Economic Modelling 93 (2020) 112–124

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.journals.elsevier.com/economic-modelling

The static and dynamic connectedness of environmental, social, and governance investments: International evidence

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ARTICLE INFO

JEL classification:
G10
G11
G15

Keywords:
ESG investments
Connectedness
European sovereign debt crisis
COVID-19 pandemic
Portfolio diversification

ABSTRACT

We investigate the connectedness of the most significant global equity indices that comprise companies with the highest environmental, social, and governance (ESG) performance. Motivated by the rapid growth of socially responsible investing during the last two decades, we examine whether these investments are prone to similar exogenous economic and financial shocks as their conventional counterparts. Employing a variety of influential macroeconomic and financial variables over the period 10/1/2007–4/15/2020, we document statistically significant and consistent transmissions between the employed equity indices throughout the sample period. In particular, the connectedness exhibits dynamic patterns during three periods: the European sovereign debt crisis, the systemic Greek problems, and the outbreak of the coronavirus pandemic. We also find that developed equity markets are the shock transmitters to Asian and other emerging markets. Our results highlight the risk of contagion and the diminishing portfolio diversification benefits of these equity indices during turbulent periods.

1. Introduction

The adoption of environmental, social, and governance (ESG) criteria in the investment process is a rapidly rising international trend. ESG criteria comprise a set of standards regarding companies' operations that investors can use in selecting potential investments. ESG criteria address (1) environmental factors, as evidenced by a company's efforts to address climate change by reducing greenhouse gas emissions, effective waste management, the use of renewable energy sources, etc.; (2) social factors such as human rights, labor standards, illegal child labor, and adherence to workplace health and safety regulations; and (3) governance factors, which refer to rules that define the rights, responsibilities, and expectations of different stakeholders in the company's governance. By allowing nonfinancial attributes to influence investments, socially responsible investment (SRI) offers such benefits as superior return, lower risk during turbulent periods, reputation management, and peace of mind (Bollen, 2007; Riedl and Smeets, 2017; Umar and Suleman, 2017).

The appeal of ethically, environmentally and socially responsible investments over the past couple of decades can be contrasted with the unrestricted investment portfolio of modern finance, which is considered to the best option for an investor wishing to allocate funds (EUROSIF, 2014).[1] Ethical and environmentally and socially responsible investments have partially been aided by financial crises (e.g., the global financial crisis) and financial scandals (e.g., Enron). The notable rise of ESG is demonstrated by the fact that socially responsible investment has risen more than 34% since 2016 globally, according to the Global Sustainable Investment Alliance (GSIA), with more than $30 trillion in total assets under management at the start of 2018. According to the European Sustainable Investment Fund (EUROSIF), the last two decades show clear signs of SRI becoming integral to European fund management, while ESG integration, which remains by far the preferred strategy, has grown by 60%. In addition, ESG equity mutual funds have attracted record net flows in recent years (Koutsokostas and Papathanasiou, 2017; Koutsokostas et al., 2019). Europe accounts for the largest concentration of ESG assets worldwide, totaling $14.1 trillion in 2018, followed by the US with $12 trillion; the latter increased by 38% from 2016. Japan is the third

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[1] The European Union is currently working to establish new rules to support environmentally sustainable investments in order to provide a taxonomy for such investments and increase standardization (EU, 2019a, 2019b).

https://doi.org/10.1016/j.econmod.2020.08.007
Received 20 September 2019; Received in revised form 25 July 2020; Accepted 5 August 2020
Available online 12 August 2020

largest market for sustainable investing after Europe and the US, with managed assets rising from 3% to 18% during the same period. SRI also grew by 42% over the same 2-year period in Canada and accounts for half of the country's total assets under management. Australia also has a high proportion of sustainable assets relative to total assets under management.

This study investigates the connectedness and spillover effects across various equity indices that comprise companies with the highest ESG performance for the period 10/1/2007–04/15/2020. Our sample consists of the daily closing prices of MSCI ESG Leaders Indices for 10 equity markets: the US, Australia, Canada, China, Europe, India, Japan, Russia, South Africa, and the UK. The selected indices invest in the most significant ESG markets in terms of depth and breadth, and represent a high percentage of SRI of global market capitalization. Our sample represent both developed and emerging market indices enabling us to analyze the spillover and portfolio diversification benefits across these well known market segments (Umar, 2017a, 2017b; Kenourgios et al., 2020). In addition, a set of macroeconomic and financial variables, including the VIX implied volatility index, the US economic policy uncertainty index (EPU), the international crude oil price, and changes in the US 10-year Treasury bond yield, are taken into account in order to identify possible channels that transmit spillovers between ESG markets. These variables represent well-known indicators of uncertainty in stock markets and reflect contingent fluctuations in the global financial system during periods of turmoil. We first conduct a Granger (1969) causality test in order to evaluate causality between our sample indices, then check for connectedness and spillover effects across the indices by employing the Diebold and Yilmaz (DY, 2012) method.[2]

Motivated by the impact of global sustainable investing during the last two decades, and especially after the global financial crisis, we seek to answer five main research questions: (1) Do ESG equity markets interconnect during the last decade? (2) Are there spillover effects across ESG markets, and do they display a static or dynamic pattern? (3) Which ESG markets play the role of net contributor/receiver for other markets? (4) Which transmission channels seem to operate between ESG markets? (5) How has the connectedness of ESG indices evolved and affected portfolio diversification benefits across time?

