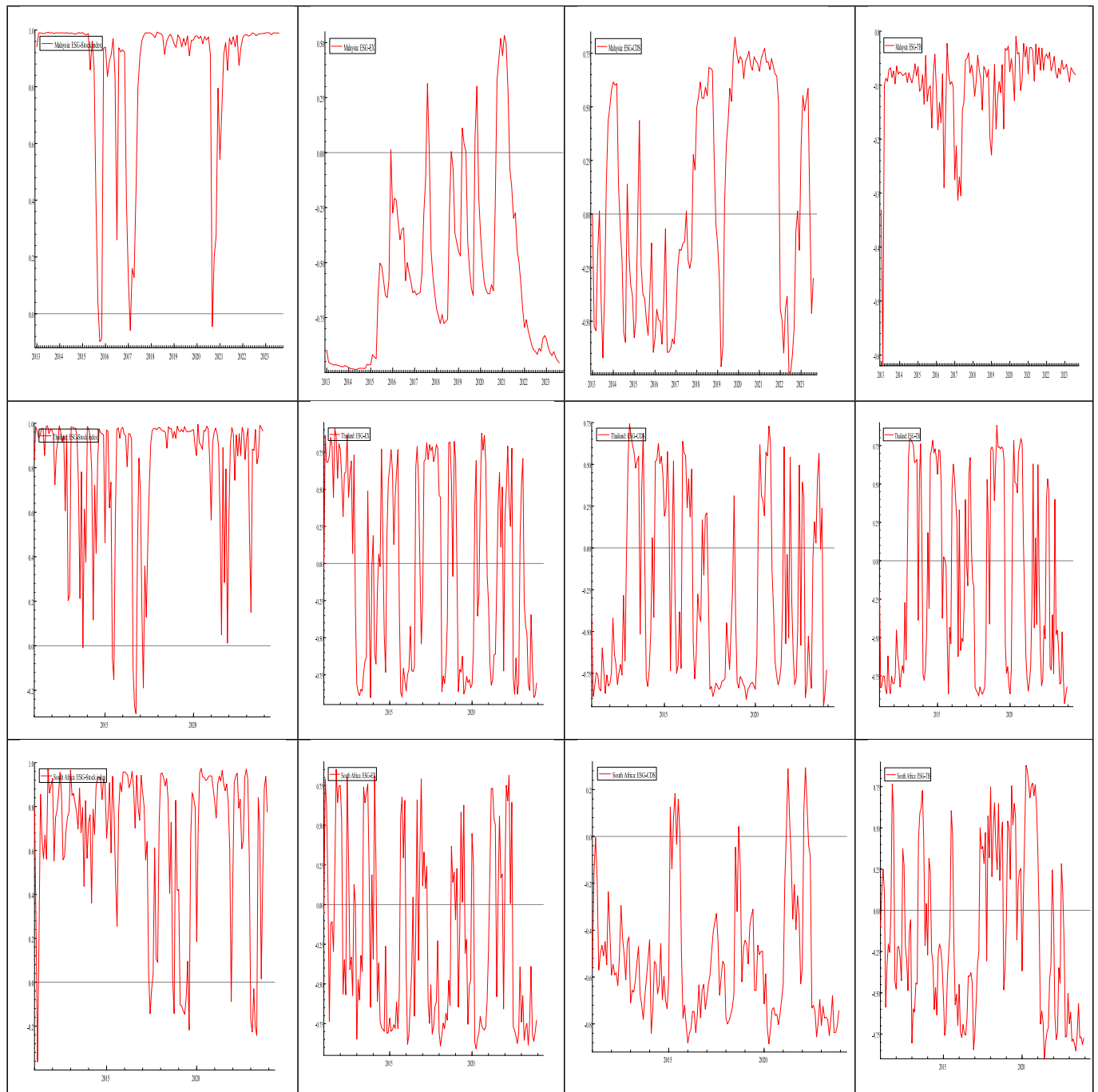


Fig. 1. (continued).

from blue to red, indicating low to high variations. Arrows on the plots denote phase relationships: right and left tails indicate in-phase (positive correlation) and anti-phase (negative correlation) relationships, respectively. Right-down or left-up pointing arrows signify that the first series leads, while right-up or left-down arrows indicate the second series leads.

From Fig. 2, it is evident that the coherence between ESG equity and the stock index in Brazil is prominent in warmer zones at medium to low frequencies, particularly across the 4–16-month scale during 2013–2022. This suggests a strong linkage during bullish economic and market conditions. Similarly, the coherence between ESG indices and the stock market in India is notably high, marked by a dramatic red swirl across all frequency scales. This indicates a significant relationship between ESG equity and stock market performance, providing support for

H1. Rightward arrows suggest positive co-movement between ESG equity and the stock index, while right-up arrows indicate that the stock market typically leads ESG movements, except during certain periods. Positive coherence is also observed in Indonesia, Thailand, and South Africa, implying that ESG equity closely follows stock market trends during favourable economic conditions. In Malaysia, predominant co-movements are evident at medium- and low-frequency scales between 2014 and 2022, indicating short-term anti-risk capabilities, as supported by Friede, Busch, and Bassen (2015). These findings contrast with Andersson, Hoque, Rahman, Uddin, and Jayasekera (2022), who found no long-term causality among ESG, stock, and currency returns.

Interestingly, limited coherence is observed in China, where the relationship between ESG equity and the stock market is intermittent and confined to lower frequencies. This rejects **H1** and highlights that

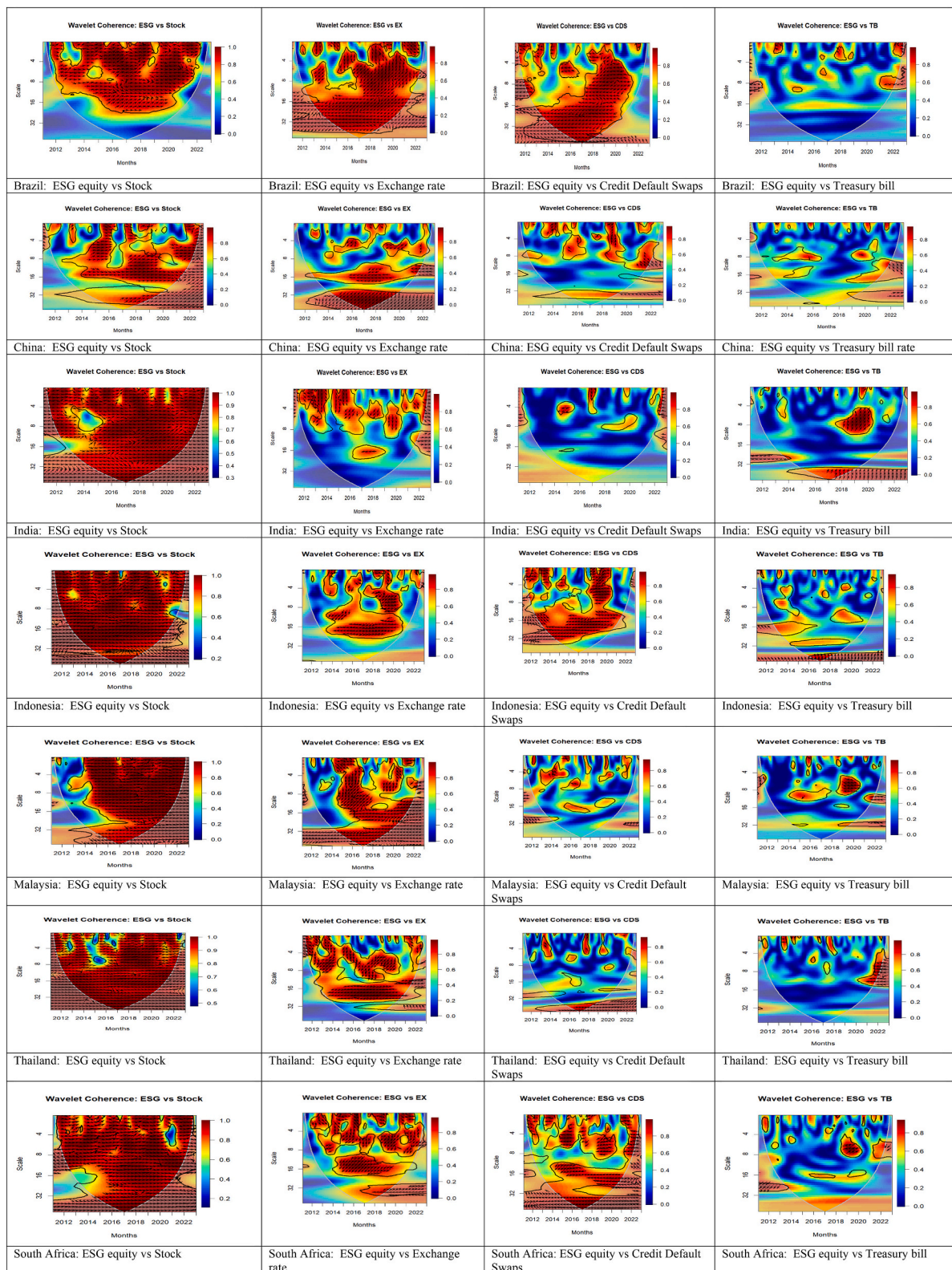


Fig. 2. shows the wavelet coherence pairwise plots on monthly data. ESG stands for Environment Social and Governance equity index, Stock stands for Stock index, EX stands for Exchange rate, CDS stands for Credit Default Swaps and TB stands for Treasury bill. The sample countries include Brazil, China, India, Indonesia, Malaysia, Thailand and South Africa. The black contour represents the 5 % significance level, and the white line indicates the cone of influence. The colour tonality ranges from blue to red, respectively, for low to high coherence. The arrows pointing towards right depict the in-phase pairs, while the arrows pointing to the left indicate the anti-phase pairs. The right down or left up pointing arrows signify that the first series is leading, while the right up or left down pointing arrows indicate the lead by the second series. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.) (Source: Authors' own estimations.)

investor responses to shocks in different asset classes vary significantly. The results also reveal strong positive co-movements between ESG and exchange rates (EX) in Brazil, Malaysia, and Thailand, although the anti-phase direction indicates an inverse relationship. In South Africa, ESG-EX pairs display intermittent interdependence across periods and frequencies. Frequency-varying correlations provide valuable insights for investors with different horizons, considering factors such as risk preferences, and cash flow needs. Transitory events like financial panics and shifts in market sentiment primarily affect short-horizon relations, while ESG-EX coherence is minimal in China and India. Overall, the findings suggest that ESG equity is highly sensitive to foreign exchange market fluctuations, often lagging behind EX variables and reacting inversely to adverse economic conditions.

The ESG-CDS pairs illustrate clusters of coherence during 2014–2020,⁵ signifying the leading role of CDS over ESG equity. Short-, medium-, and long-term relationships exhibit weaker correlations compared to EX, but significant linkages at lower frequencies are observed in Brazil, Indonesia, and South Africa. During this period, left-downward arrows indicate that ESG equity lags negatively behind CDS, implying an inverse relationship. This highlights the hedging properties of CDS against ESG equity, particularly during periods of economic uncertainty, when investors shift towards safer, and more liquid assets. However, the ESG-CDS relationship is largely insignificant in Malaysia, India, China, and Thailand. These findings confirm that ESG equity is influenced primarily by stock and forex markets, supporting H2. The lagged relationship implies that ESG equity lacks forward-looking information about future economic conditions, rejecting H3. Additionally, the relationship between ESG indices and treasury bills (TB) is negligible across all economies, indicating that TBs are an independent asset class with minimal influence on ESG markets.

In summary, ESG equity coherence demonstrates strong connections with the stock market, foreign exchange market, and CDS in most countries, with the notable exception of China. The findings suggest that ESG-stock pairs exhibit positive co-movements in both the short and long term, while ESG-EX and ESG-CDS pairs show negative linkages in the medium to long term. However, the minimal interaction between ESG equity and TB underscores the independence of treasury bills as an asset class, highlighting their limited role in the development of ESG markets in recent years.

5.3. Main estimation: Continuous Wavelet Transform (CWT) in developed countries

We extend the analysis of the relationship between ESG indices and predictive economic variables to a sample of developed countries, including Australia, Canada, Japan, Sweden, Switzerland, the United Kingdom, and the United States. Fig. 3 illustrates that the correlation between ESG indices and stock indices in Australia is notably strong, with a pronounced red swirl across all frequency scales. This high coherence underscores the significant relationship between ESG equity and the stock market. The positive co-movement, indicated by upward-right arrows, suggests that the stock market consistently leads ESG indices across all periods. Moreover, the coherence maps highlight that the strongest co-movements occur across high-, medium-, and low-frequency scales during 2014–2022. Similar patterns of positive coherence are observed in Canada, Japan, Sweden, Switzerland, and the United States, where a significant relationship between ESG and stock indices is evident across all frequency scales and time periods. These findings provide robust support for H1 and H2, confirming that ESG indices closely follow stock market dynamics.

⁵ The average ESG portfolio experienced a decline during the early phase of the pandemic (Bloomberg, 2022). Due to weakened confidence in the markets, the chances of insolvency in CDS increases during crises. As a result, lenders become more risk averse, and lending terms tighten further.

Overall, the observed co-movements are predominantly positive, with stock indices emerging as leading economic variables during the study period. This suggests that ESG indices closely follow signals from stock markets, consistent with patterns seen in emerging countries. Across all the developed countries examined, significant coherence between ESG and stock indices is observed at medium to low frequencies, generally spanning the 4–16-month scale from 2013 to 2022, highlighting a strong linkage during bullish economic and market conditions. Additionally, the long-term uncertainty caused by the global pandemic further prompted ESG markets to align with movements in financial markets and securities. These findings align with the conclusions of [Paltrinieri, Dreassi, Migliavacca, and Piserà \(2020\)](#), who identified strong interconnectedness between sustainable securities and equity markets during periods of market turmoil. However, the results contrast with the findings of [Andersson, Hoque, Rahman, Uddin, and Jayasekera \(2022\)](#), who reported no long-term causality among ESG, stock, and currency returns.

