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Return and risk spillovers between the ESG global index and stock markets: Evidence from time and frequency analysis

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Abstract

In this paper, we examine comovements between stock market returns and investments that take into account Environmental, Social, and Governance (ESG) factors by studying the interconnections between the two returns in time and frequency space. We study interdependencies between the conventional stock market and ESG stocks using daily data from 2007 to 2021 for 19 developing and 19 developed countries. Our results show significant comovement patterns between ESG returns and stock returns at various frequencies, time scales, and sample episodes in all countries, particularly during periods of financial turmoil. For the most part, we document positive (in-phase) comovements between the stock returns and ESG returns in developing countries and negative (out-of-phase) comovements in developed countries. This implies limited portfolio gains from adding ESG stocks to portfolio diversification in developing countries but significant gains in developed countries.

JEL classification: G11; G15; G19

Keywords: Wavelet coherence analysis; ESG investing; Stock markets; Portfolio diversification

1. Introduction

To meet the social, ethical, ecological, and economic interests of investors, socially responsible investing (SRI) is an investment approach that combines social and/or environmental benefits with financial rewards (Brzeszczyński & McIntosh, 2014, p. 335). It does so by taking into account environmental, social, and governance (ESG) factors in the inclusion of securities in the portfolio (Vives & Wadhwa, 2012, p. 320; Jain et al., 2019, p. 2), as opposed to a classical investment approach that focuses only on financial returns (Pasquini-Descomps & Sahut, 2014, p. 2). In a sense, SRI seeks to generate moral as well as financial gains. Thus, the investment process also incorporates nonfinancial interests, including moral, social, and environmental considerations (Foo, 2017, p. 4). ESG investing is an umbrella term that is used interchangeably with Social Responsibility Investing (SRI), Responsible Investing (RI), Sustainable Investing (SI), and Impact Investing (a subset of SRI) (Gorka & Kuziak, 2021, p. 7128). In some studies, ESG investments are included in

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Corporate Social Responsibility (López et al., 2007) and ethical investments (Renneboog et al., 2008).

There are three types of ESG investments, each with a different investment objective: the first type is ESG integration, which has the main objective of enhancing the risk-return characteristics of a portfolio; the second type involves the investor trying to match the portfolio with norms and beliefs; and the third is impact investing, whereby investors use their wealth to bring about social or environmental change, such as quickening the economy's decarbonization (Giese et al., 2019, p. 69). Some investors make investment decisions based on their due diligence, while others use information from ESG rating agencies, indices, and funds produced using some of these strategies (Vives & Wadhwa, 2012, p. 320). There is a wide range of SRI investors with differing beliefs, conventions, and philosophies, and these variances are reflected in the different funds (Sandberg et al., 2009, p. 519). Usually, investors are ready to forego financial profits in exchange for investments that will have a greater social or environmental impact (Brzeszczyński & McIntosh, 2014, p. 335). Nonfinancial factors will also be taken into account by these investors in their investment research (Atan et al., 2016, p. 356). As such, ESG investments may have unique criteria and these investments have been growing in importance since the beginning of the 2000s.

Institutional investors are becoming increasingly interested in ESG investments as public money, communities, and politicians exert increasing moral pressure on companies to be more environmentally friendly. As a result of the 2007 financial crisis 2007 and the subsequent adoption of new policies and regulations, the popularity of responsible investing has continued to grow. SRI has proven to be a safer investment in falling markets and has rewarded investors with a certain moral satisfaction, thus emerging as a tempting alternative investment approach (Pasquini-Descomps & Sahut, 2014, p. 2). Companies and financial markets were forced to reconsider their exposure to systemic risk as a result of the global financial crisis brought on by the 2007 credit crunch. As a result, key players have realized how crucial it is to incorporate ESG factors and sustainability into corporate and investment decision-making now rather than later. Companies, investors in financial markets, and regulators are examining fresh issues, assessing fresh dangers, and seeking fresh opportunities in the markets of the future. ESG factors are becoming increasingly important in the quest for long-term value creation for shareholders, necessitating new approaches that call for both companies and investors to think strategically about the long-term implications of their financial decisions (WBCSD & UNEP, 2010, p. 26).

SRI investments are becoming more popular because they combine the pursuit of financial returns with nonfinancial goals related to ESG, making them appear less risky than conventional alternatives (Balcilar et al., 2017, p. 1). The paper by the Expert in Responsible Investment Solutions Foundation highlights the incorporation of ESG elements into investment research as a means of mitigating risk and achieving new potential (Collin, 2009, p. 9). ESG-intensive portfolio investments continue to increase annually. For example, ESG-driven assets have exceeded US$40 trillion in global capitalization, and major investors (e.g., World Business Council on Sustainable Development) are now emphasizing ESG issues to generate higher future returns (Dillian, 2020). Capital flows from high-risk assets to ESG portfolios are encouraged by these reassessments because these strategies are likely to outperform the market during times of crisis (Singh, 2020, p. 1). For example, at the start of the Covid-19 pandemic, some of the leading ESG stock indices, such as the S&P 500 ESG index, the Morgan Stanley Capital International (MSCI) emerging markets ESG leader index, and the MSCI Asia ESG leader index, outperformed their main indices by 0.6%, 0.5%, and 3.83%, respectively (Khew et al. al., 2020). As the pandemic spread, the significant trend of ESG stocks integrating into investors' portfolio selection decisions (Rubbaniy et al., 2022: p. 240) provides evidence of the value investors place on ESG criteria in their portfolio choices. An emerging body of literature finds that SRIs can be a safe haven during crises (Arif et al., 2022 Rubbaniy et al., 2022; Broadstock et al., 2021; Mousa et al., 2022; Piserà & Chiappini, 2022). Accordingly, in this study, we examined the return and volatility spillovers between ESG global indices and the developed and emerging stock markets owing to various factors, including the growing importance of ESG in recent years, the positive performance of the ESG indices during COVID-19, and its evidence of being a safe haven in times of crisis.

A variety of SRI measures are used to reduce investment losses. The first is an exclusion strategy, which entails eliminating investments in “unethical” companies. In general, there are two methods for applying exclusions: company risks or industry classification, which focuses on businesses' actual exposures to certain activities using a percentage of revenues from those activities. When a company is excluded from the screening process because it doesn't adhere to international norms or conventions, the exclusions may be based on ESG criteria or have a normative component. A few examples of this are screening for “sin stocks,” or avoiding investments in businesses that are thought to support negative social consequences, like the cigarette, alcohol, gambling, and adult entertainment sectors. It also applies to divesting from businesses that cooperate with repressive governments or transgress moral, ethical, or religious principles. This strategy is an attempt to contain the danger of reputational damage when an investment is connected to a negative occurrence or unethical corporate conduct (Mikołajek-Gocejna, 2018, pp. 26–27). Historically, sustainable investors were driven by ‘values’ and focused on screenings to eliminate companies deemed to have a negative environmental or social impact (Vives & Wadhwa, 2012, p. 318). The SRI strategy was formerly based on negative screening, quite simply. Accordingly, SRI portfolios were created taking into account social, environmental, and ethical criteria, and stocks and industries that did not meet these criteria would be removed from the portfolio. These portfolios did not contain enterprises that dealt in alcohol, cigarettes, gambling, the defense sector, or had a history of poor labor relations or environmental protections. Poor employment

conditions, abortion, pornography, reckless international activities, human rights abuses, and animal testing are among the other red flags. Some SRI funds only exclude businesses from their investment pool when their revenue from "asocial or unethical" industries exceeds a certain level. There are very few SRI funds that apply filters based on conventional ideologies or religious sensibilities, such as not investing in pork-producing companies, saving institutions that pay interest, or insurance companies that cover unmarried couples as insured (Radu & Funaru, 2011, pp. 159–160).