SRI, along with ethical investments that adhere to Islamic or Shariah-compliant equity indices, is considered to be an alternative form of investment and, specifically, a form of ethical finance. This paper is also motivated by the rapid growth of ethical finance, which has spurred interest from investment practitioners and academics alike, as well as the ongoing research agenda that examines SRI and Islamic banking and finance to understand how they differ from the conventional approach. Although there is ample research on risk transmission and contagion between faith-based and conventional investment (see for example, Kenourgios et al., 2016; Shahzad et al., 2017; Hkiri et al., 2017; Umar et al., 2018, 2020; Jawadi et al., 2019 and references therein), as well as on the performance of SRI and conventional investment (e.g., Hamilton et al., 1993; Climent and Soriano, 2011; Oikonomou et al., 2018), the connectedness of SRI has not been thoroughly investigated.

Our contributions to the literature are threefold. First, we add depth to the connectedness literature that focuses on several asset classes by investigating for the first time, to the best of our knowledge, the spillover effects between ESG equity indices. Second, we add breadth by using a comprehensive dataset that spans the last 12 years and features 10 major world ESG markets and four economic crises—the global financial crisis (GFC), the European sovereign debt crisis (ESDC), the oil crisis, and the COVID-19 pandemic—to compare connectedness patterns in ESG equity indices. Third, given that markets that adopt ESG criteria have been characterized by continual fluctuations during the last decade, we identify whether specific global risk factors could act as transmitting channels for spillovers between ESG equity indices in the same way they act for conventional ones, and how this mechanism has evolved over time. We believe that our analysis of connectedness will be valuable for global investors, traders, and portfolio managers in terms of whether diversification across ESG equity indices can be achieved during turbulent periods. Furthermore, our results will appeal to policymakers, because the co-movement of ESG indices should be taken into consideration in periods when financial stability is required.

Our analysis finds significant spillover effects between the MSCI ESG Leaders Indices and the selected macroeconomic and financial variables throughout the sample period. In general, total connectedness exhibits a static pattern during 10/1/2007–04/15/2020. However, during two subperiods—from mid-2011 to mid-2013 and mid-2015 to late 2017—characterized by turbulence in the Eurozone, the connectedness becomes dynamic. This implies that major economic and financial shocks kept the volatility of ESG markets high. The same holds for the coronavirus outbreak (Feb. 2020–April 2020), during which total connectedness exhibit a rise of approximately 30%. These findings suggest that the markets under consideration are strongly connected. Key players in ESG capital markets—notably, the US, Canada, Europe and the UK—transmit shocks to other markets (net transmitters), while Japan, China, and India are influenced by developed countries (net receivers). The VIX volatility index is found to be the main transmission channel that influences markets that comply with ESG criteria.

The rest of the paper is organized as follows. Section 2 reviews the literature on socially responsible investing. Section 3 describes the data and methodology. Section 4 presents and discusses the results, and Section 5 concludes.

2. Literature review

In this section we give a brief review of the various strands of literature on the topic of ESG investments.

The first strand of studies deals with the comparative performance of ESG screened mutual funds with their conventional peers or the benchmarks. These studies document mixed results. Renneboog et al. (2008) find that the performance of SRI funds in the US, the UK and in many European and Asia-Pacific countries follows closely the performance of conventional funds and falls short of the performance of their equivalent benchmarks. Derwall and Koedijk (2009) also find the performance of SRI bond funds to be similar to the performance of their conventional peers for the period 1987–2003. However, they document that SRI balanced funds outperformed the conventional balanced funds by 1.3% per year. On the other hand, Gi-Bazo et al. (2010) document that the US SRI funds outperform the conventional funds for the period 1997–2005, by taking into account both gross and net returns. They also find that, to a certain degree, there are no significant differences in management fees between SRI and conventional funds, except that SRI funds tend to be cheaper than conventional funds when they are offered by the same management company. Finally, Joliet and Titova (2018) present an analysis of investment decisions taken by US equity SRI funds based on holdings. They conclude that both SRI and conventional funds incorporate ESG information as well as financial criteria in their investment decisions, however SRI funds achieve higher sustainability scores.