Beyond the stock market, notable relationships between ESG indices and exchange rates are observed. In Australia, significant coherence is evident at both high and medium frequencies, suggesting that ESG indices closely follow foreign exchange market trends during favourable economic conditions. In contrast, an anti-phase relationship is observed in Canada, where leftward-upward arrows indicate that ESG indices negatively lead exchange rate movements, potentially forecasting adverse trends in the foreign exchange market. This finding aligns with [Filippou and Taylor \(2021\)](#), who identify a negative leading relationship between ESG and forex returns. In Japan, a brief negative relationship is detected in 2014, but this becomes insignificant in subsequent years. The ESG-exchange rate relationship remains negligible in Japan, Switzerland, and the United States.

Regarding credit default swaps (CDS), the findings reveal a negative anti-phase relationship in Australia, particularly at short, intermittent frequencies. This suggests that ESG indices lead CDS movements during these periods, lending support to H3. A similarly limited and intermittent negative relationship is observed in Japan between 2018 and 2020, while no significant relationship is detected between ESG indices and CDS in Canada, Switzerland, and the United States. Overall, the results indicate that, in developed countries, ESG indices are primarily influenced by fluctuations in stock markets, with select countries also exhibiting significant responses to foreign exchange market dynamics. Furthermore, the negligible relationship between ESG indices and treasury bills in developed countries corroborates earlier findings, suggesting that ESG indices are predominantly shaped by equity and foreign exchange market dynamics.

5.4. Continuous Wavelet Transform (CWT) using energy-related and sustainability predictors

In addition to the baseline economic and financial predictors, we conducted additional analysis to examine the relationship between ESG and predictive variables by incorporating energy and sustainability predictors into our model. Specifically, we utilised Brent Crude Oil (BCO), the Green Energy Index (GE), the Clean Energy Index (CE), and the Sustainability Index (SI) as additional measures, following the methodologies outlined in studies by [Lorente, Mohammed, Cifuentes-Faura, and Shahzad \(2023\)](#), [Mohsin and Jamaani \(2023\)](#), and [Younis, Shah, Missaoui, and Tang \(2024\)](#).

5.4.1. Developing countries

Fig. 4 presents the findings for emerging countries. The findings reveal intriguing patterns across these economies. In Brazil, the wavelet coherence analysis demonstrates that the relationship between ESG and both the Green Energy (GE) and Clean Energy (CE) indices is predominantly limited throughout the analysed period. Notable exceptions are observed during specific periods, such as 2015–2016 and 2019–2020, where higher coherence at high frequencies suggests a short-term

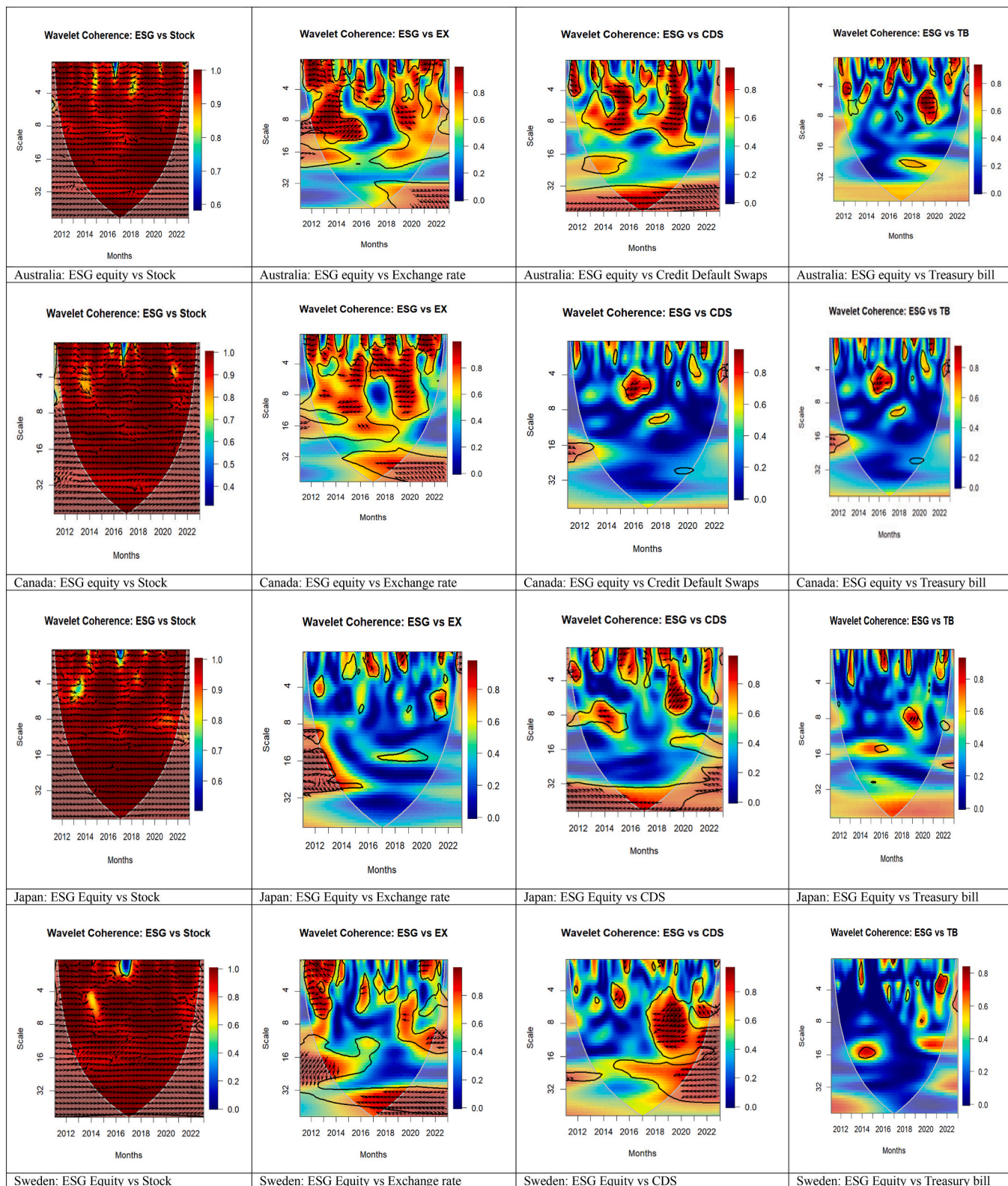


Fig. 3. shows the wavelet coherence pairwise plots using monthly data. ESG stands for Environment Social and Governance equity index, Stock stands for Stock index, EX stands for Exchange rate, CDS stands for Credit Default Swaps and TB stands for Treasury bill. The sample countries include Australia, Canada, Japan, Sweden, Switzerland, United Kingdom and United States of America. The black contour represents the 5 % significance level, and the white line indicates the cone of influence. The colour tonality ranges from blue to red, respectively, for low to high coherence. The arrows pointing towards the right depict the in-phase pairs, while the arrows pointing to the left indicate the anti-phase pairs. The right down or left up pointing arrows signify that the first series is leading, while the right up or left down pointing arrows indicate the lead by the second series. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Source: Authors' own estimations.)

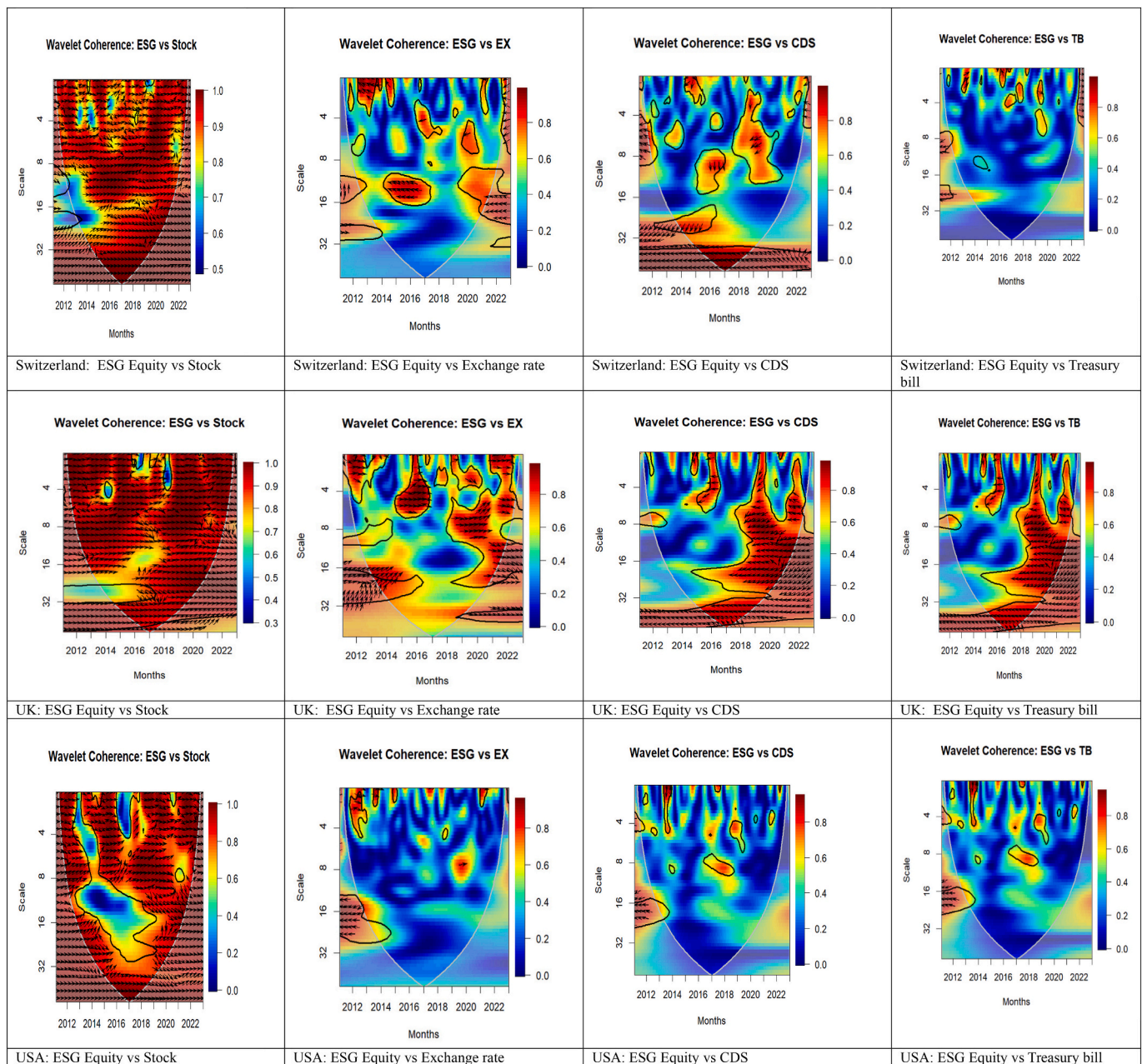


Fig. 3. (continued).

relationship between ESG and both GE and CE. Despite these observations, the overall relationship remains intermittent and inconsistent across the entire timeframe, indicating a lack of robust long-term coherence in the Brazilian context. A similar limited coherence is evident in the relationship between ESG, GE and CE for other emerging countries, including China, Malaysia, South Africa, and Thailand. However, India presents a distinct case, with substantial coherence observed between ESG and GE over short- to long-term periods from 2017 to 2022. Similarly, Indonesia shows significant coherence between ESG and CE over the same period, highlighting stronger connections in these contexts. These findings support H1, suggesting that ESG indices are significantly connected with clean energy predictive indicators.

A comparable trend emerges in the relationship between ESG and Brent Crude Oil (BCO). While higher coherence is observed intermittently at high frequencies during selected periods, the relationship remains largely insignificant throughout the analysis period. This pattern is consistent across the sample of emerging countries, indicating a lack

of a robust and sustained connection between ESG and BCO. In contrast, the coherence between ESG and the Sustainability Index (SI) is more pronounced. Across the sample of emerging/developing countries, significant coherence is evident during 2013–2016 and 2020–2022, particularly at high and medium frequencies. These results suggest a positive relationship between ESG and SI, with SI leading ESG equity during these periods. In China, a significant relationship between ESG and SI is observed from 2012 to 2018 at short to medium frequencies, underscoring the directional influence of sustainability-focused indices on ESG performance. India, on the other hand, exhibits high coherence between ESG and SI across high, medium, and low frequencies throughout the analysed period, suggesting a strong and consistent connection. Similarly, in South Africa and Thailand, high positive co-movements are observed, with SI positively leading ESG in the short to medium term over the entire time horizon. This supports H2, which implies that predictive variables influence ESG investment, causing ESG to follow sustainability predictive indicators. However, these results