Historically, the first form of SRI, which took place in the 18th century, excluded sectors related to weapons, alcohol, tobacco, etc., for religious or moral purposes. Modern SRI employs a range of positive screening techniques, such as the "best-in-class" strategy, which gives preference to businesses that are better rated by ESG standards than other businesses in the same sector. Active tactics have also become more prevalent, such as the utilization of shareholder rights or funds with sustainability-related themes (Pasquini-Descomps & Sahut, 2014, p. 2).[1]

Company-specific ESG scores and market-specific ESG indices are created by scanning ESG criteria. Companies that issue "green bonds" and attractive bonds, which are seen as appealing investments, are those that are included in the ESG index. Businesses have a strong incentive to fund themselves through the issuance of "green bonds." By enhancing their ESG rating, businesses attract greater attention to the capital market and, if they are traded on the stock market, increase the value of their stocks. Companies can boost market demand for their shares after they are given the "green" designation and receive enough media coverage. Companies' returns may benefit if they receive more accolades for their environmental management. In conclusion, achieving a better ESG score or being chosen for the ESG index is advantageous at the level of corporate revenues and stock prices by garnering more attention and exposure to positive public media (Liu & Hamori, 2020, p. 2). ESG scoring is a popular method of portfolio selection in the capital markets; a firm with a high ESG score is regarded as having minimal investment risk, and vice versa (Vadithala & Tadoori, 2021).

Sustainability indices are generally created as benchmarks for 'sustainable investments,' a term that encompasses a range of concepts and asset classes, including the use of ESG information in portfolio development and shareholder voting on carbon trading and clean-tech investment policies (Vives & Wadhwa, 2012, p. 318). Sustainable indices have only been around for a short time. The PAX World Fund, which started in 1971 and didn't invest in stocks in the military sector, is generally considered the first SRI mutual fund. In May 1990, almost 20 years after the PAX World Fund was started, Kinder, Lydenberg, Domini, and Co. released the Domini 400 Social Index, making it the first sustainable index in the world. In the early 2000s, the growing acceptability of SRI within institutional and investing communities aided the promotion of a number of other sustainable indices, including Dow Jones, E. Capital, Ethibel, FTSE4, Humanix, Jantzi, KLD Analytics, and Vigeo (Fowler & Hope, 2007, p. 243). International institutions like the United Nations, the European Union, and the OECD offer several incentives to strengthen institutional structures, supply chains, and societal standards, including health and safety regulations. These modifications extend beyond the financial industry and profession. The number of ESG indices, however, is continuously rising thanks to significant producers of financial decision tools like MSCI, and, as a result, there are an increasing number of ESG stock ETFs available globally (Kerkemeier & Kruse-Becher, 2022, p. 1).

Environmental challenges, including pollution, resource depletion, and ecological imbalances, are becoming more and more important global economic and political issues for societal progress and human existence. There is agreement that environmental protection must be stepped up in order to ensure sustainable economic and social development. In particular, with regard to addressing environmental issues and tackling climate change, international organizations, governments, and academic institutions are investigating various approaches to achieving sustainable development policies (Deng & Cheng, 2019, p. 1). Policymakers and regulators are being forced by social inequality and climate change to concentrate their efforts on reducing climate and social hazards (La Torre et al., 2020, p. 1). ESG methods integrate business tactics to draw in and keep investors and customers (Vadithala & Tadoori, 2021). Many businesses may see an opportunity or a compelling path forward as a result of the rising demand for sustainable products, but doing so entails new expenses and dangers that are currently mostly environmental in nature. A powerful illustration of how environmental rules can affect a company's financial performance through compliance and reputational risk is the 2014 Volkswagen emissions scandal, which resulted in an 18% decline in the automobile manufacturer's stock price (La Torre et al., 2020, p. 1). Examples such as these illustrate the value of ESG in the business and finance sectors, as well as the increasing interest by investors, regulators, financial market actors, and researchers. Although the preceding discussion stressed the positive aspects of ESG, one of the most prominent criticisms of socially responsible investing is the application of nonfinancial criteria that limit investment possibilities, diminish diversification efficiency, and negatively impact performance (Lee et al., 2010, p. 351).

The principal objective of this study is to examine return and volatility spillovers between the ESG global index and developed and developing stock markets using data from 2007 to 2021. As alluded to above, the return and risk profile of the ESG market may vary from periods of market calm and distress; as such, we use a wavelet coherence analysis to ascertain the connectedness between ESG and stock markets in terms of time and frequency. This study differs from the existing literature in several ways. First, most research focuses on the relationship between ESG indices and firm performance. Very few studies have examined the spillover effects between

[1] See Radu & Funaru (2011, p. 160) for more details on negative and positive scans based on environmental, social, or ethical criteria structured by Sparkes (2003) and defined by Renneboog et al. (2008).

ESG indices and stock markets, and the number of markets included in the samples in these studies is limited. In contrast, we consider the return and risk spillover between ESG indices and developed and emerging stock markets (19 developed and 19 emerging). Second, while DJSI is generally used as the sustainability index in the literature, we used the MSCI ESG Global Index. Finally, to the best of our knowledge, this is the first study that focuses on return and volatility spillovers between ESG and stock markets using the wavelet coherence analysis.

The paper proceeds as follows: we provide a brief literature review in the next section. Section 3 presents the econometric method and Section 4 contains data and empirical results. The final section concludes.

2. Literature review

Because of the growing interest among investors and regulators in socially responsible and impact investments, the importance of ESG factors in investment decision-making has grown in recent years. According to finance research, ESG factors are generally associated with firm performance (Charlo et al., 2015; Friede et al., 2015; Landi & Sciarelli, 2019; Martínez-Ferrero & Frías-Aceituno, 2015; Nagy et al., 2016; Velte, 2017). Studies have investigated whether ESG-based investments provide diversification opportunities (Balcilar et al., 2017; Hoepner, 2010; Kim et al., 2022).

Many sustainable indices have been created by equity markets to provide investors with the option of prioritizing sustainable companies. The development of sustainable indices also appears to be an indicator of the growing interest in environmental and social issues. Several studies have been conducted that compare the performance of these indices.

Studies have compared and examined the relationship between corporate social responsibility and the financial performance of businesses listed on both general and sustainable indices. Alshehhi et al. (2018) conducted a meta-analysis of the impact of Corporate Social Responsibility (CSR) on the financial performance of companies and found that 78 percent of studies indicate there was a positive link between corporate social responsibility and financial performance. Charlo et al. (2017) examined the differences between two groups of Spanish IBEX companies in terms of accounting and stock market for the 2008–2013 period. The first group is made up of companies listed on the Responsible Company Index and the second group is made up of companies not listed on the Responsible Company Index. Based on the CSR strategic approach, there were significant differences between the two groups. The results showed that the stock returns of the companies in the sustainable index are more sensitive to changes in the market rate of return. Since their average value of beta is less than 1, they can be used as defensive securities against changes in the stock market. López et al. (2007) examined whether there were appreciable variations in performance metrics between European companies that adopted and did not implement CSR to determine whether business performance is impacted by the adoption of CSR strategies. The Dow Jones Sustainability Index (DJSI) was used to analyze the effects of CSR compliance, and specific accounting metrics were used to gauge performance. A group of companies included in the DJSI and a different group of companies included in the Dow Jones Global Index (DJGI) but not the DJSI were compared. Two sets of 55 businesses from the 1998–2004 period made up the sample. The performance variations between DJSI and DJGI companies attributable to CSR practices was supported by the empirical investigation. It has been established that there is no positive correlation between performance metrics and CSR; and that the introduction of sustainability practices has a detrimental influence on performance indicators in the initial years. Using data from the Sao Paulo Stock Exchange Index and the Corporate Sustainability Index, Santis et al. (2016) compared the financial and economic performance of the two sets of companies. The results did not reveal any proof of variation in organizations' economic and financial success. Fowler and Hope (2007) concluded that returns of responsible investment instruments have either underperformed or failed to exceed equivalent market indices after examining the performance of sustainable investing indices.