Another strand of literature documents the effect of environmental, social and governance disclosure on firm value. Li et al. (2018) use a large sample of 350 firms listed on FTSE and cross-sectional data to address the aforementioned issue. They show a positive correlation between ESG

[2] We are aware of alternative methodologies available to analyze spillover and connectedness dynamics, such as dynamic copulas with and without regime switching, global vector autoregression models, wavelets, etc. Our choice to use the DY (2012) method builds on its ability to maintain comparability with much of the existing literature that analyzes similar characteristics for different asset classes. Also, relative to copulas and wavelets, the DY model is easier to implement and interpret. Therefore, this approach has been extensively used in financial economics literature to analyze spillovers across various assess classes and asset markets (Shahzad et al., 2017; Umar et al., 2019; Bostanci and Yilmaz 2020 to cite a few).

disclosure level and firm value, indicating that transparency, accountability and stakeholder trust boosts firm value. They document that higher CEO power ameliorates the effect of ESG disclosure on firm value, suggesting that stakeholders relate firms' ESG disclosure to higher CEO power and greater adhesion to ESG practice. Similarly, Fatemi et al. (2018) document that ESG activities and their disclosure increase firm value, while the lack of such activities decreases it.

Portfolio performance of SRI investments is another widely documented strand of literature. Consolandi et al. (2009) compare the returns of the Dow Jones Sustainability Stoxx Index (DJSSI) with the returns of the Surrogate Complementary Index (SCI) to explore the possibility of divergence in performance. In addition, the authors investigate the impact of the announcements regarding the inclusion and deletion in the DJSSI on abnormal returns. Their empirical results show that the DJSSI slightly underperformed the benchmark portfolio for the period 2001–2006, but the inclusion announcement generated positive cumulated abnormal returns, emphasizing the role of SRI in asset allocation. Moreover, Halbritter and Dorfleitner (2015) examine the correlation between the social and financial performance based on ESG ratings and argue that investors can not generate profits by trading a difference portfolio of high and low rated firms. Similarly, Auer and Schuhmacher (2016) infer that selecting high- or low-rated stocks of ESG firms does not provide investors with superior returns, as they find ESG performance similar to the market's for Asia-Pacific and US investors, but lower than the market's in the case of Europe. Jawadi et al. (2019) compare conventional vs. ethical investments (Islamic, sustainable, and industrial indices) and find that the latter show comparable levels of uncertainty, but vary with phases of the business cycle. On the other hand, Tripathi and Bhandari (2016) argue that socially responsible companies are better performers than general companies in the Indian stock market by generating significant abnormal returns. Oikonomou et al. (2018) also document that the screening criterion for ethical investing are not necessarily harmful for investors, since a portfolio featuring SRI yields superior risk-return trade-offs compared to the unrestricted portfolio of investments.

The issue of contagion and connectedness between various types of investments has been widely documented. (Akhtaruzzaman et al., 2014, 2019; Akhtaruzzaman and Shamsuddin, 2016; Awartani et al., 2016; Spierdijk and Umar, 2017; Malik and Umar, 2019; Zaremba et al., 2020; Naeem et al., 2020; Stereńczak et al., 2020; Umar et al., 2019). However, little evidence is there regarding the connectedness of ESG leader investments. Reboredo and Ugolini (2019) is a notable exception who investigated the connectedness between green bonds and financial markets by using a structural vector autoregressive model. Their empirical findings show that the green bond market is a net spillover receiver, while treasury and currency markets are net spillover transmitters. Similarly, Reboredo et al. (2020) also demonstrate that the green bonds receive spillover effects from treasury and corporate bonds prices. This study contributes to this sparse strand of literature by discussing the connectedness of ESG leader equity indices.

3. Data and methodology

The data for this study is obtained from Thompson Reuters DataStream. We use MSCI ESG leader equity indices as a proxy for the ESG investments. These indices are designed to include companies that have the highest environmental, social and governance rated performance. We employ daily frequency data of equity indices covering ten developed and developing markets; USA, Australia, Canada, China, Europe, India, Japan, Russia, South Africa, the United Kingdom. The daily frequency for calculating returns contributes to the enhancement of the predictive power of the models employed in this study. Also, daily data contains richer information than other data frequency (monthly, quarterly or weekly). The time-period of our analysis range from October 1, 2007 to April 15, 2020, enabling us to employ 3273 daily observations. We choose to investigate the connectedness during the aforementioned period as: 1) socially responsible investing has witnessed a remarkable growth over the last decade; 2) markets adopting ESG criteria have endured intense fluctuations during 2007–2020; 3) this time period include major events such as the global financial crisis of 2007–2009, the European debt crisis of 2010–2016, the oil-price crash of July 2014–December2, 015[3] and the recent COVID-19 pandemic.