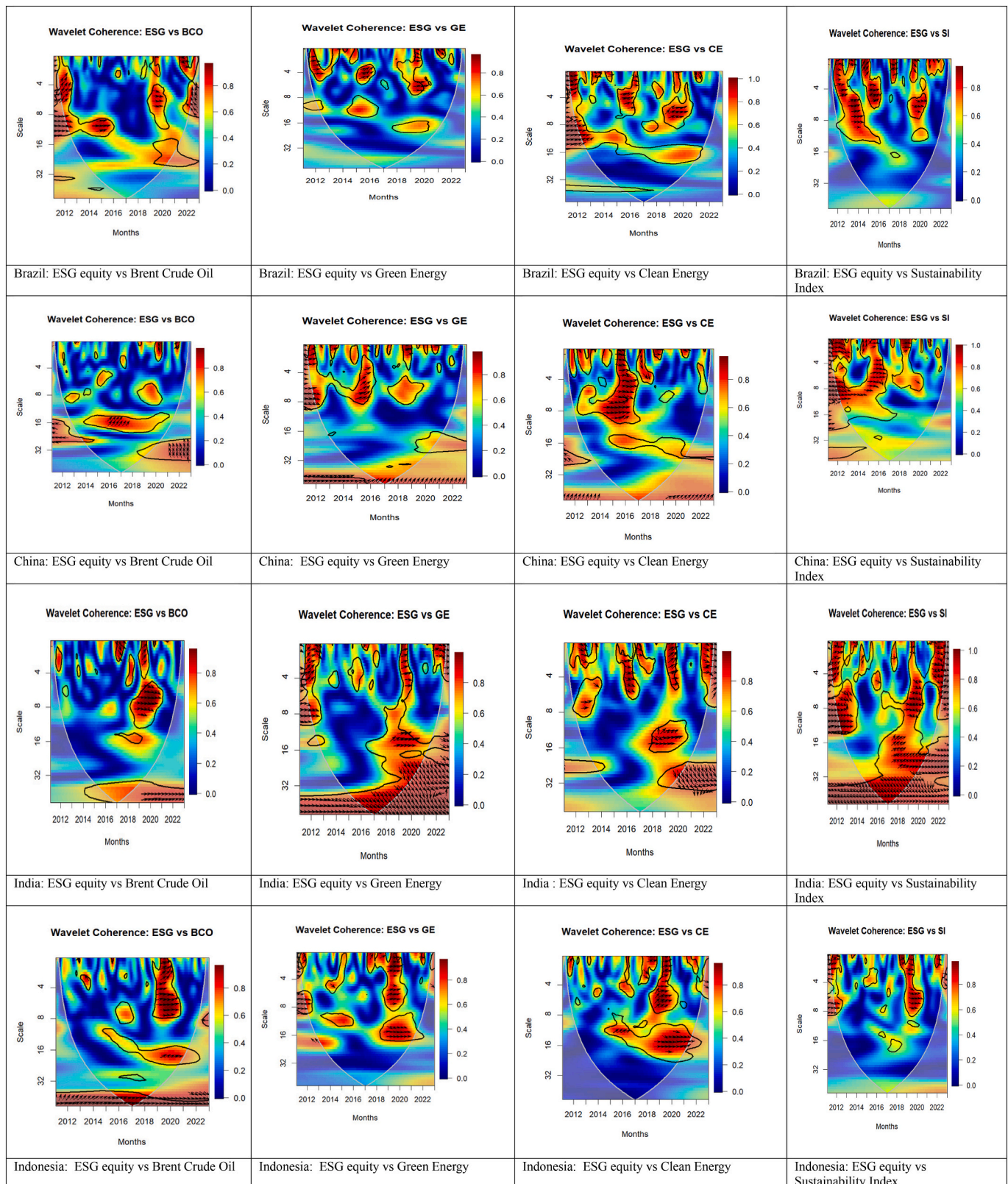


Fig. 4. shows the wavelet coherence pairwise plots. ESG stands for Environment Social and Governance equity index, BCO stands for Brent Crude Oil, GE stands for Green Energy Index, CE stands for clean energy index and SI stands for Sustainability Index. The sample countries include Brazil, China, India, Indonesia, Malaysia, Thailand and South Africa. The black contour represents the 5 % significance level, and the white line indicates the cone of influence. The colour tonality ranges from blue to red, respectively, for low to high coherence. The arrows pointing towards right depict the in-phase pairs, while the arrows pointing to the left indicate the anti-phase pairs. The right down or left up pointing arrows signify that the first series is leading, while the right up or left down pointing arrows indicate the lead by the second series. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Source: Authors' own estimations.)

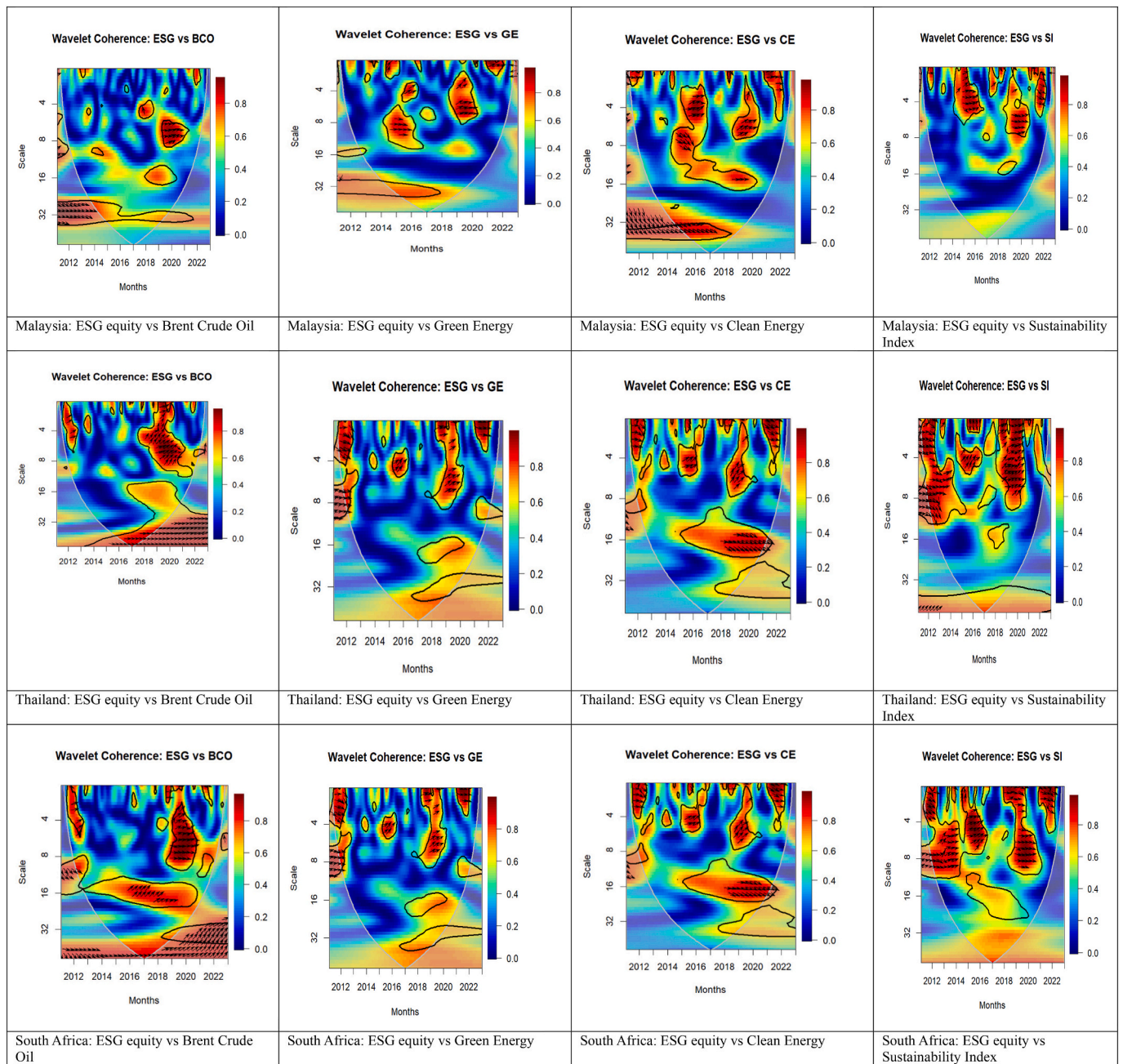


Fig. 4. (continued).

reject H3, which posited that ESG equity leads the predictive variables and may presage future economic conditions.

These findings highlight the varying dynamics of ESG coherence with different predictors across developing countries, emphasising the pivotal role of sustainability-focused indices in shaping ESG performance in specific contexts. Notably, ESG demonstrates stronger coherence with baseline economic and financial predictors compared to energy-related and sustainability predictors in developing countries. This stronger connection can be attributed to the nascent stage of ESG adoption in these markets and the challenges posed by underdeveloped regulatory frameworks (Gu, Renwick, and Xue, 2018). Additionally, the inconsistent integration of clean energy investments, driven by exogenous shocks such as high volatility, global commodity prices, geopolitical risks, and policy uncertainty, further weakens the relationship between ESG and energy-related or sustainability predictors (Umar, Kenourgios, and Papathanasiou, 2020).

5.4.2. Developed countries

We extend our analysis to the sample of developed countries to investigate the relationship between ESG indices and energy-related and sustainability predictors. The results are presented in Fig. 5. The sample includes Australia, Canada, Japan, Sweden, Switzerland, the United Kingdom, and the United States. The results indicate a notably high coherence between ESG indices and renewable energy indices in all developed countries. This is evident from the prominent red swirls across all frequency scales in the wavelet coherence plots, which signify a significant alignment between ESG and energy-related and sustainability predictors. The relationship between ESG and the Green Energy Index (GE) is particularly strong during the period 2015–2023 across short-, medium-, and long-term frequencies. At low frequencies, the rightward-down arrows suggest that ESG leads GE in the long term. Conversely, at short- to medium-term frequencies, the rightward-up arrows indicate that ESG follows the movements of GE. A similar

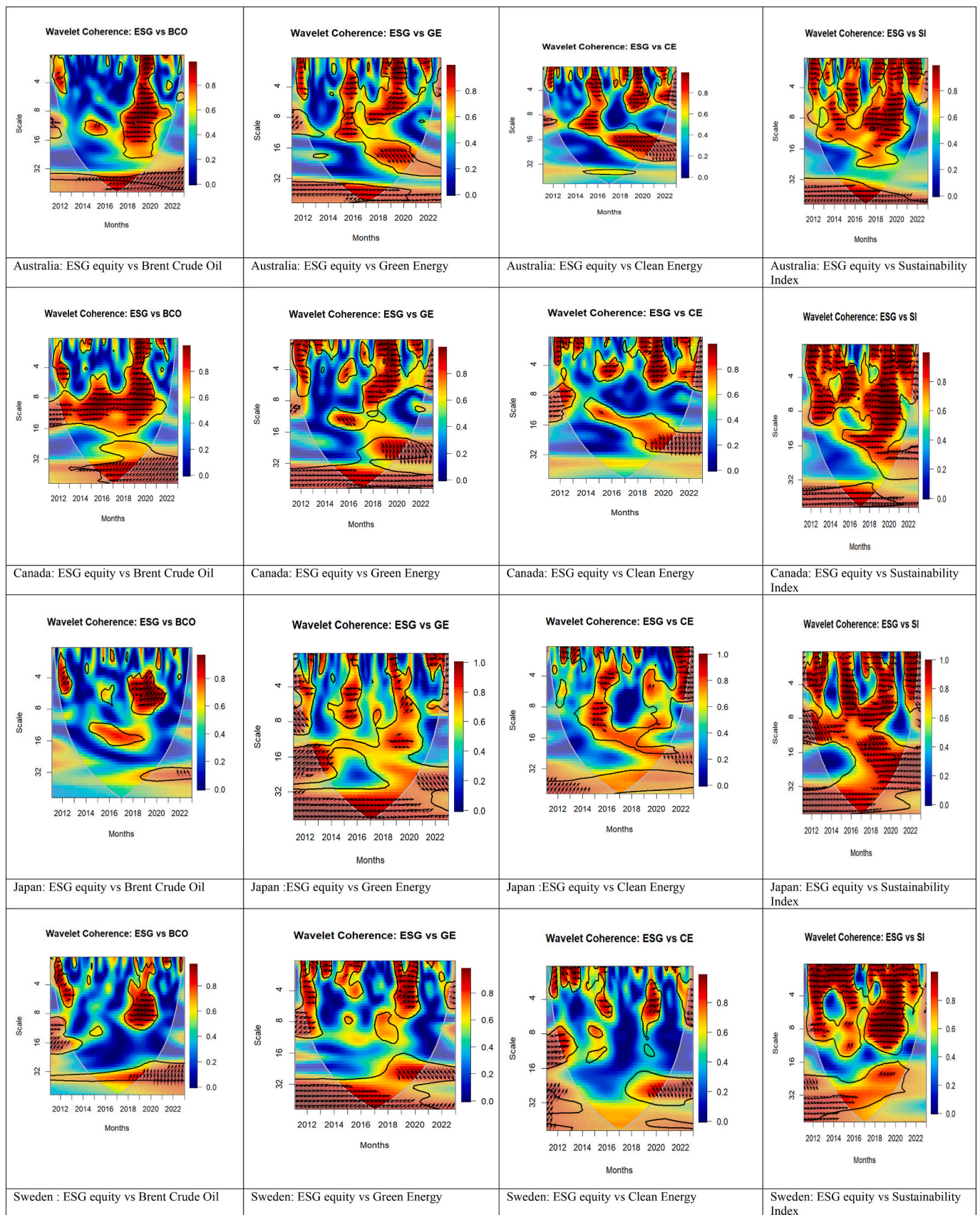


Fig. 5. shows the wavelet coherence pairwise plots. ESG stands for Environment Social and Governance equity index, BCO stands for Brent Crude Oil, GE stands for Green Energy Index, CE stands for clean energy index and SI stands for Sustainability Index. The sample countries include Australia, Canada, Japan, Sweden, Switzerland, United Kingdom, and United States of America. The black contour represents the 5 % significance level, and the white line indicates the cone of influence. The colour tonality ranges from blue to red, respectively, for low to high coherence. The arrows pointing towards the right depict the in-phase pairs, while

the arrows pointing to the left indicate the anti-phase pairs. The right down or left up pointing arrows signify that the first series is leading, while the right up or left down pointing arrows indicate the lead by the second series. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Source: Authors' own estimations.)