Compared with studies on corporate financial performance, studies on the links between ESG or sustainability indices and conventional indices or other sustainability indicators have been investigated less frequently. In this line of research, sustainability indices were often represented by the Dow Jones Sustainability Index (Balcilar et al., 2017; Giannarakis et al., 2011; Mensi et al., 2017; Skare & Golja, 2012; Tularam et al., 2010). Balcilar et al. (2017) investigated risk spillovers and dynamic correlations between conventional and sustainable stock indices (DJSI and DJGI) from various areas to analyze if SRIs might provide a diversification opportunity against conventional stock portfolios. The analysis revealed significant unidirectional volatility spillovers from conventional equities to sustainable stocks. While there are notable dynamic correlations between conventional and sustainable stocks, particularly in Europe, an analysis of both in-sample and out-of-sample dynamic portfolios demonstrates that adding sustainable benchmarks to conventional stock portfolios improves the stock portfolio's risk/return profile globally. Overall, the results point to the possibility of global diversification for traditional stock portfolios through sustainable investments. Using vector autoregression and variance decomposition methods, Roca et al. (2010) examined the scope and nature of stock price interdependence between the SRI markets of Australia, Canada, Japan, the United Kingdom, and the US between 1994 and 2010. The results showed that SRI markets are extremely interconnected and have grown more so over time. The most interconnected markets are those of the US and the UK, whereas the most influential markets are Canada and Australia. The amount of integration remains low, however, despite the markets' substantial integration. La Torre et al. (2020) tested whether there was a statistical difference between the performance levels of the IPC sustainability (IPCS) index and the broad market IPCcomp index to investigate the mean-variance efficiency of sustainable investment (SI) implementation in Mexico. The tests covered the period

from November 2008 to August 2013 and used the daily standard deviation, Sharpe ratio levels, ratio of variance, and single-factor CAPM. The outcomes demonstrated that the SI strategy in Mexico was as mean-variance efficient as the broad market strategy and ultimately proved to be a good substitute. Mensi et al. (2017) used the DECO-FIAPARCH model and the Diebold and Yilmaz (2012) spillover index in their studies to examine the relationship between gold, and the Dow Jones conventional, sustainability, and Islamic stock index aggregates, as well as 10 related disaggregated Islamic sector stock indices. The study showed that while the sustainability and conventional aggregate DJIM indices and the remaining Islamic equity sectors are net contributors to the risk spillovers, the gold, oil, finance, energy, technology, and telecommunications sectors are net recipients of the risk spillovers. Tularam et al. (2010) examined the association between the Australian SRI market and all other markets for 1994–2009 (DJSI data for 15 countries) and found the links grew stronger during the global financial crisis. The Australian market's connection with Canada, Denmark, Norway, and the United Kingdom grew during the course of the sample, while its correlation with other countries stayed consistent. Benson and Humphrey (2008) examined how present and historical monthly/annual return measurements affected fund flows when comparing and contrasting the factors that affect the flows of money between SRI funds and conventional funds. The results showed that the flows of SRI funds are less susceptible to returns than those of conventional funds. The model also demonstrated that the flow is ongoing and that SRI investors are more inclined than conventional investors to make investments in funds they currently hold. The study also highlighted the difficulty SRI investors experience in locating alternative investments that satisfy their nonfinancial objectives. In terms of performance, Schröder (2007) contrasted SRI indices with traditional indices. In the study, 29 SRI stock indices were examined using both single-equation models and multi-equation systems that used cross-sectional data. The results showed that SRI stock indices have the same degree of risk-adjusted returns as traditional indices. Many SRI indices, however, carry greater risk than the benchmarks.

Extant studies generally used DJSIs as a measure of sustainability index, and the focus has been on the CSR-CFP link and performance comparisons between the indices. In this study, we use wavelet coherence analysis to examine the relationship between the global ESG index and stock markets. Since wavelet analysis allows us to combine the time and frequency domain relationships between two variables, it has been widely used in empirical finance. Vacha and Barunik (2012) indicated that the wavelet transform provides localized frequency decomposition of the series and hence it can be successfully used to examine frequency components. Moreover, they argued that the wavelet analysis outperforms the basic Fourier analysis when the series is not globally stationary and homogeneous. Similarly, Aloui and Hkiri (2014) emphasized that wavelet analysis is a useful method in signal processing; hence, wavelet coherence analysis gives more comprehensive results in terms of time and scale components for the connectedness between international stock markets.

Therefore, in this study, we examine the time and frequency domain relationship between ESG global indices and developed and developing countries' stock markets by wavelet coherence analysis under Morlet's specification. The wavelet coherence analysis is specifically appropriate for non-normal returns, which is typical for financial time series.

3. Econometric framework: Wavelet coherence analysis

The continuous wavelet transform of a time series $x(t)$ can be represented as follows:

$$W_x(\tau, s) = \int_{-\infty}^{\infty} x(t)\tilde{\psi}^*_{\tau,s}(t)dt \tag{1}$$

In Equation (1), s is the scaling factor that defines the wavelet's length and τ is the translation parameter determining the wavelet location in time. $\tilde{\psi}^*_{\tau,s}(t)$ is the complex conjugate function of $\psi^*_{\tau,s}(t)$ and $\tilde{\psi}$ is determined via scaling and shifting the mother wavelet ψ:

$$\tilde{\psi}^*_{\tau,s}(t) = \frac{1}{\sqrt{|s|}}\psi\left(\frac{t-\tau}{s}\right), s, \tau \in \mathbb{R}, s \neq 0 \tag{2}$$

The Morlet wavelet suggested by Goupillaud et al. (1984) can be used as the mother wavelet ψ. The cross-wavelet transform for two times series such as $x(t)$ and $y(t)$ can be represented as:

$$W_{xy}(\tau, s) = W_x(\tau, s)W^*_y(\tau, s) \tag{3}$$

We define the wavelet coherence between $x(t)$ and $y(t)$ as follows:

$$R^2(\tau, s) = \frac{\left|S\left(s^{-1}W_{xy}(\tau, s)\right)\right|^2}{S\left(s^{-1}\left|W_x(\tau, s)\right|^2\right)S\left(s^{-1}\left|W_y(\tau, s)\right|^2\right)} \tag{4}$$

In Equation (4), S is the smoothing parameter and $0 \leq R^2(\tau, s) \leq 1$. The $R^2(\tau, s)$ is the square of the correlation between x and y localized in time and frequency. Note that although the wavelet coherence shows the presence of comovement between the variables in the time and frequency domain, it does not allow us to distinguish between negative and positive correlation. Torrence and Compo (1998) suggested a useful approach to distinguishing negative and positive correlations between the variables as follows:

$$\Phi_{xy}(u, s) = tan^{-1}\left(\frac{\mathcal{I}\left\{S\left(s^{-1}W_{xy}(\tau, s)\right)\right\}}{\mathcal{R}\left\{S\left(s^{-1}W_{xy}(\tau, s)\right)\right\}}\right) \tag{5}$$

In Equation (5), $\mathcal{I}$ is the imaginary and $\mathcal{R}$ is the real part of the smoothed cross-wavelet transform. Equation (5) gives the phase difference, which details the delays of oscillation (cycles) of a pair of time series under consideration. Black arrows show the phase in the wavelet coherence graphs. A zero phase difference suggests the presence of comovements. Right (left) arrows indicate that variables are in-phase (out-of-phase) or

there is a positive (negative) correlation between the variables. While an upward pointing arrow shows that the first variable leads the second variable by $\pi/2$, an arrow pointing down indicates that the second variable leads the first variable by $\pi/2$. Most often, there are many combinations of positions used.

4. Data and empirical results

We utilize daily data for the MSCI ESG global index and equity markets, totaling 3721 observations between August 28, 2007, and December 31, 2021. As in the literature, we use the MSCI ESG global index as a gauge of the ESG stock market. Conventional stock markets are represented by 19 developed (Australia, Austria, Belgium, Canada, France, Germany, Ireland, Israel, Italy, Japan, Kuwait, New Zealand, Portugal, Qatar, Spain, Switzerland, the UAE, the UK, and the US) and 19 developing countries (Argentina, Brazil, Chile, China, Colombia, Czech Republic, Egypt, Hungary, India, Indonesia, Jordan, Malaysia, Mexico, Morocco, Poland, Russia, S. Africa, S. Korea, Turkey).[2] Refinitive Eikon is used to gather daily closing prices for all stock markets. We calculate the return series using the first differences of logarithm of price series. As in Omane-Adjepong et al. (2019), we calculate unconditional volatility using the absolute return series.