Moreover, several risk factors are also included in our study. Risk-taking behavior of market participants is accounted for by employing variables that have a remarkable influence on the global financial environment. These are: the VIX volatility index, the US equity market-related uncertainty index, the US 10-year Treasury bond yield and the WTI (West Texas Intermediate) crude oil price. The VIX index, also known as "Fear Gauge" or "Fear Index", is the Chicago Board Options Exchange (CBOE) volatility index which represents the market participants' expectations regarding the volatility of the S&P 500 index options over the forthcoming 30 days. Increasing values of the VIX index denote unpropitious future prospects in the stock market and are related to decreases in the stock prices. The US (equity market-related) economic policy uncertainty index (EPU), developed by Baker et al. (2012), is based on the number of newspaper archives referring to issues about stock market uncertainty. As in the case of the VIX volatility index, an increase in the level of the US uncertainty index is associated with a drop in the stock market prices. The US 10-year Treasury bond yield is used as a proxy for the long-term interest rates. In most cases, the relationship between the long-term interest rates and stock returns is inverse, as denoted by Shahzad et al. (2017). Thus, a rise in the long-term interest rates shall reduce stock prices. However, a positive relationship between these variables cannot be excluded when the economic prospects are favorable (Ferrer et al., 2016). Finally, the WTI oil price is used as a proxy for the international crude oil price. As an essential input in the production of a variety of goods and services, oil prices constitute a major factor of uncertainty in economy, although the literature has not given concrete results concerning the relationship between oil and stock prices (Jones and Kaul, 1996; Miller and Ratti, 2009). The data series for all the aforementioned risk factors are obtained from Thompson Reuters Datastream.

At a preliminary stage, the Granger (1969) causality test is firstly implemented in order to examine the relationships among the indices under consideration. The Granger (1969) test is commonly used in determining whether one time series is useful in forecasting another time series. To check for Granger (1969) causality, we assume the following y and x stationary time series:

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i Y_{t=1} + \sum_{i=1}^{m} \beta_i X_{t-1} + u_t \tag{1}$$

$$X_t = \alpha_0 + \sum_{i=1}^{m} \gamma_i Y_{t-1} + \sum_{i=1}^{m} \delta_i X_{t-1} + e_t \tag{2}$$

where m is the number of lagged values, a_0, α_i, β_i, γ_i, δ_i are regression's parameters and u_t, e_t error terms. In Equation (1), we presume that the current values of the Y_t variable are function of its lagged values and of the lagged values of X_t variable. In the same manner in Equation (2), the current values of the X_t variable are function of the lagged values of Y_t variable and of its own lagged values. If:

- β_i are statistically significant, while γ_i statistically insignificant, then X Granger-causes Y.
- β_i are statistically insignificant, while γ_i statistically significant, then Y Granger-causes X.

[3] During the oil-price crash, the average oil price dropped from $103 to around $31.The ESDC is assumed to begin shortly before the Greek bailout in May 2010 from the Eurozone and the IMF, and spans until the exit of Cyprus from the economic adjustment program on the 31st March 2016.

- both β_i and γ_i are statistically significant, then a bi-directional Granger causality occurs.
- both β_i and γ_i are statistically insignificant, then no Granger causality exists.

After the application of Granger (1969) causality test, we assess the connectedness among the sample markets, following the Diebold and Yilmaz (2012) approach. This approach is based on variance decomposition, in which the forecast error variance of a variable is decomposed into parts attributed to various variables in the system. Diebold and Yilmaz (2012) suggested the resulting H-step-ahead generalized forecast-error variance decomposition as follows:

$$\theta_{ij}(H) = \frac{\sigma_{jj}^{-1}\sum_{h=1}^{H-1}\left(e_i' A_h \sum e_j\right)^2}{\sum_{h=0}^{H-1}\left(e_i' A_h \sum A_h' e_i\right)} \tag{3}$$

where e_j is a selection vector with jth element equal to one and zero otherwise, A_h is the coefficient matrix multiplying the h-lagged shock vector in the infinite moving-average representation of the non-orthogonalized VAR, Σ is the covariance matrix of the shock vector in the non-orthogonalized VAR and σ_{jj} is the jth diagonal element of Σ. The spillover index yields a $n \times n$ matrix $\theta(H) = [\theta_{ij}(H)]$, where each entry represents the contribution of variable j to the forecast error variance of variable i. The own-variable contributions are included in the main diagonal of the $\theta(H)$ matrix, while cross-variable contributions in the off-diagonal elements.

Moreover, since $\sum_{j=1}^{n}\theta_{ij}(H) \neq 1$, each entry of the variance decomposition matrix is normalized by its row sum as follows:

$$\tilde{\theta}_{ij} = \frac{\theta_{ij}(H)}{\sum_{J=1}^{n}\theta_{ij}(H)} \tag{4}$$

with $\sum_{j=1}^{n}\tilde{\theta}_{ij}(H) = 1$ and $\sum_{i,j=1}^{n}\tilde{\theta}_{ij}(H) = n$ by construction.