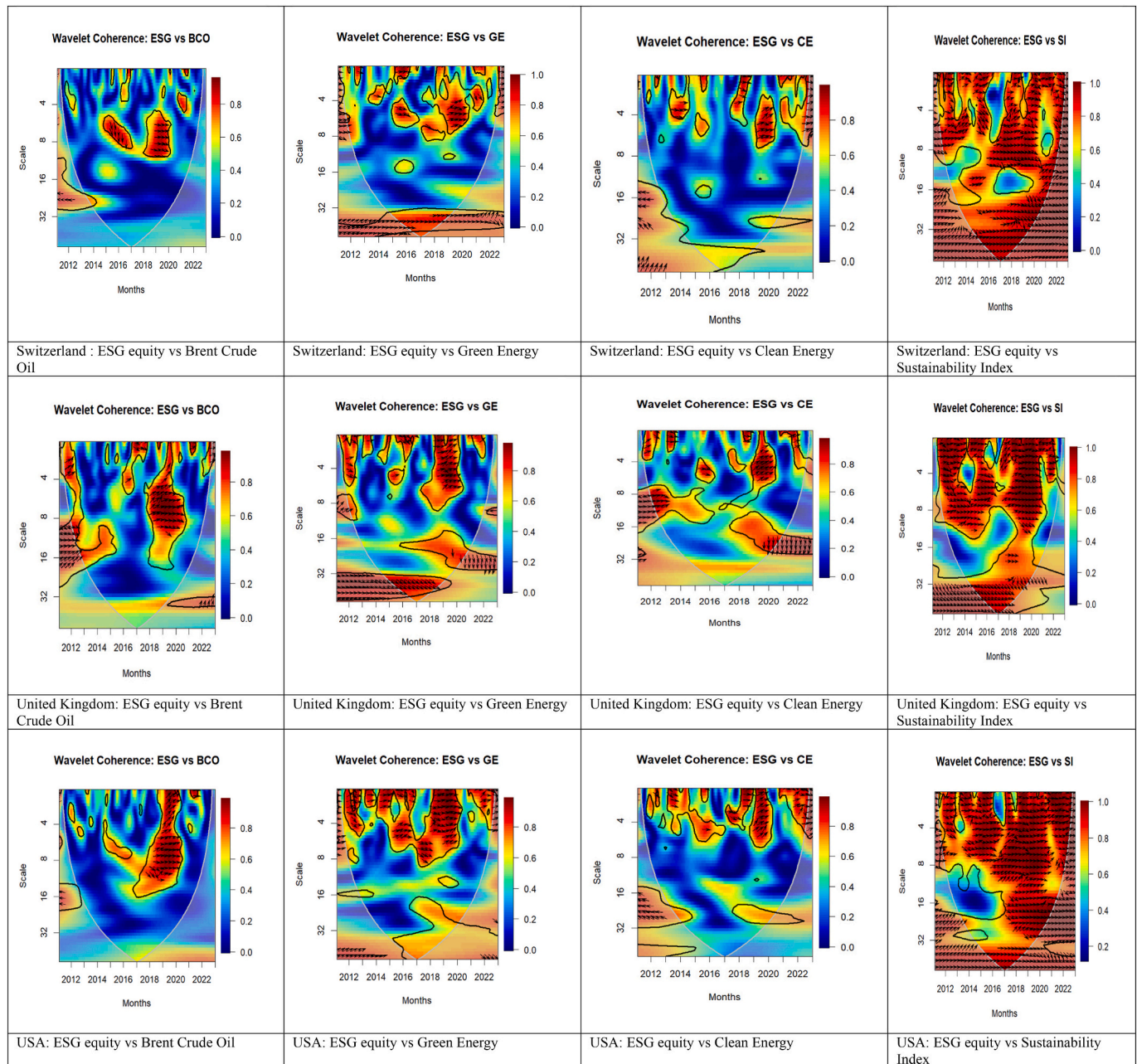


Fig. 5. (continued).

trend is observed between ESG and the Clean Energy Index (CE), where ESG leads CE over the long term during 2017–2020.

The ESG-BCO pairs exhibit significant coherence from 2017 to 2021 across all frequencies, with BCO consistently leading the ESG indices. The in-phase directional patterns indicate a favourable relationship between ESG and BCO in nearly all developed countries during this period. A plausible explanation for this phenomenon is the role of the oil market as a benchmark for energy transition dynamics, which gained heightened attention following the adoption of the Paris Agreement (IEA, 2021). Additionally, Gormus, Nazlioglu, and Gormus (2024) highlight that ESG investments are strongly influenced by oil price fluctuations, as companies tend to proactively respond to policy changes

in the energy sector, further reinforcing this relationship.

For the ESG- SI pairs, the rightward arrows indicate positive co-movement between ESG and the Sustainability Index (SI), while rightward-up arrows suggest that SI leads ESG across most timeframes. Significant linkages are observed at high, medium, and low frequencies, implying that ESG equity strongly aligns with SI, particularly during favourable economic conditions. This positive coherence is consistent across all developed countries in the sample, including Australia, Canada, Japan, Sweden, Switzerland, the United Kingdom, and the United States. These findings stand in sharp contrast to the results from the developing countries sample, where coherence between ESG and sustainability predictors—except for SI—is generally low to negligible.

Although ESG-SI pairs exhibit significant coherence in the developing countries sample, the relationship is more pronounced across all scales and time periods in the developed countries. The warmer zones observed at medium to low frequencies, typically spanning the 4–16-month scale from 2013 to 2023, indicate a strong linkage between ESG and SI during bullish economic and market conditions.

Overall, the positive co-movements and directional patterns suggest that the SI is a leading economic variable in developed countries, providing strong support for H2. ESG equity closely follows the strong signals from sustainability measures adopted by these nations, reflecting the advanced integration of sustainability into their economic and financial systems. The stronger interconnectedness between ESG equity and energy-sustainability predictors in developed countries can be attributed to advancements in green initiatives, the establishment of robust sustainability reporting frameworks, and comprehensive policy support for clean energy adoption (Ioannou and Serafeim, 2017). These elements foster a conducive environment for integrating ESG performance with sustainability strategies, setting developed economies apart from their developing counterparts.

5.5. Partial wavelet coherence

The Partial Wavelet Coherence (PWC) analysis provides the relationships between ESG and financial predictors, while controlling for the confounding effects of VIX (market volatility) and EPU (economic policy uncertainty).⁶ Figs. 6 and 7 present the plots for developing countries and developed countries, respectively.

In the context of Brazil, PWC reveals that both VIX and EPU exert a relatively stronger impact on the pairwise connectedness between ESG and stock indices compared to other predictors. By comparing the original coherence (Fig. 2) with the PWC results, we observe a substantial reduction in co-movement between ESG and stock indices after controlling for these confounding variables. This reduction indicates that VIX absorbs a significant portion of the variability in the ESG-stock relationship, underscoring the influence of market volatility on ESG dynamics.

When examining the temporal patterns, the significant coherence between ESG and stock indices observed in Fig. 2 notably diminishes in the PWC analysis. The red zones become more restricted to specific periods (e.g., 2013–2016 and 2019–2020) and medium-term frequencies. This finding implies that VIX significantly affects the ESG-stock relationship, with the initially observed association partly driven by market volatility. The reduced coherence highlights the critical role of economic risk and uncertainty in shaping ESG performance. These findings align with those of Umar, Kenourgios, and Papathanasiou (2020), who confirmed that the VIX influence ESG performance, emphasising that heightened market uncertainty significantly impacts the interconnectedness and risk transmission within ESG investments.

Similarly, EPU demonstrates a strong influence on the ESG-stock relationship. After controlling for EPU, coherence becomes more concentrated during specific periods, such as 2015–2017 and 2019–2021, which align with key policy-driven uncertainty events (e.g., Brexit, trade wars, and pandemic recovery). This suggests that the ESG-stock relationship in Brazil is indirectly influenced by policy uncertainty.

Interestingly, in the case of Brazil, the ESG-EX and ESG-CDS pairs maintain a stable and resilient relationship even after incorporating the confounding effects of VIX and EPU. A similar trend is evident in China, India, and Indonesia, where these relationships remain robust across

different conditions. However, in Indonesia and South Africa, the ESG-EX pair weakens due to the confounding effect of EPU, indicating greater sensitivity to policy uncertainty.

For energy and sustainability predictors, we observe a noticeable reduction in coherence between ESG and SI after controlling for VIX and EPU. This pattern is particularly evident in Brazil, South Africa and Indonesia, where the red zones are limited to medium frequencies around 2015–2016. This suggests that the direct relationship between ESG and SI weakens when the confounding effects of VIX and EPU are accounted for, emphasising the significant influence of market and policy-driven uncertainties on sustainability metrics.

Conversely, in China, the PWC plots exhibit strengthened coherence between ESG and Stock compared to the original analysis (CWC). The consistent and pronounced coherence at medium- and long-term frequencies indicates that removing the impact of VIX and EPU reveals a robust and intrinsic association between ESG and Stock. This in-phase relationship reflects the structural alignment of ESG principles with stock market dynamics in China, showcasing the resilience and stability of ESG integration in China's markets despite market volatility and policy uncertainty. A similar strengthened coherence is observed in India, Malaysia, and Thailand, particularly for ESG-stock and ESG-EX pairs.

In developed countries, the PWC results are largely consistent with the baseline model. The coherence between ESG and key predictors (e.g., Stock, EX, GE, SI) remains strong across short-, medium-, and long-term frequencies, even after controlling for VIX and EPU. This suggests a robust and intrinsic association between ESG and financial indices during periods of market stability. Notable exceptions include the ESG-stock-VIX relationship in Japan and the ESG-EX-EPU relationship in Canada, where coherence weakens due to the confounding effects of these variables. For most other relationships, the results indicate resilience, reflecting the integration of ESG principles into developed financial markets, which remain stable despite volatility and policy uncertainty.

While the results are mixed, the reduction in coherence due to VIX and EPU is more pronounced in developing countries than in developed countries. This finding underscores the susceptibility of ESG performance in emerging markets to heightened market and policy uncertainties (Zhang, Gao, Wang, Hao, and Wang, 2024). However, the continuing significant coherence in PWC plots suggests that ESG and financial and economic indices still maintain some direct, intrinsic relationships independent of external volatility and policy-driven uncertainties. This residual relationship highlights the intrinsic value of ESG investments in driving long-term performance.

Overall, the PWC results provide critical insights for investors and policymakers. Distinguishing between direct and indirect linkages driven by market volatility and policy uncertainty is essential when formulating sustainable investment strategies. These findings underscore the importance of accounting for macroeconomic factors, such as VIX and EPU, when analysing ESG dynamics. In particular, in developing markets, the influence of policy uncertainty on ESG-stock relationships emphasises the need for greater policy stability to strengthen ESG performance and foster resilient financial markets.

5.6. Vector wavelet coherence

Vector wavelet coherence (VWC) analysis provides results in the form of scalograms, represented as heatmaps that illustrate the strength of co-movements between variables. The x-axis denotes time, with observational counts at the bottom and years displayed at the top, while the y-axis represents periodicities or frequencies relevant to trading scales. A colour bar on the right indicates coherence levels, with warm colours (green to blue) signifying low coherence and hot colours (yellow to red) indicating high coherence. In VWC analysis, three variables create a multiple wavelet, four form a quadruple wavelet, and five or more generate an n-dimensional wavelet. The results are interpreted

⁶ The PWC analysis in this section focuses on variables that demonstrated significant results in the CWC analysis in Sections 5.2, 5.3 and 5.4. Variables that were insignificant in the CWC also exhibited similar insignificant relationships in the PWC analysis. For brevity, the results for these insignificant variables have not been included in this report but are available upon request.

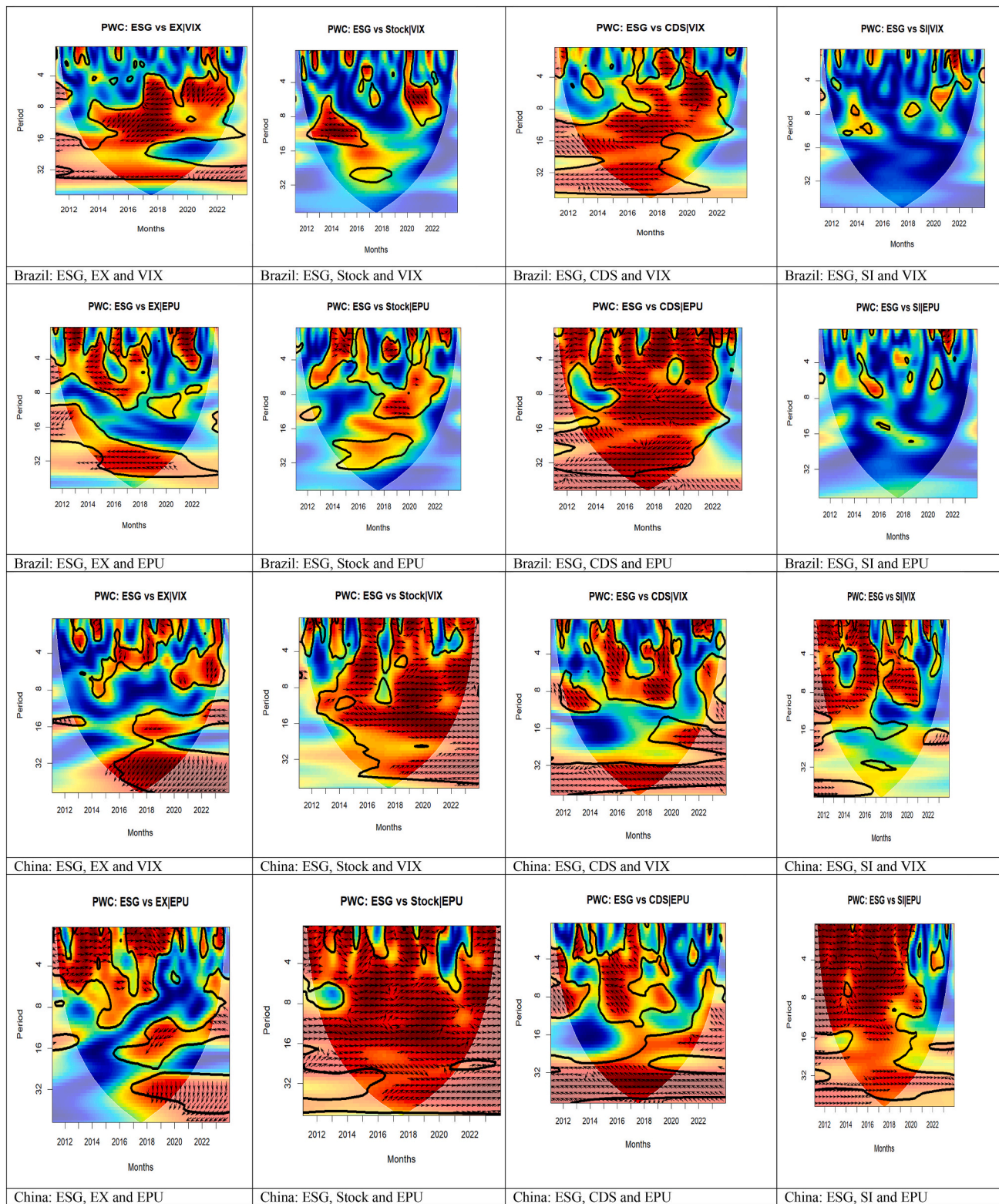


Fig. 6. shows the Partial wavelet coherence pairwise plots. ESG stands for Environment Social and Governance equity index, Stock stands for Stock index, EX stands for Exchange rate, CDS stands for Credit Default Swaps, SI stands for Sustainability Index, VIX stands for market volatility and EPU stands for Economic policy Uncertainty. The sample countries include Brazil, China, India, Indonesia, Malaysia, Thailand and South Africa. The black contour represents the 5 % significance level, and the white line indicates the cone of influence. The colour tonality ranges from blue to red, respectively, for low to high coherence. The arrows pointing towards right depict the in-phase pairs, while the arrows pointing to the left indicate the anti-phase pairs. The right down or left up pointing arrows signify that the first series is leading, while the right up or left down pointing arrows indicate the lead by the second series. Source: Authors' own estimations. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