Tables 1 and 2 show descriptive statistics for return series for developed and developing countries, respectively. Additionally, Table 1 displays descriptive statistics for the ESG global index returns. For developed countries, Spain has the highest daily return value at 14.523%, while Kuwait has the lowest daily return value at −22.710%. In terms of the mean returns, it can be seen that Portugal has a minimum mean of −0.022% and the United States has the highest mean of 0.031%. The distribution of returns series of all developed countries is leptokurtic and negatively skewed. The ESG global index returns vary between 8.623% (the highest) and −10.269 (the lowest) during the sample. The ESG global index return series exhibits a leptokurtic distribution and a negatively skewed appearance, similar to stock market indices.

In the case of developing countries, the maximum daily return is in India, with 16.423% returns, and Argentina has a daily return value of −51.131%, which is the lowest. In terms of the mean values, it can be seen that India has the highest mean (0.029), while Jordan has the lowest mean (−0.039). Furthermore, it is evident that all developing countries' stock market returns, with the exception of Mexico, are negatively skewed and leptokurtic.

In the first stage of the empirical analysis, we use the ADF and PP unit root tests as well as the KPSS stationarity test for each country return series and the ESG global index return series to confirm stationary processes; results are given in Tables 1 and 2. According to the ADF and PP unit root tests, the null hypothesis of a unit root can be rejected. Similarly, the KPSS test indicates that the null hypothesis of stationary returns for all countries cannot be rejected. In addition, the stock market indices of the countries and the ESG global reject normality per the JB normality test. This makes wavelet coherence analysis an appropriate method as a nonlinear estimator.

Next, we use wavelet coherence analysis to examine the linkages between ESG global indices and stock markets in terms of returns and volatility and present the results in Figs. 1–4. In these figures, the black contours indicate correlations at the 5% significance level, where significance is determined using Monte Carlo simulations with 1000 repetitions. The white line indicates the influence cone. When interpreting charts, the ranges 0–64, 64–256, and 256–1024 represent the short-, medium-, and long-term time scales, respectively. Note that 64 trading days represent a quarter, whereas there are 256 trading days in a year and there are 1024 trading days in a 4-year period. In addition, the vertical and horizontal axes in the figure represent frequency and time, respectively. Regions in warmer colors represent regions with significant dependence and the colder the color represented in a dark shade of blue, the less dependent the two series. For example, the blue and red colors represent minimal and high series dependence, respectively.

In-phase (positive comovements) and out-of-phase connections (negative comovements) are shown by arrows pointing to the right and left, respectively. In addition, the arrows pointing up indicates that ESG global index leads the stock index, whereas the down arrow indicates that the stock index leads the ESG index. When there is a mixed position, it can be a combination; e.g., an upward right arrow means the ESG index and stock index are in-phase while the ESG index is leading the stock index. Similarly, when there is a downward left arrow, it indicates the ESG index and stock index are out-of-phase while the stock index is leading the ESG index.

Fig. 1 illustrates the connection between ESG global and stock returns. The figure documents significant links between ESG returns and stock returns at various frequencies, time scales and various sample episodes in all developing countries, with the exception of Jordan and Morocco. Despite the fact that this positive link is mainly in the short and medium term for Argentina, a long-term positive correlation exists, especially during 2012–2016. In addition, it is seen that stock returns lead to ESG returns in the medium term, and ESG returns predate stock returns in the long term. Similarly, while there is a positive association between ESG returns and stock returns at different frequencies for Brazil, the positive relationship that arose during the 2008 global financial crisis was from stock returns to ESG returns. Brazil, China, Chile, Czech Republic, Egypt, India, Indonesia, South Korea, Malaysia, Poland, South Africa, and Turkey have positive long-term correlations in the 2012–2016 period, just like Argentina. The long-term association going from stock returns to ESG returns throughout the global financial crisis for China is apparent, as is the relationship from ESG returns to stock returns in the 2019–2020 period, which corresponds to the Covid-19 pandemic. Moreover, it is evident that ESG returns precede stock returns during the Covid-19 period for Colombia, Hungary, and Mexico, and

[2] Although Kuwait, Qatar and the UAE are classified as GCC countries by the MSCI, we consider them with the developed country group.

Table 1
Descriptive statistics for ESG global and developed countries stock market returns.

	ESG Global	Australia	Austria	Belgium	Canada	France	Germany	Ireland	Israel	Italy
n	3720	3720	3720	3720	3720	3720	3720	3720	3720	3720
Mean	0.019	0.002	−0.014	−0.007	0.011	0.008	0.006	−0.012	−0.003	−0.014
Median	0.060	0.022	0.000	0.018	0.047	0.028	0.037	0.000	0.000	0.012
Maximum	8.623	7.145	12.759	10.448	11.802	10.363	11.125	13.383	8.135	10.985
Minimum	−10.269	−10.411	−14.893	−16.470	−13.334	−13.150	−13.341	−17.746	−11.091	−18.791
Std. Dev.	1.087	1.142	1.778	1.411	1.190	1.384	1.368	1.780	1.135	1.617
Skewness	−0.744	−0.637	−0.337	−1.173	−0.989	−0.318	−0.263	−0.594	−0.887	−0.688
Kurtosis	15.492	11.129	10.204	17.279	24.329	11.681	11.759	12.315	12.164	13.254
Jarque-Bera	24,530.86 [0.000]	10,494.63 [0.000]	8113.438 [0.000]	32,457.75 [0.000]	71,118.78 [0.000]	11,744.56 [0.000]	11,934.9 [0.000]	13,666.82 [0.000]	13,503.85 [0.000]	16,591.19 [0.000]
ADF	−14.4458***	−17.6869***	−11.0451***	−11.0332***	−10.7214***	−23.3256***	−60.8435***	−10.8997***	−21.8212***	−28.3396***
PP	−57.959***	−65.7712***	−57.7489***	−59.5444***	−67.1575***	−62.5046***	−60.8497***	−60.4504***	−62.3891***	−63.3516***
KPSS	0.0635***	0.0603***	0.069***	0.1937***	0.0284***	0.0531***	0.0688***	0.2411***	0.037***	0.0455***
	Japan	**Kuwait**	**New Zealand**	**Portugal**	**Qatar**	**Spain**	**Switzerland**	**UAE**	**UK**	**USA**
n	3720	3720	3720	3720	3720	3720	3720	3720	3720	3720
Mean	0.005	−0.010	0.005	−0.022	0.006	−0.012	0.010	−0.002	0.002	0.031
Median	0.000	0.000	0.000	0.000	0.000	0.004	0.018	0.000	0.005	0.044
Maximum	13.062	9.200	6.225	10.338	11.259	14.523	10.506	18.627	9.265	11.043
Minimum	−10.435	−22.710	−6.107	−12.079	−13.871	−15.464	−9.692	−17.261	−11.503	−12.922
Std. Dev.	1.380	1.253	0.998	1.363	1.331	1.571	1.095	1.655	1.189	1.281
Skewness	−0.333	−2.587	−0.170	−0.299	−0.934	−0.321	−0.447	−0.794	−0.388	−0.596
Kurtosis	11.000	44.579	6.146	10.581	21.298	12.874	13.094	21.500	13.156	16.743
Jarque-Bera	9987.357 [0.000]	272,111.7 [0.000]	1551.789 [0.000]	8963.922 [0.000]	52,435.72 [0.000]	15,176 [0.000]	15,917.34 [0.000]	53,438.65 [0.000]	16,082.2 [0.000]	29,493.5 [0.000]
ADF	−36.8292***	−11.6556***	−45.1318***	−17.7153***	−10.504***	−36.7471***	−27.3569***	−39.1794***	−23.3258***	−14.6272***
PP	−60.8908***	−58.4016***	−60.961***	−57.3234***	−57.0861***	−60.977***	−59.637***	−55.5882***	−62.6741***	−70.4001***
KPSS	0.1177***	0.0375***	0.1553***	0.0272***	0.0393***	0.0416***	0.0762***	0.118***	0.049***	0.0716***

Note: [.] is p-value. *** indicates stationary at a 1% significance level.