This enables us to define a total spillover index as follows (Husain et al., 2019):

$$TS\left(H\right) = \frac{\sum_{i,j=1,i\neq j}^{n}\tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{n}\tilde{\theta}(H)} \times 100 = \frac{\sum_{i,j=1,i\neq j}^{n}\tilde{\theta}_{ij}(H)}{n} \times 100 \tag{5}$$

Finally, we can record the directional spillovers received by market i from all other markets j and vice versa, i.e. the ones transmitted by market i to all other markets j, as computed in the following equations:

$$DS_i \leftarrow j\left(H\right) = \frac{\sum_{j=1,j\neq i}^{n}\tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{n}\tilde{\theta}_{ij}(H)} \times 100 = \frac{\sum_{i,j=1,j\neq i}^{n}\tilde{\theta}_{ij}(H)}{n} \times 100 \tag{6}$$

$$DS_i \rightarrow j\left(H\right) = \frac{\sum_{j=1,j\neq i}^{n}\tilde{\theta}_{ji}(H)}{\sum_{i,j=1}^{n}\tilde{\theta}_{ji}(H)} \times 100 = \frac{\sum_{i,j=1,j\neq i}^{n}\tilde{\theta}_{ji}(H)}{n} \times 100 \tag{7}$$

By subtracting Eq. (6) from Eq. (7), we estimate the net spillovers from each market to all other markets:

$$NS_i(H) = DS_i \rightarrow j(H) - DS_i \leftarrow j(H) \tag{8}$$

4. Empirical results

In this section we report the empirical results. We start with the results for Granger causality, thereafter we study the static connectedness for the entire sample period, followed by the dynamic connectedness.

4.1. Granger causality

Table 1 presents the descriptive statistics regarding the daily returns of the ESG indices and the global risk factors under investigation.

Table 1 shows that the coefficients of skewness are negative for most

Table 1
Descriptive statistics.

	USA	AUS	CAN	CHN	EUR	IND	JP	RUS	SA	UK	VIX	EPU	OIL	10YTB
Mean	0.00019	−0.00015	−0.00004	0.00016	−0.00007	0.00008	−0.00001	0.00002	−0.00005	−0.00019	2.96974	4.55114	−0.00043	0.00012
Median	0.00031	0.00020	0.00042	0.00008	0.00014	0.00000	0.00024	0.00025	0.00045	0.00025	2.90279	4.53271	0.00000	0.00015
Maximum	0.10547	0.08763	0.11564	0.14773	0.10646	0.19506	0.11682	0.36829	0.11529	0.11499	4.25526	6.60843	0.22048	0.04053
Minimum	−0.12925	−0.15964	−0.13944	−0.09930	−0.13745	−0.14736	−0.09553	−0.23472	−0.13186	−0.13248	2.41368	1.19997	−0.38829	−0.02874
Std. deviation	0.01318	0.01651	0.01514	0.01699	0.01482	0.01634	0.01370	0.02688	0.02039	0.01450	0.32569	0.57977	0.02691	0.00489
Skewness	−0.60097	−0.81746	−0.93445	0.23415	−0.26767	0.04813	−0.15266	0.07015	−0.28121	−0.49388	0.99229	0.01531	−0.92229	0.03680
Kurtosis	16.93	12.70	17.01	10.56	12.00	15.64	9.01	23.31	6.96	15.16	3.87	3.61	28.13	6.59
Jarque-Bera	26670.26*	13200.50*	27237.00*	7815.98*	11087.03*	21797.53*	4935.53*	56257.72*	2178.67*	20282.02*	639.93*	50.16*	86593.46*	1756.47*
Observations	3273	3273	3273	3273	3273	3273	3273	3273	3273	3273	3273	3273	3273	3273

Note: This table presents the sample statistics (daily frequency) for the ESG stock indices of USA, Australia, Canada, China, Europe, India, Japan, Russia, South Africa, the United Kingdom, and for VIX index, US economic policy uncertainty (EPU) index, WTI crude oil (OIL) and US 10-year Treasury bond yield (10YTB) over the period 10/31/2007–04/15/2020. * defines significance at 5% level.

of the equity market series except China, India, Russia and VIX, EPU index and 10-year Treasury bond yield. Similarly, the kurtosis coefficients are high implying fat tails. The Jarque and Bera (1980) test rejects the hypothesis that the return series for our sample markets are normally distributed. All the returns series of our sample are stationary at level using the augmented Dickey and Fuller (1979) and KPSS tests with p-value = 0.[4] We employ the Granger (1969) causality test to investigate the causality between various variables. The results are shown in Table-2. We can conclude the following from Table 2:

1. The pairs of US-Canada, US-China, US-Europe, USA-Russia and USA-South Africa exhibit bi-directional causality. On the other hand, Australia, India, Japan and the UK do not seem to influence the US market, which in turn affects all the sample markets.
2. Australia and the remaining markets are mutually interacting, except US, Russia and the UK where this relation is one-directional (US→Australia, Russia→Australia, UK→Australia).
3. A two-way Granger causality appears between Canada and the rest of the markets, with the exception of India and Russia where this relation is one-way (Canada→India, Canada→Russia).
4. A bi-directional Granger causality exisits between the Chinese and all the other markets of our sample.