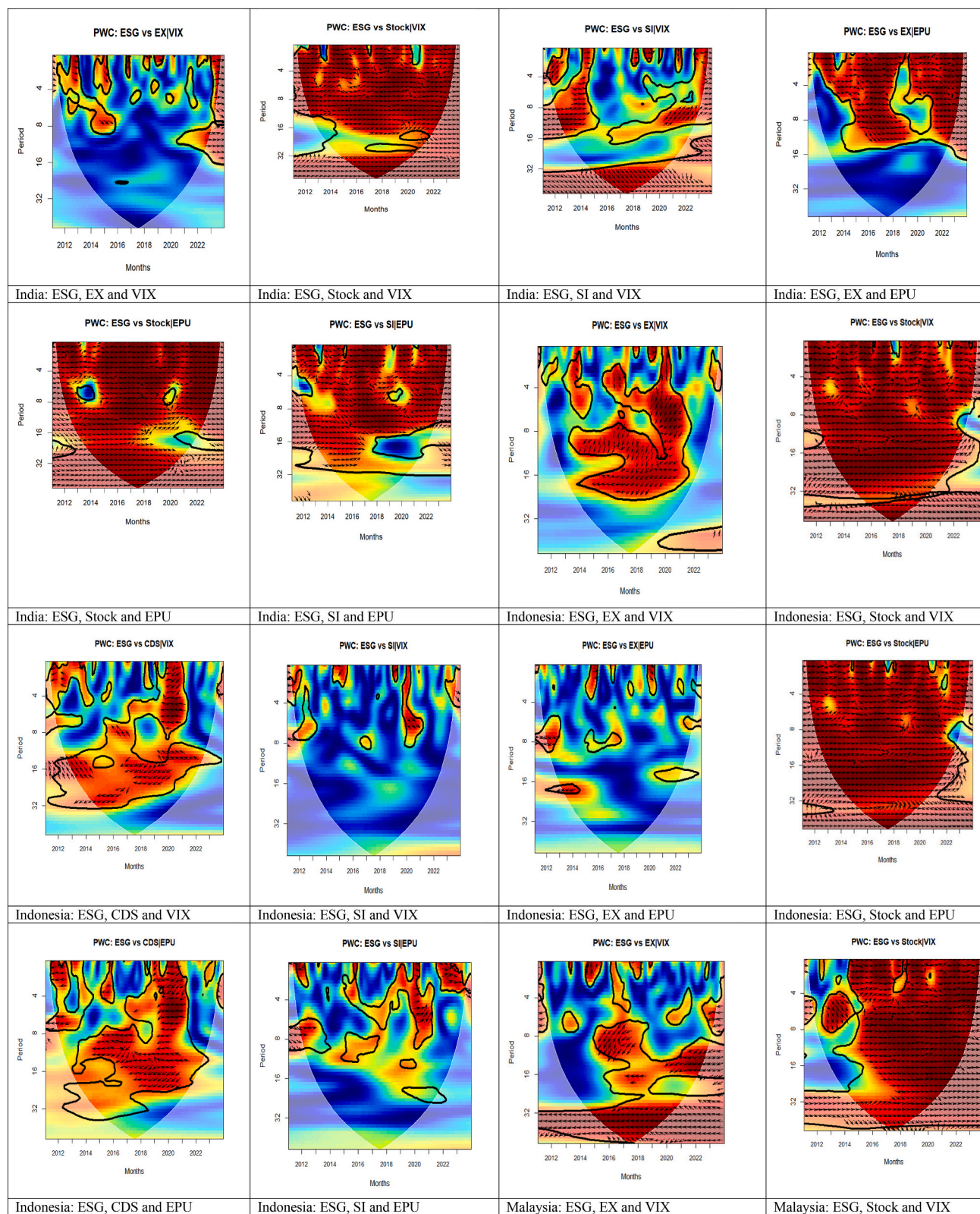


Fig. 6. (continued).

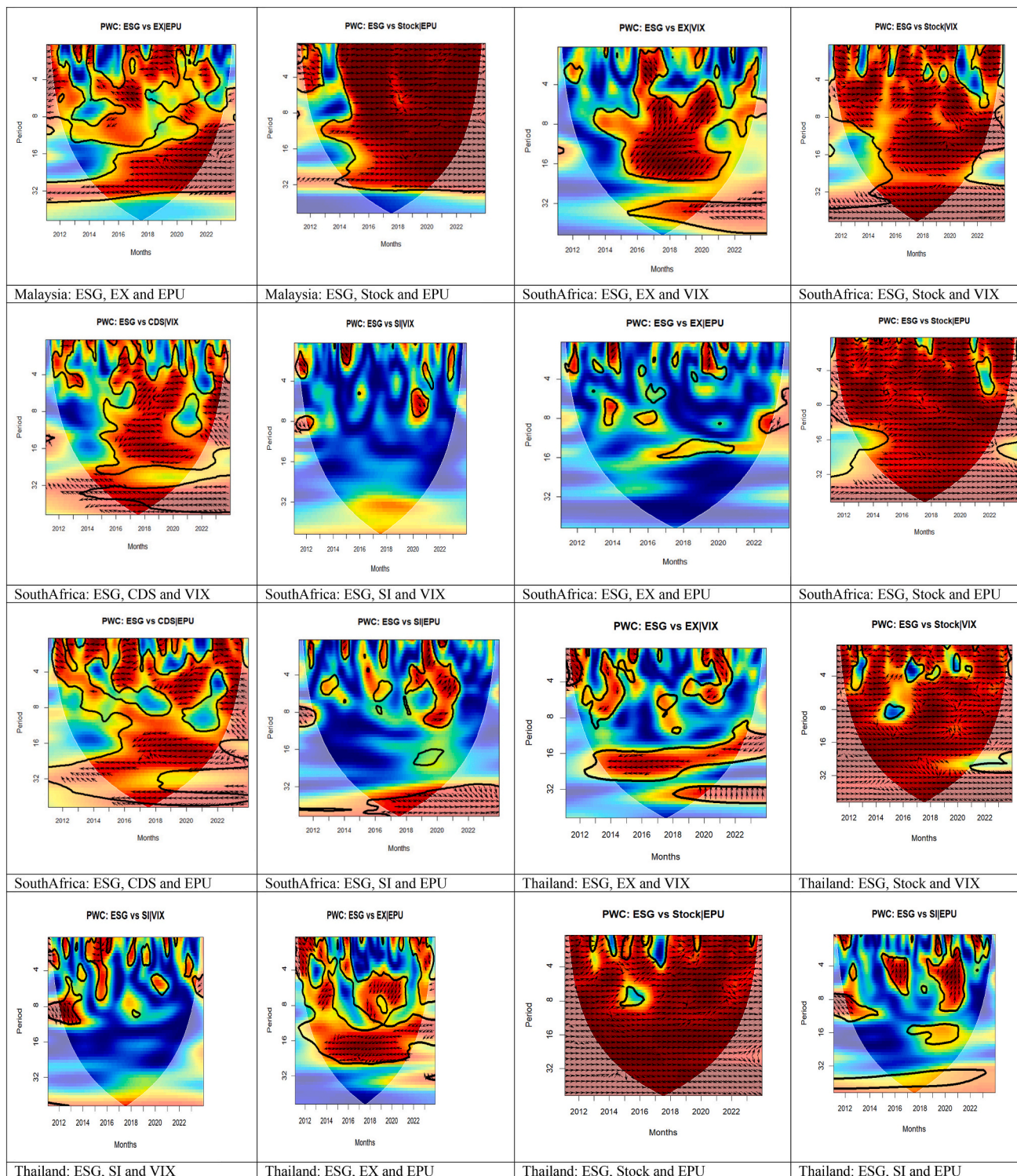


Fig. 6. (continued).

based on these guidelines.

Fig. 8 exhibits VWC-based multiple wavelet coherence between ESG indices and both financial/economic predictors and energy-related sustainability predictors for both developed and developing countries. The analysis is conducted across three variable combinations: (1) ESG vs. Stock, EX, CDS, (2) ESG vs. GE, CE, SI, and (3) ESG vs. Stock, EX, BCO. These results build upon the original coherence insights observed in Figs. 2, 3, 4, and 5. The first and third columns of Fig. 8 focus on the coherence between ESG and financial/economic predictors such as

Stock, EX, CDS, and BCO, while the second and fourth columns focus on ESG and sustainability metrics (GE, CE, SI). Overall, the analysis indicates high coherence between ESG indices and the examined predictors.

5.6.1. Developing countries

In developing countries, the coherence between ESG and financial predictors (Stock, EX, CDS) is notably strong during certain periods. In Brazil, for example, significant coherence is observed during 2014–2016

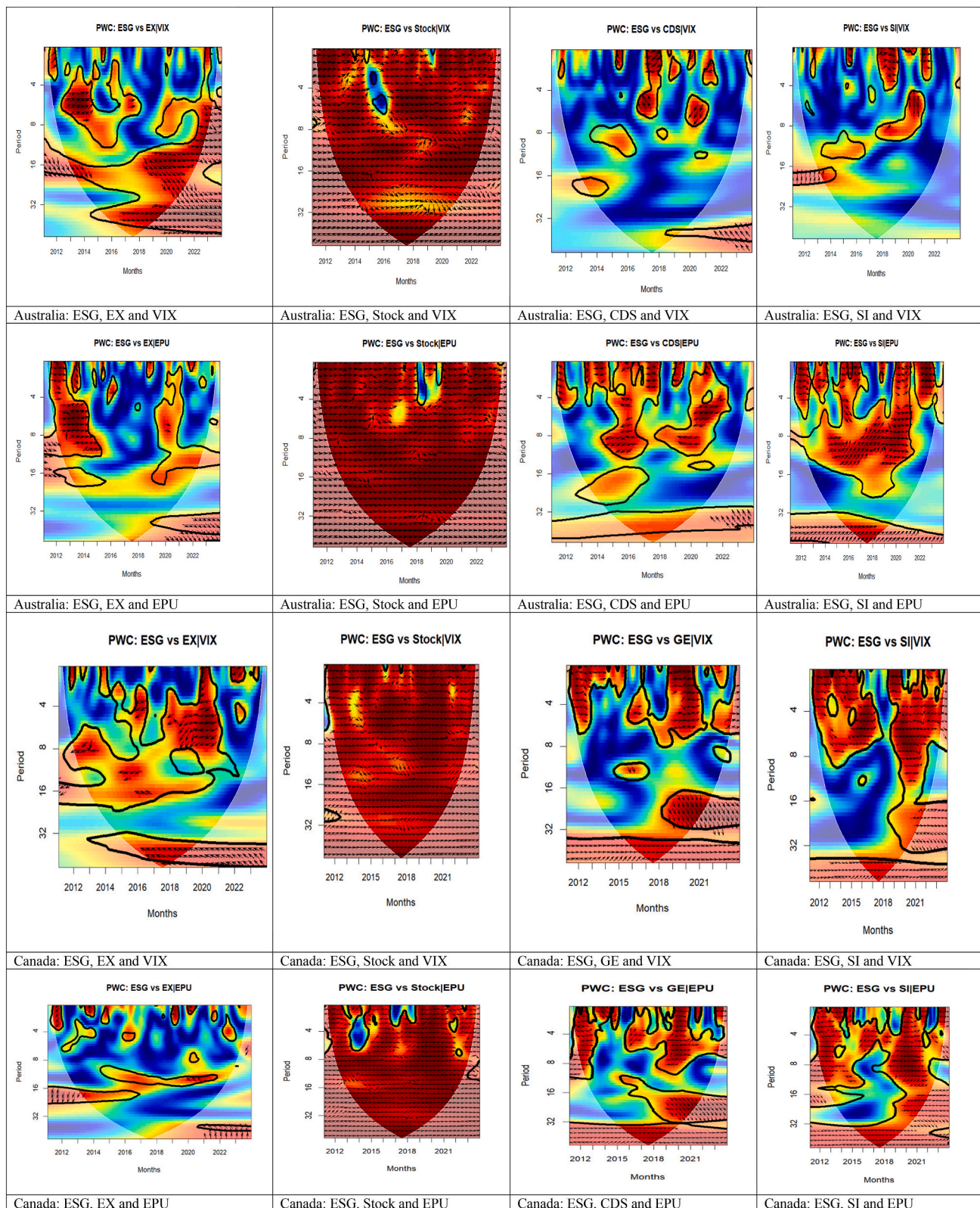


Fig. 7. shows the Partial wavelet coherence pairwise plots. ESG stands for Environment Social and Governance equity index, Stock stands for Stock index, EX stands for Exchange rate, CDS stands for Credit Default Swaps, BCO stands for Brent Crude Oil, GE stands for Green Energy Index, CE stands for clean energy index, SI stands for Sustainability Index, VIX stands for market volatility and EPU stands for Economic policy Uncertainty. The sample countries include Australia, Canada, Japan, Sweden, Switzerland, United Kingdom and United States of America. The black contour represents the 5 % significance level, and the white line indicates the cone of influence. The colour tonality ranges from blue to red, respectively, for low to high coherence. The arrows pointing towards right depict the in-phase pairs, while the arrows pointing to the left indicate the anti-phase pairs. The right down or left up pointing arrows signify that the first series is leading, while the right up or left down pointing arrows indicate the lead by the second series. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