Table 2
Descriptive statistics for ESG global and developing countries stock market returns.

	Argentina	Brazil	Chile	China	Colombia	Czech	Egypt	Hungary	India	Indonesia
n	3720	3720	3720	3720	3720	3720	3720	3720	3720	3720
Mean	−0.007	0.006	−0.004	−0.002	0.011	−0.013	0.010	0.006	0.029	0.020
Median	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.000
Maximum	12.525	13.441	13.759	14.036	15.752	14.638	12.968	15.112	16.423	14.444
Minimum	−51.131	−15.766	−14.805	−12.832	−18.161	−15.297	−17.815	−14.548	−13.740	−11.449
Std. Dev.	2.540	1.706	1.226	1.664	1.293	1.322	1.647	1.703	1.380	1.554
Skewness	−2.552	−0.498	−0.596	−0.069	−0.960	−0.684	−0.960	−0.277	−0.234	−0.152
Kurtosis	50.943	14.404	22.351	10.681	32.616	22.357	15.595	12.257	17.431	10.855
Jarque-Bera	360,308 [0.000]	20,310.35 [0.000]	58,264.54 [0.000]	9147.523 [0.000]	136,521.1 [0.000]	58,365.59 [0.000]	25,157.84 [0.000]	13,331 [0.000]	32,311.45 [0.000]	9578.114 [0.000]
ADF	−22.405***	−13.8583***	−15.7817***	−10.9768***	−38.5619***	−14.1247***	−39.7822***	−16.9025***	−18.2288***	−19.3534***
PP	−60.4048***	−65.9503***	−56.3402***	−59.2638***	−54.4472***	−58.0994***	−55.2299***	−58.0522***	−59.1813***	−56.3112***
KPSS	0.0567***	0.0306***	0.0311***	0.05***	0.0471***	0.0452***	0.0896***	0.0566***	0.0415***	0.0361***
	Jordan	**Malaysia**	**Mexico**	**Morocco**	**Poland**	**Russia**	**S. Africa**	**S. Korea**	**Turkey**	
n	3720	3720	3720	3720	3720	3720	3720	3720	3720	
Mean	−0.039	0.000	0.013	−0.007	−0.013	0.004	0.020	0.015	0.024	
Median	0.000	0.000	0.000	0.000	0.000	0.036	0.000	0.000	0.007	
Maximum	9.231	6.794	10.393	5.423	7.855	23.950	7.229	11.722	12.723	
Minimum	−45.675	−10.242	−7.710	−10.303	−14.470	−25.279	−9.476	−10.973	−10.761	
Std. Dev.	1.331	0.759	1.206	0.883	1.422	1.911	1.276	1.291	1.628	
Skewness	−10.985	−0.794	0.036	−0.559	−0.525	−0.627	−0.372	−0.279	−0.322	
Kurtosis	379.296	17.905	10.818	13.343	9.541	32.679	8.104	11.793	7.747	
Jarque-Bera	22,022,582 [0.000]	34,826.49 [0.000]	9473.936 [0.000]	16,775.4 [0.000]	6802.052 [0.000]	136,770.7 [0.000]	4124.183 [0.000]	12,031.98 [0.000]	3556.925 [0.000]	
ADF	−29.1096***	−18.7852***	−28.1438***	−23.3865***	−43.8507***	−9.5518***	−23.7911***	−11.6***	−41.4767***	
PP	−57.0928***	−56.9605***	−58.1995***	−53.0996***	−58.5298***	−56.5888***	−61.6162***	−61.3215***	−59.9049***	
KPSS	0.0439***	0.0715***	0.0604***	0.0424***	0.0569***	0.0434***	0.0462***	0.0381***	0.0518***	

Note: [.] is p-value. *** indicates stationary at a 1% significance level.

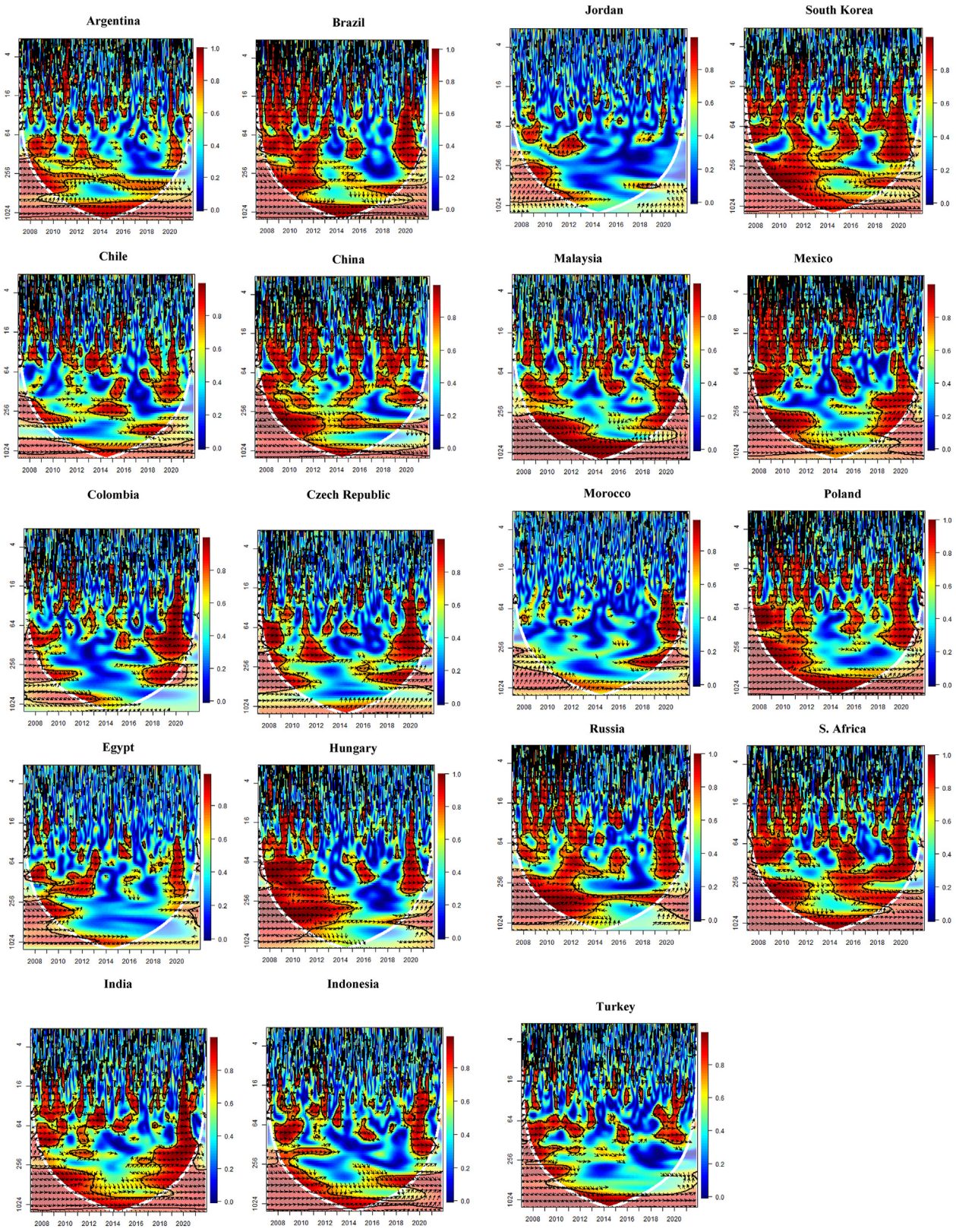

Fig. 1. Wavelet coherency between ESG global index returns and developing countries stock returns.

the effects are often long-lasting. Similar to China, stock returns precede ESG returns during the global financial crisis in Malaysia and Mexico. For the most part, there are positive in-phase comovements between the stock returns and ESG returns in developing countries with no consistent picture about which market leads the other.