Overall, our empirical results exhibit mutual interaction among the markets, with a few exceptions. Our findings are in line with Akhtaruzzaman and Shamsuddin (2016), who use a large sample of 49 countries to report significant transmissions of shocks and contagion, attributable to the level of equity market development and bilateral trade intensity, through financial and non-financial firms.

The Granger causality relations among the markets at 5% level are illustrated in Fig. 1. By looking the color of the arrows, we observe that China displays the highest causality with the other markets (red marked arrows), while 10-year T-bills the lowest one (blue marked arrows).

4.2. Static connectedness

Next, we analyze the static connectedness of the variables under consideration by estimating the spillover matrix for the entire sample period ranging from January 10, 2007 to 04/15/2020. Table-3 shows that the highest pairwise connectedness is from Europe to UK (UK to Europe) with a value of 16.77% (16.17%). Taking into account several events that took place during our sample period (for instance the European debt crisis and the Brexit referendum), the relatively higher pairwise connectedness between these markets seems plausible. The next largest pairwise directional connectedness is from Canada to the US (US to Canada) at 14.89% (13.39%). Given the shared borders, North American Free Trade Agreement (NAFTA) and the stable and mutually beneficial international relationship in terms of imports, exports and tourism, the high values of connectedness reported are in line with expectations.

The interaction of the UK with the US and Canada also seems to be strong. The pairwise connectedness from the UK to the US (US to UK) equals 10.27% (10.39%). Approximately, the same connectedness figures appear in the case of UK-Canada respectively, showing that these three markets are connected to each other. Moreover, the European and the Canadian market are mutually interacting, as the connectedness values are 11.40% and 10.94% respectively. The co-movement of the European and the US market is also apparent, as the pairwise directional connectedness from Europe to US (US to Europe) is 10.60% (10.20%). These values seem reasonable because these markets are among the largest markets in their depth and breadth.

Other notable values reported in Table 3 are the directional connectedness of the US, Canada and Europe to Australia (10.35%, 10.10% and 10.21%, respectively) and from Europe and the UK to South Africa (11.73% and 10.91%, respectively). Finally, Japan seems to be affected by the US market to a great extent (12.19%) and Russia by the Canadian market (10.29%), but once again these relationships are primarily one-directional.

The row sum of the pairwise connectedness is the total directional connectedness from other markets to each of the ten markets. Stated differently, the “FROM” column estimates the share of shocks received from other markets in the total variance of the forecast error for each market. As shown in Table 3, the total directional connectedness in the “FROM” column ranges from 10.34% to 78.65%.

Similarly, the column sum of the pairwise connectedness is the total directional connectedness from a specific market to all other markets. In other words, the “TO” row measures the sum of shocks transmitted from a specific market to the variance of the forecast error for each market. Furthermore, Table 3 shows that the total directional connectedness in the “TO” row varies between a low of 0.28% (EPU) and a very high of 116.30% (US). US, Europe, Canada and the UK have one of the highest values of connectedness (exceeding 100%) to other markets. South Africa and Australia also exhibit significant connectedness to others.

The subtraction of “total directional connectedness from others” from “total directional connectedness to others” gives us the “net total directional connectedness to others”. As it can be seen from the last row of Table 3, the USA prevails (41.55%), followed by Canada (38.39%), Europe (36.95%) and the UK (30.74%). On the other hand, Japan (−56.30%), China (−22.62%) and India (−18.17%) are financial markets with high negative values of net total directional connectedness to others. Our empirical findings are compatible with the findings of Akhtaruzzaman et al. (2019) who document the United States as a significant contributor of spillover effects through financial firms. When it comes to China, our results are incongruous with their findings though, as they report significant spillovers transmitted from the Chinese market, which in our case does not apply. As concerns the macroeconomic and financial variables of our analysis, the majority of them are identified as net receivers of spillovers, with the exception of the volatility index (VIX) which marginally appears as a net transmitter.

Fig. 2 depicts all the net directional connectedness generated between the pairs of the sample markets. As shown in Fig. 2, it is evident that Europe and Canada are net contributors of spillovers to other markets, whereas the EPU index displays the weakest net pairwise directional connectedness. The USA is primarily a net contributor, but it appears to be a net receiver also, to a lesser extent though.

Total directional connectedness reaches 63.90% (Table 3), a value rather high, indicating the strong correlation between markets that adopt the ESG criteria. One reason for this high value of total connectedness could lie on the fact that the included markets in our analysis abide by the ESG standards. Thus, both industry-wide, and macroeconomic shocks as well, have a significant impact on each one of these markets and can be transmitted to other markets, resulting in a high degree of total connectedness (Diebold and Yilmaz, 2014).