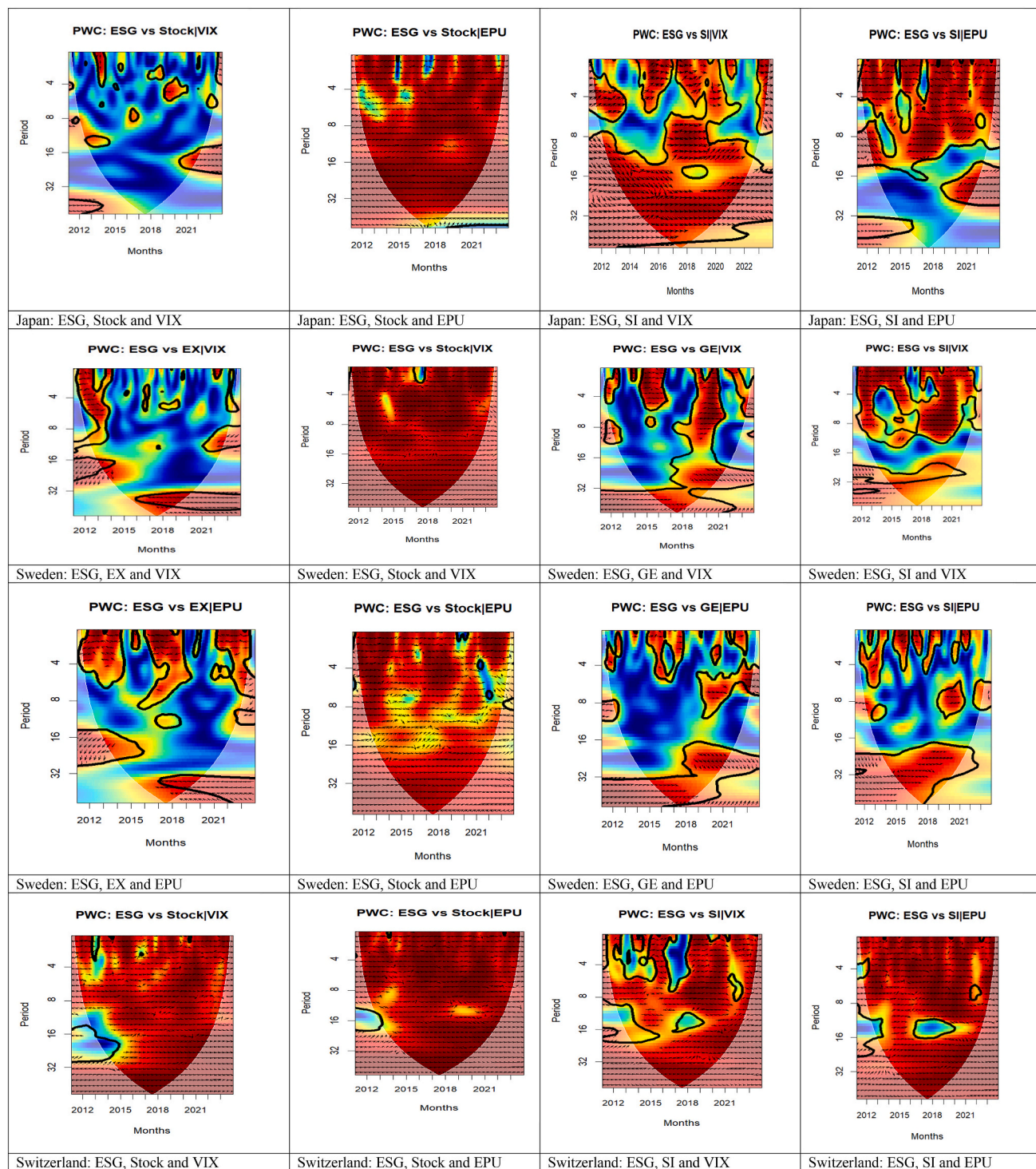


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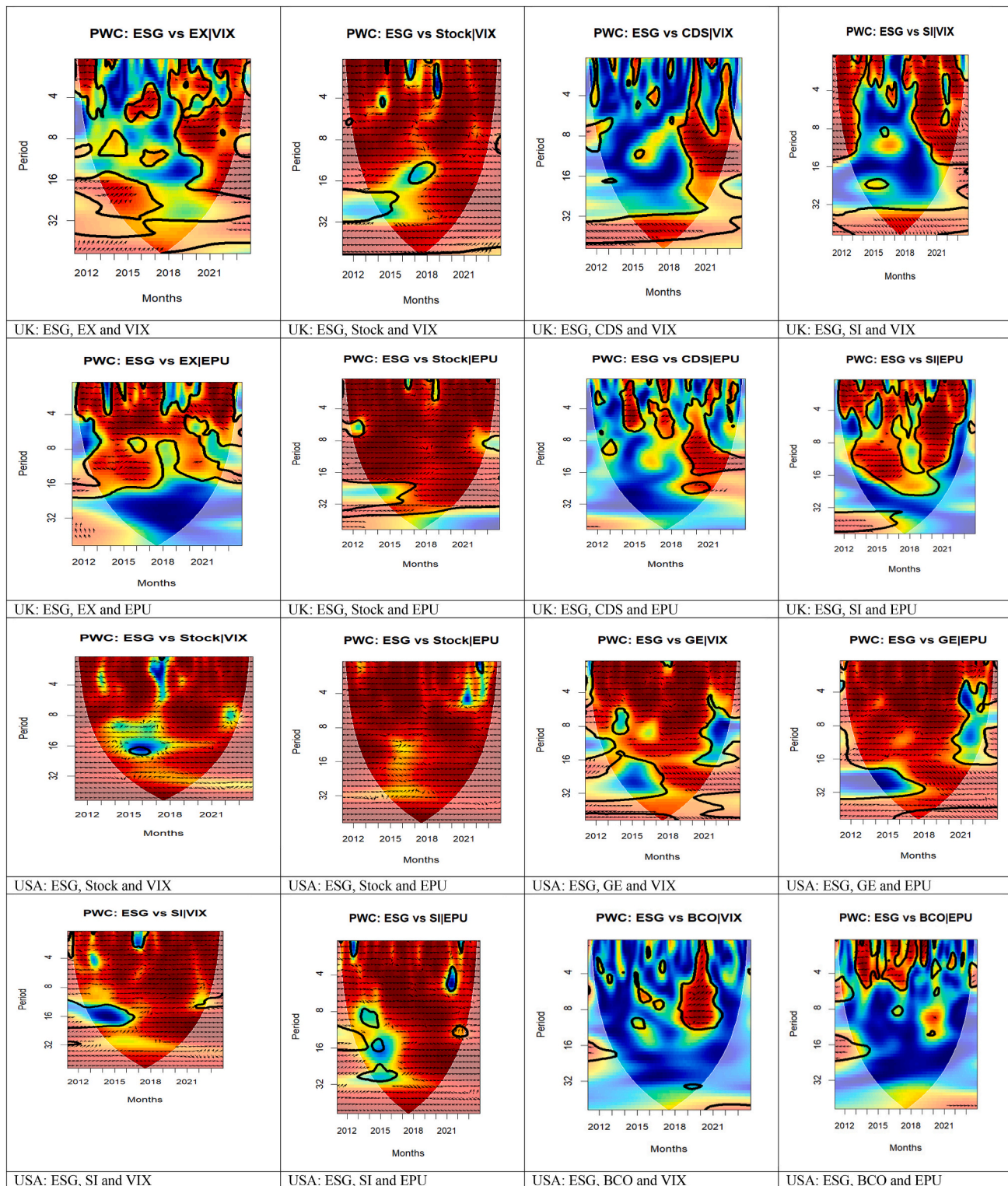


Fig. 7. (continued).

and 2019–2021 at low frequencies, indicating a long-term relationship between ESG and financial/economic variables. Similar patterns emerge in India, Malaysia, Indonesia, South Africa, and Thailand, where ESG consistently aligns with financial predictors from 2014 to 2022. These findings underscore the substantial role of stable financial market conditions in shaping ESG performance in these countries. However, developing markets remain highly volatile and exposed to external shocks. As noted in studies by [Gu, Renwick, and Xue \(2018\)](#) and [Umar,](#)

[Kenourgios, and Papathanasiou \(2020\)](#), policy uncertainty and macro-economic instability often undermine the coherence between ESG and financial variables in these regions, leading to fragmented relationships ([Zhang, Gao, Wang, Hao, and Wang, 2024](#)).

The coherence between ESG and sustainability-related predictors (GE, CE, SI) is more sporadic in developing countries. In countries like Brazil, Malaysia, and Indonesia, significant red zones appear primarily during 2015–2017 and 2016–2018, reflecting the moderate and

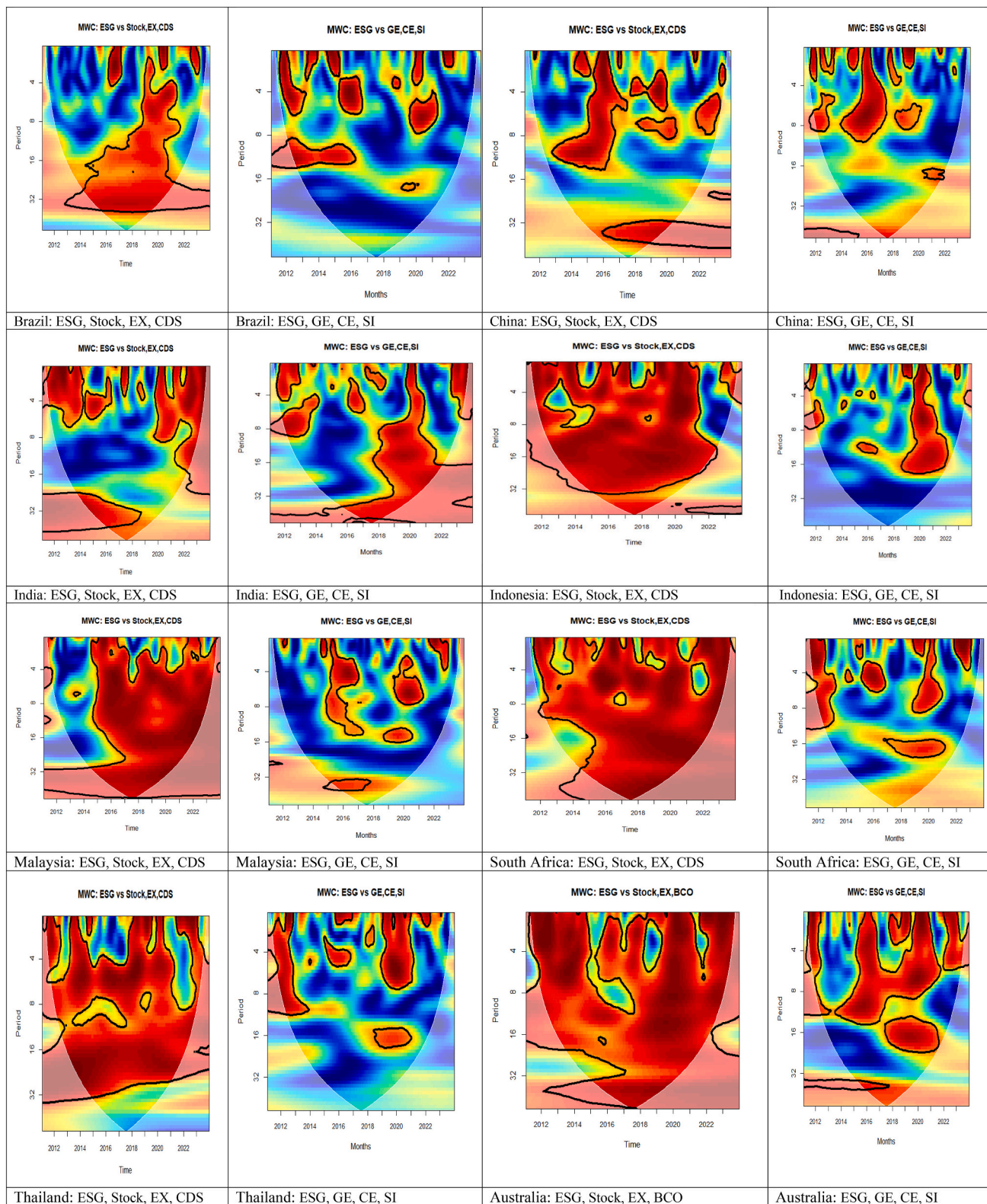


Fig. 8. shows the Vector/Multiple wavelet coherence pairwise plots. ESG stands for Environment Social and Governance equity index, Stock stands for Stock index, EX stands for Exchange rate, CDS stands for Credit Default Swaps, BCO stands for Brent Crude Oil, GE stands for Green Energy Index, CE stands for clean energy index, SI stands for Sustainability Index. The sample countries include Brazil, China, India, Indonesia, Malaysia, Thailand and South Africa, Australia, Canada, Japan, Sweden, Switzerland, United Kingdom and United States of America. The black contour represents the 5 % significance level, and the white line indicates the cone of influence. The colour tonality ranges from blue to red, respectively, for low to high coherence. Source: Authors' own estimations. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