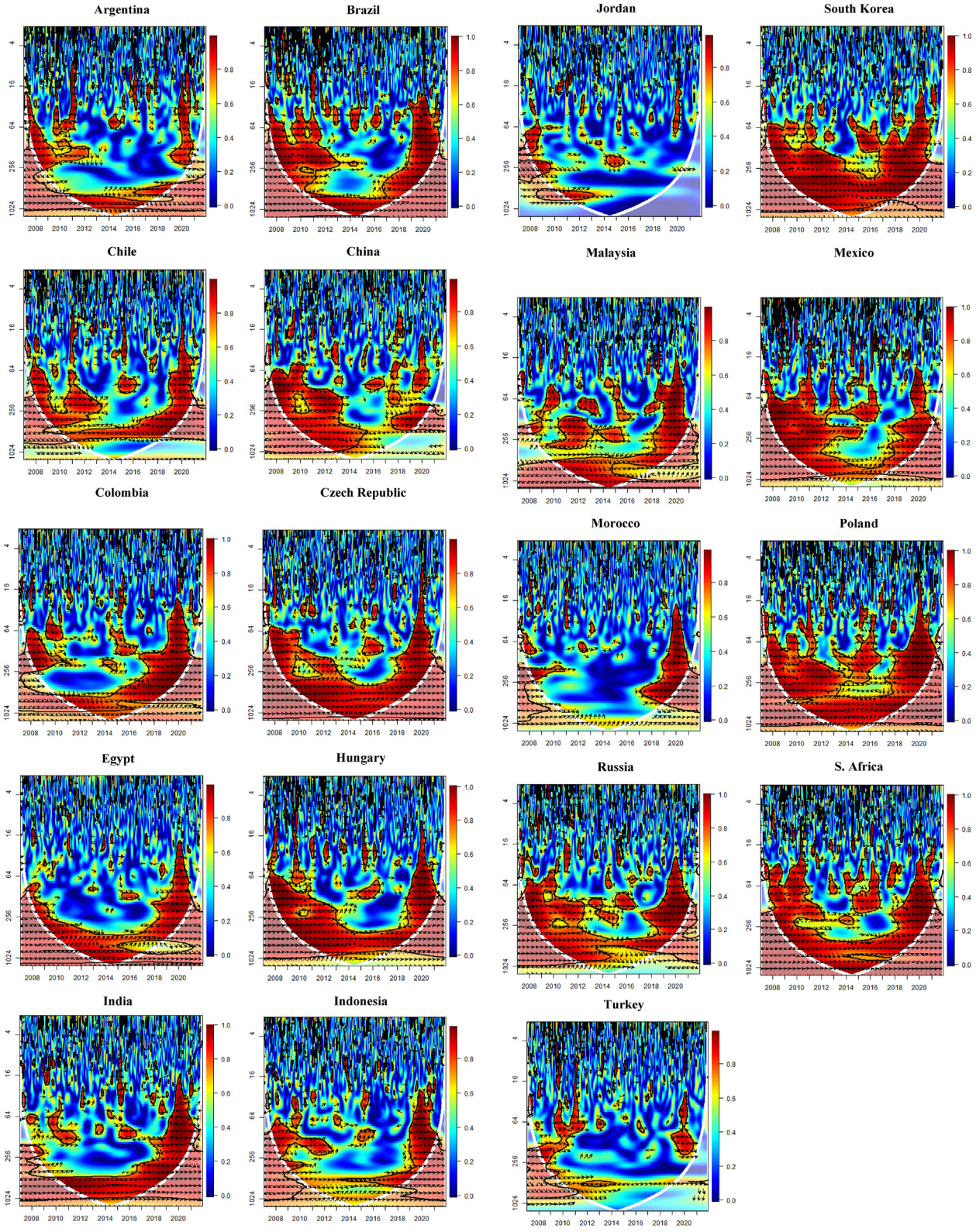

Fig. 2. Wavelet coherency between ESG global index volatility and developing countries stock market volatility.

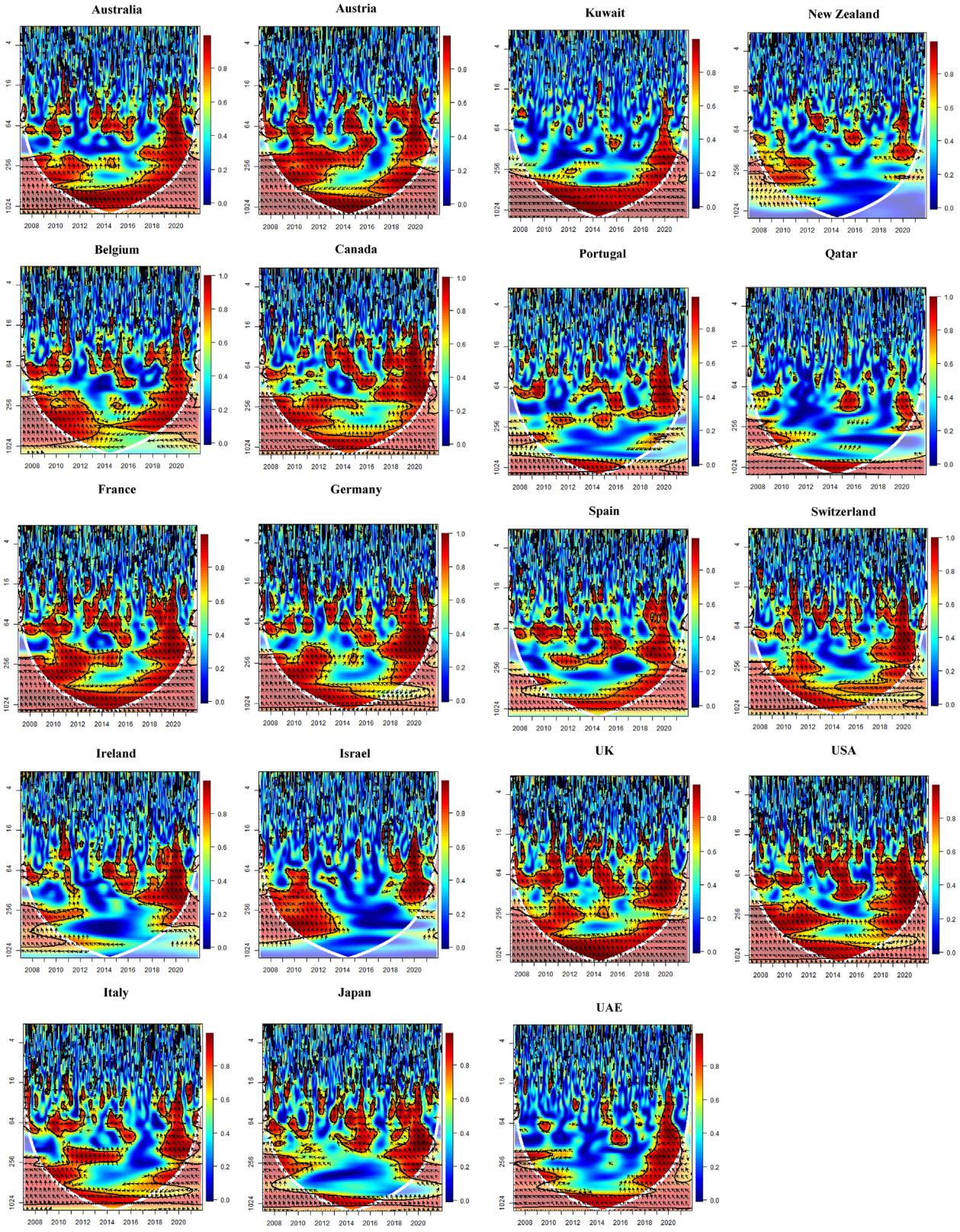

Fig. 3. Wavelet coherency between ESG global index returns and developed countries stock returns.