4.3. Dynamic connectedness

After analyzing the connectedness over the entire sample period, we proceed and study the dynamics of connectedness over the sample period by employing a rolling window approach. We employ a rolling window of approximately 9 months and analyze the changing dynamics in

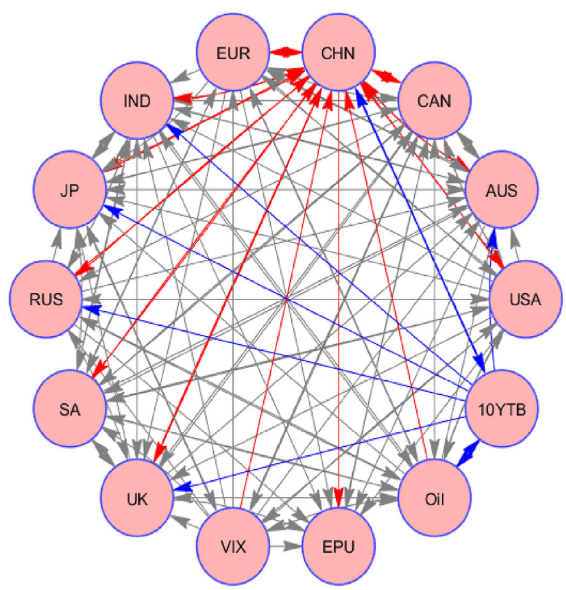
[4] In order to allow for the possibility of a structural change, we also use the Zivot and Andrews (1992) sequential test for a unit root with the alternative hypothesis of stationarity and a single structural change in the deterministic trend. The breakpoints, as identified by the Zivot-Andrews test, are statistically significant and vary across countries. All stationarity test results are available up on request.

Table 2
Granger causality test results.

	USA	AUS	CAN	CHN	EUR	IND	JP	RUS	SA	UK	VIX	EPU	OIL	10YTB
USA	0.00	0.09	0.00	0.02	0.00	0.25	0.08	0.03	0.00	0.22	0.00	0.06	0.00	0.22
AUS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00
CAN	0.00	0.00	0.00	0.00	0.02	0.28	0.01	0.87	0.00	0.00	0.00	0.03	0.00	0.46
CHN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.00
EUR	0.00	0.04	0.00	0.00	0.00	0.09	0.50	0.17	0.00	0.08	0.00	0.43	0.00	0.10
IND	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.32	0.00	0.00
JP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00
RUS	0.00	0.11	0.00	0.00	0.15	0.04	0.78	0.00	0.16	0.36	0.00	0.44	0.00	0.01
SA	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.10	0.00	0.01	0.00	0.05	0.00	0.26
UK	0.00	0.32	0.00	0.00	0.00	0.00	0.65	0.03	0.00	0.00	0.00	0.46	0.00	0.02
VIX	0.00	0.62	0.00	0.40	0.11	0.62	0.04	0.18	0.23	0.42	0.00	0.35	0.01	0.09
EPU	0.00	0.01	0.00	0.00	0.00	0.00	0.05	0.01	0.25	0.00	0.00	0.00	0.26	0.10
OIL	0.00	0.12	0.00	0.06	0.01	0.01	0.29	0.00	0.02	0.00	0.00	0.08	0.00	0.01
10YTB	0.10	0.54	0.17	0.00	0.16	0.44	0.12	0.12	0.21	0.11	0.49	0.25	0.03	0.00

Note: This table shows the p-values of the Granger causality test between the different pairs of our sample at 5% level. The sample includes ESG stock indices of USA, Australia, Canada, China, Europe, India, Japan, Russia, South Africa and the United Kingdom, as well as the VIX index, US economic policy uncertainty (EPU) index, WTI crude oil (OIL) and US 10-year Treasury bond yield (10YTB) over the period 10/31/2007–04/15/2020.

5. The European market is influenced by US, Australia, Canada, China and South Africa and influences all markets except Russia.
6. There is a bi-directional relation between India-Australia, India-China, India-Japan, India-Russia, India-South Africa and Inida-UK. On the other hand, US, Canada and Europe do not seem to be influenced by the Indian market, while the Indian market is affected by them (US→India, Canada→ India, Europe→ India)
7. Japan and the rest of the remaining markets are mutually interacting, except the cases of Japan-US, Japan -Europe, Japan -Russia, Japan -South Africa and Japan -UK, where these relations are one-directional (USA→ Japan, Europe→ Japan, Russia→ Japan, South Africa→ Japan, UK→ Japan).
8. A bi-directional Granger causality exist between Russia-USA, Russia-China and Russia-India. On the other hand, there is a lack of any interaction between Russia-Europe and Russia-South Africa. Furthermore, a one-way Granger causality occurs in the cases of Australia, Japan, UK and Canada (Russia→Australia, Russia →Japan, Russia →UK, Russia →Canada).
9. A mutual interaction is observed between South Africa and the rest of the markets, with the exception of Russia where no dependency is documented, and Japan where the relationship is one-directional (South Africa→Japan).
10. The only markets that do not affect the UK are Australia and Japan. On the other hand, the UK market does not affect the USA, Europe and Russia.
11. Finally, among the global risk factors of our sample, the VIX volatility index and WTI crude oil price seem to be a great influence on all markets, while the EPU index appears to be affected by them. Changes in the US Treasury bond yield spread play a more neutral role in the causality among the sample markets.