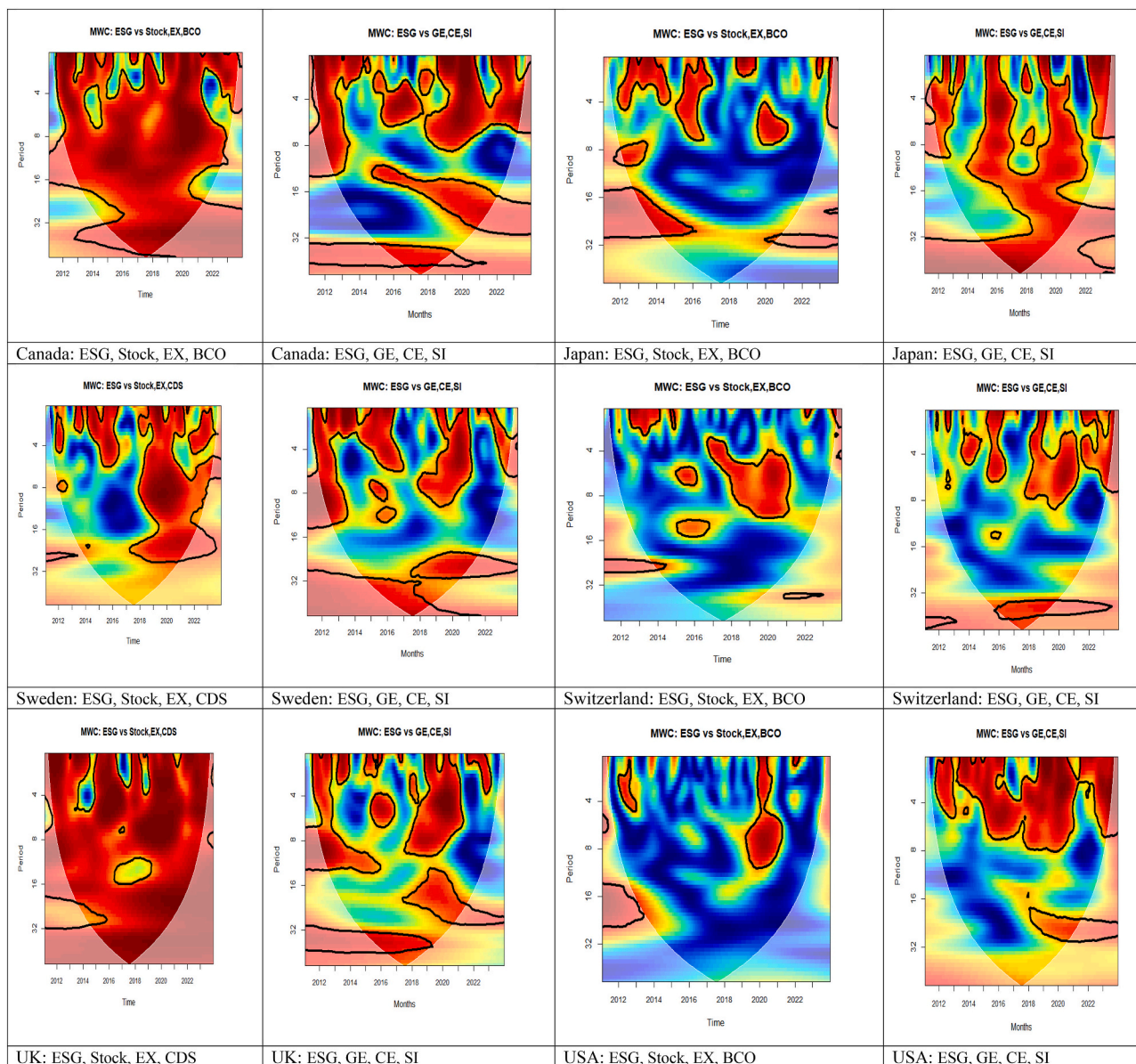


Fig. 8. (continued).

inconsistent influence of sustainability metrics on ESG performance. In contrast, China exhibits a robust and consistent relationship between ESG and financial/economic variables across medium- and long-term frequencies from 2014 to 2022, signalling the strong integration of ESG principles into its financial markets. However, the coherence between ESG and sustainability metrics in China is visible but limited, with notable periods of alignment occurring between 2015 and 2017 and 2019–2021. These periods signal a growing, yet still inconsistent, impact of renewable energy and sustainability factors on ESG performance. India stands out among developing countries, exhibiting strong and consistent coherence between ESG and sustainability predictors, suggesting that renewable energy and sustainability factors play a significant role in shaping ESG performance.

5.6.2. Developed countries

In developed countries, ESG demonstrates strong and consistent coherence with financial and energy predictors (Stock, EX, BCO). For instance, in Australia, Canada, Japan, Switzerland, and the USA, significant coherence is evident across medium- and long-term frequencies between 2015 and 2020, indicating the critical role of financial and

energy predictors in driving ESG performance. This is supported by Ioannou and Serafeim (2017), who highlight the stability and maturity of developed financial systems, which enable a tighter integration of ESG with stock markets, exchange rate stability, and energy markets. In particular, BCO exhibits high coherence with ESG indices in energy-intensive economies such as the USA and Canada, emphasising the influence of energy market dynamics on ESG trends in these regions. The coherence between ESG and sustainability metrics (GE, CE, SI) is more pronounced in developed countries compared to their developing counterparts. For example, in Australia and the USA, substantial coherence is observed during medium-term frequencies (2017–2019), reflecting the growing influence of sustainability factors on ESG performance. However, in Canada, Japan, Sweden, Switzerland, and the UK, coherence with sustainability metrics appears less pronounced, with intermittent red zones indicating a moderate and sporadic influence of these predictors.

Across all countries, ESG exhibits stronger and more consistent coherence with financial predictors in developed economies such as the UK, USA, Sweden, and Switzerland. These findings reflect the mature and well-developed financial systems in these regions, where ESG

indices are tightly integrated with stock market performance, exchange rate stability, and credit risk pricing (Amiraslani, Lins, Servaes, and Tamayo, 2023; Iqbal, Umar, Ruman, and Jiang, 2024). Furthermore, the advanced ESG frameworks and stable financial markets in developed countries contribute to a stronger alignment between ESG and financial variables (Höck, Bauckloh, Dumrose, and Klein, 2023). In contrast, the coherence between ESG and financial predictors is weaker and more fragmented in developing countries such as Brazil, India, and South Africa.

Finally, ESG demonstrates strong coherence with crude oil (BCO) in developed countries, particularly in energy-intensive economies like the USA, Canada, and Switzerland. This relationship is prominent at both medium- and long-term frequencies during periods of market stability and energy price volatility, highlighting the significant influence of energy markets on ESG indices in these regions. In contrast, the ESG-BCO relationship is less robust and coherent in developing countries, with significant coherence observed only during specific periods, such as 2015–2016 and 2019–2020, in countries like Brazil and Indonesia. This suggests that developing markets are more vulnerable to energy price shocks and that the integration of ESG principles into energy markets remains limited due to the absence of comprehensive energy transition policies. The weak ESG-BCO relationship in developing economies may also reflect the lower adoption of ESG frameworks in their energy sectors.

5.7. Additional analysis using daily data

We expanded our baseline analysis to examine the relationship between ESG indices and economic indicators using daily data from 2020 to 2023, as available from the MSCI website.⁷ This sub-sample analysis aims to determine whether the short-term relationships between ESG and financial/economic variables align with the findings of the original analysis based on monthly data. The results, presented in Fig. 9, provide insights into the temporal dynamics and coherence patterns of ESG indices at shorter time horizons.

Our findings reveal positive interdependence between ESG indices and economic variables across several periods. However, the coherence observed with daily data is weaker compared to the monthly data analysis shown in Figs. 2 and 3. Over the short, medium, and long term, thinner red zones were identified for ESG-stock relationships, particularly during 2021–2023. Significant coherence was observed in Brazil, India, and South Africa, where ESG equities exhibited both lead and lag relationships with stock indices. Medium- and long-term frequencies (64–265 days) demonstrated higher momentum, while short-term fluctuations (4–16 days) showed brief and sporadic patterns. In Thailand, ESG indices consistently led the stock market, with persistent positive correlations evident over wavelet scales of 8–32 days between 2021 and 2023. Similarly, in developed markets such as Australia, Canada, Japan, Sweden, Switzerland, the UK, and the USA, ESG-stock relationships were mixed, with ESG indices both positively leading and lagging stock markets across medium- to long-term frequency bands.⁸ These results underscore the importance of ESG equities in portfolio construction, given their consistent positive linkage with stock indices.

Conversely, the co-movements between ESG indices and EX, as well as CDS, were predominantly negative. Notable coherence was observed between ESG and EX in Brazil, where anti-phase arrows indicated an inverse relationship. Similar patterns were evident in Indonesia, Malaysia, Thailand, and South Africa, where ESG indices alternated between leading and lagging EX movements. In Indonesia, ESG indices consistently lead EX, indicating their predictive ability in forecasting

exchange rate fluctuations. For developed countries such as Australia, Canada, Sweden, Switzerland, and the UK, ESG-EX relationships also exhibited both lead and lag dynamics. Significant coherence between ESG and CDS was observed only in Indonesia and South Africa, reflecting strong interdependence across most frequencies and time periods, whereas the ESG-CDS relationship in developed countries remained negligible. In China and Japan, correlations between ESG indices and economic variables were weak, showing intermittent positive and negative coherence. Furthermore, ESG-TB relationships were insignificant across all countries, consistent with earlier findings. These results align with recent studies by Bouri, Cepni, Gabauer, and Gupta (2021), Gunay (2021), and Zhang and Hamori (2021), which highlighted heightened levels of connectedness among asset classes and financial markets.

Overall, the coherence between ESG indices and stock indices, as well as EX, is more significant than their relationships with CDS and TB over short time horizons. This pattern holds true across both emerging and developed markets, demonstrating ESG's potential as a short-term economic indicator. The findings reinforce the primary analysis, revealing higher interdependence at medium and lower frequencies, with stronger connections to stock markets and exchange rates. While ESG indices exhibit moderate to weak coherence with CDS and TB, they consistently lead in the short term, suggesting their ability to forecast economic conditions, thereby supporting H3. The time- and frequency-domain interconnectedness confirms that financial crises intensify the integration of ESG indices with economic indicators. ESG indices lead most asset classes in the short term but follow markets in the medium to long term, supporting both H2 and H3. Consistent positive correlations between ESG indices and stock markets were observed, while ESG-EX and ESG-CDS relationships were predominantly negative, with ESG playing a lagging role in the long run. The decoupling of T-bills from ESG indices highlights their inconsequential role in both emerging and developed markets. These findings underscore the responsiveness of ESG indices to market shocks and their utility in capturing short-term economic dynamics. Policymakers and investors can leverage these insights to refine strategies for sustainable investment, particularly during times of market volatility, while acknowledging the limited coherence between ESG indices and treasury bills across global markets.

5.8. Summary of the results

Overall, the analysis reveals significant interrelations between ESG equity and financial and economic indicators across both emerging and developed markets, with notable regional variations. ESG equity investments display strong positive coherence with stock markets in most countries, particularly during bullish market conditions, suggesting that stock markets often lead ESG movements. This coherence is observed at medium to low frequencies throughout the study period, underscoring the critical role of equity markets in shaping ESG dynamics. ESG equity also shows significant negative coherence with foreign exchange rates in certain countries, reflecting its sensitivity to currency fluctuations and vulnerability during adverse economic conditions. The relationship between ESG equity and credit default swaps is similarly negative, particularly during periods of uncertainty, highlighting the role of CDS as a hedge against ESG risks. In contrast, the negligible relationship between ESG equity and treasury bills suggests that ESG markets operate independently from traditional safe-haven assets. Importantly, ESG equity lacks forward-looking predictive power, reacting primarily to signals from other markets, which challenges the hypothesis that ESG investments provide insights into future economic conditions.

The findings reveal distinct dynamics in the relationship between ESG indices and energy- sustainability predictors across developing and developed countries. In developing countries, the coherence between ESG and clean energy indices (GE and CE) is generally intermittent, often limited to specific short-term periods. However, exceptions like India and Indonesia show stronger connections. In contrast, developed

⁷ The MSCI website primarily provides monthly and annual ESG data; however, daily ESG data from the MSCI website was accessible from 2020 to 2023.

⁸ The results for developed countries are not presented for brevity but are available upon request.