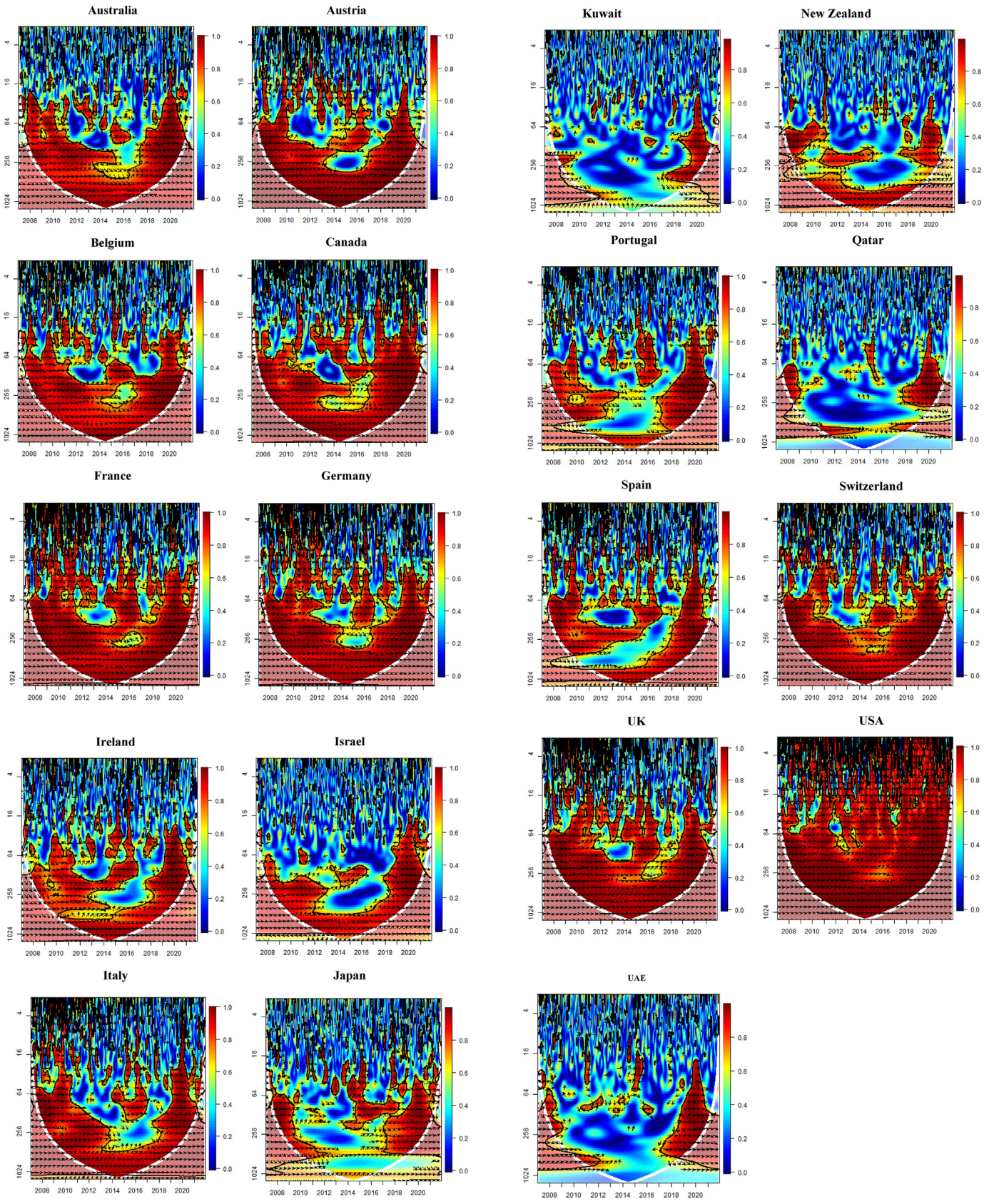

Fig. 4. Wavelet coherency between ESG global index volatility and developed countries stock market volatility.

In Fig. 2, in terms of the relationship between stock market volatility and ESG global index volatility, three significant periods stand out.[3] For example, there is a positive relationship during the global financial crisis period for Argentina, Colombia, Hungary, Poland, and Russia, where stock market volatility leads to ESG global volatility. In the case of Brazil, Chile, China, and Jordan, there is a positive and bidirectional causal association between stock market volatility and ESG global volatility. In contrast, there is a positive link and unidirectional causality from ESG global volatility to stock market volatility for the Czech Republic, Indonesia, South Korea, Mexico, South Africa, and Turkey. In addition, significant linkages and correlations exist between 2012 and 2016. Within this time frame, the relationships between 2012 and 2014 and the subperiod 2014–2016 are distinct. The 2013–2014 period is associated with the "Fed Tapering Effect," where there seems to be positive causality from stock market volatility to ESG global volatility for China, Colombia, Hungary, India, South Korea, Malaysia, and South Africa. It is also evident that ESG global volatility predates stock market volatility for the Czech Republic, Egypt, Mexico, and Poland during 2014–2016. Post-2019 is the other period where significant correlations between the variables can be observed. We attempt to assess the links in this period as the Covid-19 period, which had a substantial impact on financial markets. Generally, positive relationships between stock volatility and ESG global volatility can be observed during this period. Argentina, Brazil, Chile, India, South Korea, Mexico, Poland, Russia, and South Africa have bidirectional causal links over this period. ESG volatility appears to lead to stock market volatility in China, Colombia, Egypt, and Indonesia. In contrast, for Hungary, Malaysia, Morocco, and Turkey, stock market volatility precedes ESG volatility. The most remarkable aspect of the Covid-19 period is the persistence of the causal linkages throughout the period. Overall, there are significant positive spillovers between ESG returns and stock market returns in developing countries as the arrows point in the right direction. However, there is no consistent picture regarding which market leads the other; for some countries, the ESG index leads the stock index, whereas, for others, the stock index leads the ESG index.

As for developed countries, we first evaluate the association between stock returns and ESG global returns using wavelet coherence analysis and report the results in Fig. 3. There seem to be significant negative connections between stock market returns and ESG global returns in wealthy countries, although not in developing countries. Focusing on periods of financial turmoil reveals a significant negative correlation during the global financial crisis for Australia, Austria, Canada, France, Germany, Ireland, Israel, Italy, Japan, New Zealand, Spain, the United Kingdom, the United States, and the United Arab Emirates. In addition, this association is shown to run from stock market returns to ESG global returns. During this time, there seems to be no relationship for Kuwait, Qatar, and Switzerland. Observing major associations in 2012–2016, the relationships in this period overlap with the "oil price crash" that occurred in 2014. During this period, one can observe a negative connection and causal link from stock market returns to ESG global returns for Australia, Austria, Canada, France, Germany, Italy, Japan, Kuwait, Qatar, Spain, and the United States. On the other hand, there is no significant correlation between the two returns for Belgium, Israel, and New Zealand. In all countries, with the exception of Ireland, where statistically significant associations were identified during this period, the effects appear to be medium to long-lasting. The Covid-19 period reveals that the negative link is true for Australia, Austria, Belgium, Canada, France, Germany, Ireland, Israel, Italy, Japan, Kuwait, Portugal, Spain, the United States, and the United Arab Emirates, where the causal link runs from stock returns to ESG global returns. In the remaining countries, stock returns appear to precede ESG global returns, although substantial correlations cannot be established. During the Covid-19 period, the relationship going from stock returns to ESG returns for the United Kingdom is short-term, although there are medium- and long-term relationships for all other countries. Overall, for most developed countries, stock returns lead ESG returns and the comovements seem to be out-of-phase, indicating negative correlations as the arrows point Northeast in the significant regions.

Fig. 4 depicts the links between stock market volatility and ESG global volatility for developed nations. At first glance, it is evident that arrows pointing to the right predominate among the volatility indicators for all countries, indicating significant positive correlations in certain periods. During the global financial crisis, Australia, Austria, France, Ireland, Japan, Portugal, Qatar, and the UAE appear to have positive associations from stock market volatility to ESG global volatility. Although these effects are mainly medium to long term, Qatar and the UAE seem to have short-term links. In Canada, Germany, New Zealand, Switzerland, and the United Kingdom, however, ESG volatility appears to precede stock volatility. There is a causal relationship in both directions in Belgium, Israel, Italy, Spain, and the United States. There seem to be weak volatility spillover effects between ESG and conventional markets for Kuwait, the UAE, and Qatar, except for during the recent Covid-19 pandemic. For Australia, Canada, Portugal, Switzerland, and the United Kingdom, stock market volatility precedes ESG volatility. In contrast, the correlation from ESG volatility to stock volatility holds true for Austria, Ireland, Italy, Japan, New Zealand, and Spain. Belgium, France, Germany, and Israel are the countries where there is a bidirectional relationship between these two variables. When the interactions during the Covid-19 period are assessed, there are positive correlations, albeit the direction of the link varies for each country during this period. For Australia, Belgium, France, Germany, Israel, and Kuwait, we observe that ESG volatility leads to stock market volatility during Covid. For Qatar, Ireland, and Switzerland, however, the causality is from stock market volatility to ESG volatility. Finally, there is bidirectional causality for Austria, Canada, Italy, Japan, New Zealand,

[3] In order to check the robustness of results when a different measure of volatility is used, we use the EGACH model suggested by Nelson (1991) and obtain conditional volatility as a measure of volatility. We find similar results and the results are available upon request.

Portugal, Spain, the United Kingdom, the United States, and the United Arab Emirates. To summarize the relationships between stock market volatility and ESG global volatility for developed countries, we find that the stock markets of Gulf countries differ from those of other developed nations during the global financial crisis and the oil crisis. During Covid-19, the causation from ESG volatility to stock market volatility is significant. In addition, the frequency values of the positive correlation, which holds true throughout the sample for the United States, encompassing the short-, medium-, and long-time scales. Overall, we observe significant volatility spillovers between ESG markets and stock markets in developed countries with in-phase comovements and stock markets that seem to lead ESG markets for the most part.

The wavelet coherence analysis results show that although the ESG stock index has a significant comovement pattern with some developed and emerging stock markets, some stock markets provide a hedging opportunity for ESG investors. To that end, we construct optimal portfolios via wavelet analysis for ESG investors using developed and emerging stock markets. Using wavelet coherence analysis results, we consider the following five different portfolios. Following Das and Kumar (2021), we calculate the portfolio risk, diversification ratio, and annualized return of each portfolio:

Portfolio I
ESG and all Emerging Stock Markets

Portfolio II
ESG and all Developed Stock Markets

Portfolio III
ESG, Egypt, Jordan, Morocco and Turkey

Portfolio IV
ESG, Kuwait, New Zealand, Qatar and the UAE

Portfolio V
ESG, Kuwait, New Zealand, Qatar, the UAE, Egypt, Jordan, Morocco and Turkey

Portfolio I includes ESG global indices and all emerging stock markets. Similarly, Portfolio II consists of ESG global indices and all developed stock markets. Portfolios III, IV, and V are constructed according to the wavelet coherent analysis results. The results in Fig. 1 show the stock returns of Egypt, Jordan, Morocco, and Turkey are less connected with the ESG global index returns among emerging markets. On the other hand, the ESG global index provides more diversification benefits for Kuwait, New Zealand, Qatar, and the UAE among the other developed markets, according to the results in Fig. 3. All portfolios are constructed using an equal weighting allocation scheme. We compare portfolio performance by portfolio risk, diversification ratio and annual returns. Note that the portfolio risk is calculated by the product of the standard deviation of returns and the covariance matrix of returns. The diversification ratio is calculated as the weighted average of volatility divided by portfolio volatility and a higher diversification ratio implies a well-diversified portfolio.

Table 3
Performance of portfolios.

	Portfolio Risk	Diversification Ratio	Annual Return
Portfolio I	0.663	0.340	1.492%
Portfolio II	0.131	1.538	0.936%
Portfolio III	0.653	0.328	0.114%
Portfolio IV	0.140	1.435	0.867%
Portfolio V	0.223	0.917	0.476%

The results in Table 3 indicate that Portfolios II and IV have the lowest risk and the highest diversification ratios. This is not surprising because these portfolios consist of stock markets that exhibit lower comovements with the ESG per the wavelet coherence analysis results. Hence, these findings confirm that wavelet coherence analysis results may help international investors construct well-diversified portfolios.

5. Conclusions

In this paper, we examine the comovements between stock market returns and investments that take into account Environmental, Social, and Governance (ESG) factors by studying interconnections between the two returns in time and frequency space. Our use of wavelet tools for high-frequency financial market data is appropriate for studying financial linkages. Using the wavelet coherence approach, we show how comovements between ESG and stock returns as well as their volatilities change over time and across scales. We study interdependencies between the conventional stock market and ESG stocks using daily data from 2007 to 2021. Conventional stock markets from developed countries include Australia, Austria, Belgium, Canada, France, Germany, Ireland, Israel, Italy, Japan, Kuwait, New Zealand, Portugal, Qatar, Spain, Switzerland, the UAE, the UK, and the US whereas the 19 developing countries include Argentina, Brazil, Chile, China, Colombia, Czech Republic, Egypt, Hungary, India, Indonesia, Jordan, Malaysia, Mexico, Morocco, Poland, Russia, S. Africa, S. Korea, and Turkey.

In the first part of the empirical analysis, we focus on developing countries and examine the comovements between ESG and stock markets and their volatilities. We document that the interconnections between all stock markets change significantly over time and vary across scales. Our findings show that there are significant comovement patterns between ESG returns and stock returns at various frequencies, time scales, and various sample episodes in all developing countries, with the exception of Jordan and Morocco. The interdependencies between ESG returns and stock returns tend to be strong during periods of financial turmoil, such as the Global Financial Crisis and the Covid-19 pandemic. For the most part, there are positive in-phase comovements between the stock returns and ESG returns in developing countries with no consistent picture about which market leads the other. Moreover, there are positive volatility spillovers between stock volatility and ESG global volatility in developing countries.

As for developed countries, we document significant negative connections between stock market returns and ESG global returns, unlike developing countries. Focusing on financial turmoil periods reveals a significant negative correlation during the global financial crisis for Australia, Austria, Canada, France, Germany, Ireland, Israel, Italy, Japan, New Zealand, Spain, the United Kingdom, the United States, and the United Arab Emirates. In addition, this association is shown to run from stock market returns to ESG global returns. Overall, for most developed countries stock returns lead ESG returns and the comovements seem to be out-of-phase, indicating negative correlations as the arrows point Northeast in the significant regions. However, we observe significant volatility spillovers between ESG markets and stock markets in developed countries with in-phase comovements and stock markets seem to lead ESG markets for the most part. Comparing developing countries to developed countries, there seem to be more significant comovements in the short to medium time scale in developed countries with the exception of oil-producing countries such as Kuwait, Qatar, and the UAE. Focusing on major crisis periods such as the global financial crisis and the Covid-19 pandemic, the comovement between the ESG and conventional stock markets varied significantly over time and across frequencies.

Since our results are independent of any model, they have implications for portfolio management. Since we document significant positive comovements between ESG and stock returns over long-term scales, there are limited portfolio gains from diversification over the long-term horizons. Therefore, from a financial perspective, combining ESG and conventional stocks affords downside risk reduction at high frequencies and limited risk reduction at low frequencies for developing country stock investing. However, for most developed countries, comovements between EG stocks and conventional stocks seem to be out-of-phase, indicating negative correlations, particularly at medium-to long-term horizons. Moreover, conventional stock returns seem to lead ESG returns in most developed markets, particularly at medium-to long-term horizons. This implies adding ESG stocks to the portfolio can be beneficial over long-term horizons in developed countries. On the other hand, instructive information about ESG indices and investments by regulators and market regulators will increase social and environmental benefits for society and will also create opportunities to avoid losses or gain financial returns in various crisis periods. At this point, governments may use the information to reasonably guide market expectations. Although a green revolution is a gradual process, sustainable development seems to be an inevitable choice in the future. Also, companies must define, evaluate, and communicate ESG practices efficiently to develop strong stakeholder relationships. In the near future, including ESG in a company's strategy becomes inevitable. Companies that show examples of success in sustainable development and perform well in ESG indices can be rewarded with some concessions from government subsidies and taxation. Overall, the results of the study provide valuable insights for companies, policymakers, and portfolio managers, particularly on risk management, diversification, and portfolio selection and especially in times of crises such as the Global Financial Crisis and COVID-19.

Declaration of competing interest

There is no conflict of interest.

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