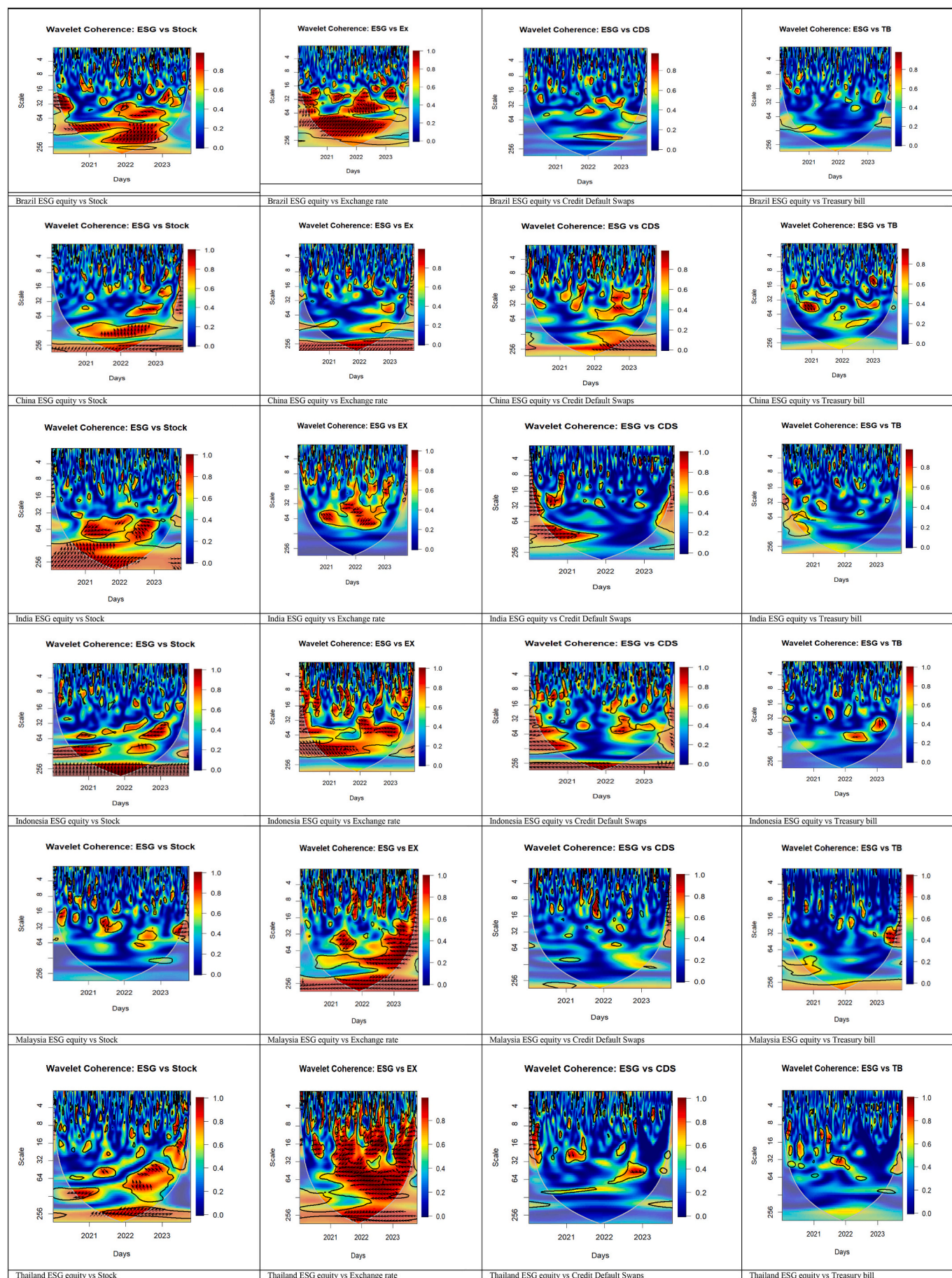


Fig. 9. shows the wavelet coherence pairwise plots on daily data. ESG stands for Environment Social and Governance equity index, Stock stands for Stock index, EX stands for Exchange rate, CDS stands for Credit Default Swaps and TB stands for Treasury bill. The sample countries include Brazil, China, India, Indonesia, Malaysia, Thailand and South Africa. The black contour represents the 5 % significance level, and the white line indicates the cone of influence. The colour tonality ranges from blue to red, respectively, for low to high coherence. The arrows pointing towards right depict the in-phase pairs, while the arrows pointing to the left indicate the anti-phase pairs. The right down or left up pointing arrows signify that the first series is leading, while the right up or left down pointing arrows indicate the lead by the second series. Source: Authors' own estimations. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

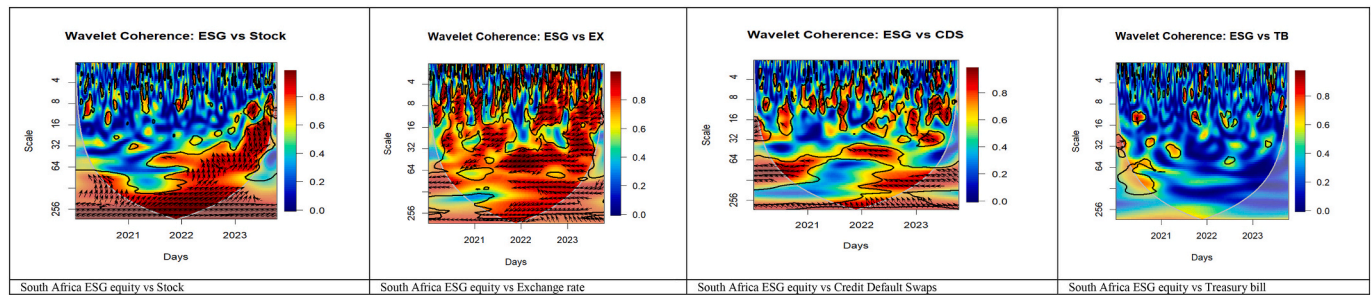


Fig. 9. (continued).

countries exhibit a more robust and consistent relationship between ESG indices and renewable energy indices (GE and CE) as well as sustainability measures (SI). The coherence is significant across all frequency scales, with GE and CE either leading or lagging ESG performance depending on the timeframe. Similarly, the relationship between ESG and crude oil (BCO) is largely insignificant in developing markets, with occasional high-frequency coherence during selected periods. However, in developed economies, the ESG-BCO relationship is pronounced, with BCO consistently leading ESG indices. This reflects the influence of oil market dynamics on energy transitions and ESG investments. Conversely, ESG demonstrates a stronger alignment with the Sustainability Index (SI), especially in countries like India, South Africa, and Thailand, where SI leads ESG performance. This supports the hypothesis (H2) that predictive variables influence ESG investments. The weaker and more inconsistent coherence with energy-related predictors in developing countries can be attributed to challenges such as the nascent stage of ESG adoption, underdeveloped regulatory frameworks, and exogenous shocks like geopolitical risks, policy uncertainty, and commodity price volatility (Zhang, Gao, Wang, Hao, and Wang, 2024). In developed economies, the SI shows strong and consistent positive comovements with ESG indices, indicating the advanced integration of sustainability frameworks, which further supports H2. These results contrast sharply with findings from developing countries, where such coherence is sporadic or weaker.

The Partial Wavelet Coherence (PWC) analysis reveals the nuanced impacts of market volatility (VIX) and economic policy uncertainty (EPU) on the relationships between ESG and financial predictors. In developing countries, both VIX and EPU significantly reduce the coherence between ESG and stock indices, demonstrating that much of the observed ESG-stock relationship is driven by market volatility and policy-related uncertainties. Conversely, in developed countries, ESG's relationships with financial and sustainability predictors (e.g., stock indices, exchange rates, and sustainability indices) remain robust and stable, even when accounting for the effects of VIX and EPU, with some notable exceptions. The findings suggest that while ESG performance in developed markets exhibits resilience, ESG in developing countries is more susceptible to market and policy-driven uncertainties.

The Vector Wavelet Coherence (VWC) analysis highlights the varying dynamics of ESG indices with financial and sustainability predictors across developed and developing countries. In developing countries, ESG demonstrates strong coherence with financial predictors, particularly under stable market conditions. However, the relationship remains fragmented due to policy uncertainty, macroeconomic instability, and external shocks. Coherence with energy and sustainability predictors is sporadic, reflecting inconsistent integration of ESG principles into

sustainability frameworks in these markets with some notable exceptions. In developed countries, ESG exhibits strong and consistent coherence with financial predictors across medium- and long-term frequencies, particularly in mature markets like the USA, UK, Canada, and Australia. These regions benefit from stable financial systems and advanced ESG frameworks, enabling tighter integration with stock markets, exchange rates, and energy markets (Amiraslani, Lins, Servaes, and Tamayo, 2023). Coherence with sustainability predictors is more pronounced in developed economies, reflecting the growing influence of green initiatives and comprehensive energy transition policies (Iqbal, Umar, Ruman, and Jiang, 2024). Additionally, ESG demonstrates a strong relationship with BCO in energy-intensive economies, emphasising the role of energy markets in shaping ESG trends in developed countries. In contrast, the ESG-BCO relationship is weaker in developing markets, where the integration of ESG principles into energy markets remains limited. Finally, the analysis of daily data from 2020 to 2023 reveals that ESG indices exhibit stronger coherence with stock indices and exchange rates (EX) compared to credit default swaps (CDS) and treasury bills (TB) in both emerging and developed markets. These findings suggest that ESG indices effectively capture short-term economic dynamics and respond to market shocks but exhibit mixed coherence with financial variables over longer time horizons.

5.9. Policy implications

Our study provides valuable policy implications for investors, market analysts, portfolio managers, and policymakers. The findings suggest that comprehensive and interactive ESG equity trends can guide institutional investors in managing targeted funds and making efficient asset allocation decisions. Given that ESG indices are more sensitive to long-term trends, investors should exercise caution regarding potential long-term financial disruptions in ESG equity markets. This allows them sufficient time to analyse market changes and act rationally, avoiding emotional biases often driven by herding behaviour. The results also emphasise the importance of accounting for currency risks and using stock market and credit default swap movements as leading indicators for ESG equities. Enhancing ESG market resilience, particularly during periods of economic uncertainty, will require robust risk management practices and broader adoption of sustainable financial instruments. For investors, leveraging ESG indices as indicators of short-term economic conditions could support portfolio optimisation. However, it is important to recognise their limited integration with instruments such as treasury bills and CDS. These findings can help strengthen ESG's role in fostering sustainable financial markets globally. Additionally, the alternating lead and lag dynamics of ESG indices signal short-term

traders to adopt prudent portfolio adjustment strategies.

The observed regional variations in ESG dynamics underscore the importance of tailoring policy and regulatory approaches to specific market contexts to promote sustainable financial development effectively. Policymakers should focus on enhancing regulatory frameworks to stabilise ESG markets, particularly in emerging economies, where ESG coherence with financial variables tends to be more volatile. Developing robust sustainability reporting standards and incorporating ESG considerations into macroeconomic policies can strengthen market resilience and align ESG trends with broader economic indicators. In particular, consistent regulatory frameworks are needed to mitigate the effects of exogenous shocks and to encourage long-term investments in renewable energy, fostering stronger linkages between ESG indices and clean energy predictors.

In developed economies, policymakers should continue advancing sustainability initiatives, such as green energy programmes and comprehensive ESG frameworks, to maintain alignment between ESG indices and sustainability goals. The strong relationship between ESG and Crude Oil highlights the need for policies that promote energy transitions and resilience to oil price fluctuations. Refined ESG disclosure and reporting standards in developed economies can establish global benchmarks, encouraging wider adoption in developing markets. Cross-market learning initiatives could facilitate the transfer of best practices in ESG integration, enhancing sustainable financial development worldwide. Governments and financial institutions must incentivise long-term investments in sustainability to reduce short-term sensitivity to policy and market fluctuations. Improved ESG transparency and standardised reporting can attract sustainable investment flows, strengthening the global ESG-financial network.

Regarding financial events, well-structured response mechanisms should be developed to prevent the amplification of financial risks. Policies aimed at fostering mature and efficient ESG markets, along with capital mobilisation for sustainable investments, can boost investor confidence and mitigate fears during financial turmoil. However, the weaker directional relationship between ESG markets and sustainable economic variables in emerging markets suggests that future economic uncertainties may disproportionately impact ESG investors during extreme events. The limited market integration of ESG in these regions reflects the early stages of sustainable financial system development (Gao, Li, Zhao, and Wang, 2022). Policymakers in emerging economies should prioritise the development of ESG-based financial systems and products to accelerate market synchronisation and integration. Finally, sustainability practices such as expanding the green equity market and raising funds to combat climate change require long-term, coherent policy support. Strengthening these frameworks will enable ESG markets to play a pivotal role in promoting global sustainability while fostering resilience in the face of financial and environmental challenges.

6. Concluding remarks

With advancements in sustainable investments and the increased importance of ESG securities, investors and regulators are becoming more concerned about future economic conditions. However, there is a lack of empirical evidence examining the interdependence mechanism between ESG securities and predictive economic variables. Our study provides the first empirical evidence on the interrelationships between ESG equity and predictive economic variables for emerging and developed countries from 2011 to 2023.

The analysis highlights significant regional variations in the relationships between ESG equity indices and financial and economic indicators across emerging and developed markets. ESG exhibits strong positive coherence with stock markets, particularly in developed economies, underscoring its alignment with equity market dynamics. In contrast, ESG demonstrates negative coherence with exchange rates and credit default swaps, reflecting its sensitivity to currency fluctuations

and its role as a less stable hedge. While ESG indices in developed markets show robust and consistent coherence with sustainability measures and energy predictors, reflecting mature ESG frameworks and stable financial systems, the coherence in developing markets remains sporadic and limited due to underdeveloped regulatory frameworks and external shocks. Importantly, ESG indices tend to react to financial market signals rather than serving as forward-looking predictors of economic conditions, particularly in developing economies.

Our study offers significant insights into the interplay between ESG securities and predictive indicators. The observed positive correlation with the stock market highlights that ESG securities are perceived as favourable investments, particularly during stable or bullish market conditions. Conversely, their negative association with the foreign exchange market and credit default swaps suggests reduced favourability in volatile and high-risk environments. Understanding these dynamics is essential for investors, financial market regulators, and policymakers. The findings indicate that ESG investments not only align with positive market trends but also provide a degree of stability, making them less responsive to short-term economic fluctuations and more reflective of long-term economic health. Investors may leverage ESG securities to enhance portfolio stability rather than for speculative gains. Over time, companies with robust ESG practices may exhibit greater resilience and stability, aligning with broader economic trends. This stability is often a byproduct of sustained and responsible practices, which correlate with economic variables rather than inducing immediate economic shifts. While our study was limited by the availability of daily data, future research could extend this scope by analysing longer time frames to better capture the dynamics of ESG securities. Moreover, the future work could be strengthened by expanding the analysis to examine the determinants of the co-movement between ESG and economic indicators and integrating advanced econometric models to examine the determinants more comprehensively. Additionally, further investigations are warranted to explore the relationship between other sustainable asset classes, financial markets and economic growth, with a focus on both developing and developed economies.

Declaration of generative AI and AI-assisted technologies in the writing process

"We have used Grammarly (Premium) and ChatGPT to improve the paper's language and readability. After employing these tools, we have reviewed and edited the content as needed and take full responsibility for the publication's content".

CRediT authorship contribution statement

Fiza Qureshi: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization. **Saba Qureshi:** Software, Methodology, Data curation. **Izlin Ismail:** Writing – review & editing, Supervision, Resources, Project administration. **Larisa Yarovaya:** Writing – review & editing, Supervision.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.eneco.2025.108407>.

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