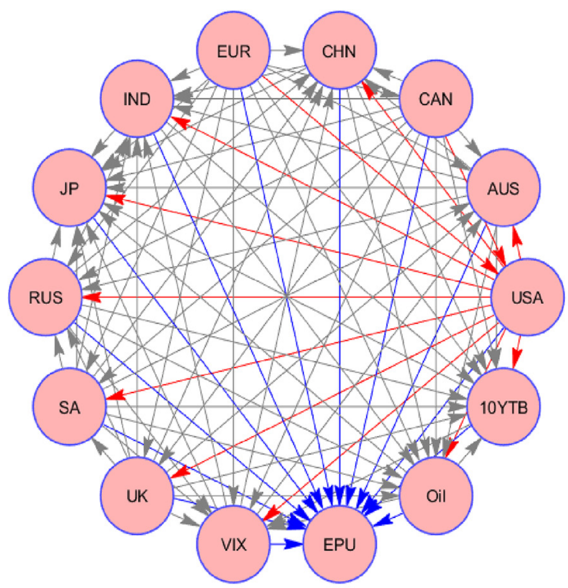
Note: Arrows indicate a statistically significant Granger causality at 5% level. The red and blue marked arrows show the highest and lowest number of causality pairs for the countries.

Fig. 1. Granger causality relations among the markets.

Table 3
Connectedness table.

	USA	AUS	CAN	CHN	EUR	IND	JP	RUS	SA	UK	VIX	EPU	OIL	10YTB	**FROM**
USA	–	5.04	14.89	2.75	10.60	3.30	0.44	4.21	5.85	10.27	10.38	0.02	2.82	4.16	74.75
AUS	10.35	–	10.10	5.33	10.21	4.84	2.88	5.89	7.55	9.72	4.96	0.02	2.30	1.48	75.62
CAN	13.39	6.94	–	2.77	11.40	3.36	0.71	6.81	7.22	10.59	5.62	0.02	5.09	3.15	77.07
CHN	7.64	7.56	6.47	–	6.75	7.94	3.24	4.32	7.91	6.83	4.29	0.01	1.31	1.59	65.86
EUR	10.20	7.33	10.94	3.03	–	3.90	0.77	6.75	9.33	16.17	5.17	0.00	2.46	2.59	78.65
IND	7.58	6.57	6.70	8.15	7.60	–	0.79	5.03	7.65	7.54	3.34	0.01	1.76	1.25	63.95
JP	12.19	5.00	8.53	3.50	9.58	2.52	–	3.65	4.28	9.14	6.01	0.01	1.17	2.10	67.68
RUS	6.55	6.80	10.29	3.58	9.87	4.21	0.53	–	7.91	8.63	3.09	0.02	4.37	3.02	68.88
SA	8.04	7.41	9.07	5.12	11.73	4.81	0.68	6.79	–	10.91	4.67	0.01	2.44	1.54	73.23
UK	10.39	7.23	10.55	3.27	16.77	4.14	0.70	6.12	8.98	–	4.94	0.01	2.24	2.51	77.83
VIX	14.80	3.08	8.87	1.99	8.19	1.98	0.33	2.84	6.28	7.14	–	0.02	2.58	3.03	61.14
EPU	1.47	0.31	1.05	0.25	0.96	0.83	0.06	0.66	0.60	0.85	2.56	–	0.33	0.39	10.34
OIL	5.19	4.06	10.79	1.52	5.68	2.39	0.18	6.38	4.56	4.98	2.59	0.05	–	2.89	51.25
10YTB	8.51	2.14	7.21	1.97	6.25	1.55	0.05	4.73	2.98	5.80	3.99	0.08	3.09	–	48.37
TO	116.30	69.46	115.46	43.24	115.59	45.78	11.38	64.17	81.09	108.57	61.62	0.28	31.97	29.71	**63.90**
NET	41.55	−6.17	38.39	−22.62	36.95	−18.17	−56.30	−4.71	7.86	30.74	0.48	−10.06	−19.28	−18.65	

Note: The ij-th entry of the upper 14 × 14 matrix represents the ij-th pairwise directional connectedness; the percent of forecast error variance of market i due to shocks from market j. The column named "from" shows total directional connectedness from all other markets to market i, whereas the row named "to" shows total directional connectedness to all other markets from market j. The row named "net" shows the total net pairwise directional connectedness (to-from). The bottom-right element (in boldface) is total connectedness (mean "from" connectedness, or equivalently, mean "to" connectedness). Own-variable contributions are neglected.



Note: Arrows indicate positive net directional connectedness from the source to the edge of the arrow. The degree of strength of net pairwise directional connectedness is indicated by the arrow's different color. The red color depicts the highest net transmitter and the blue color depicts the highest net receiver, respectively.

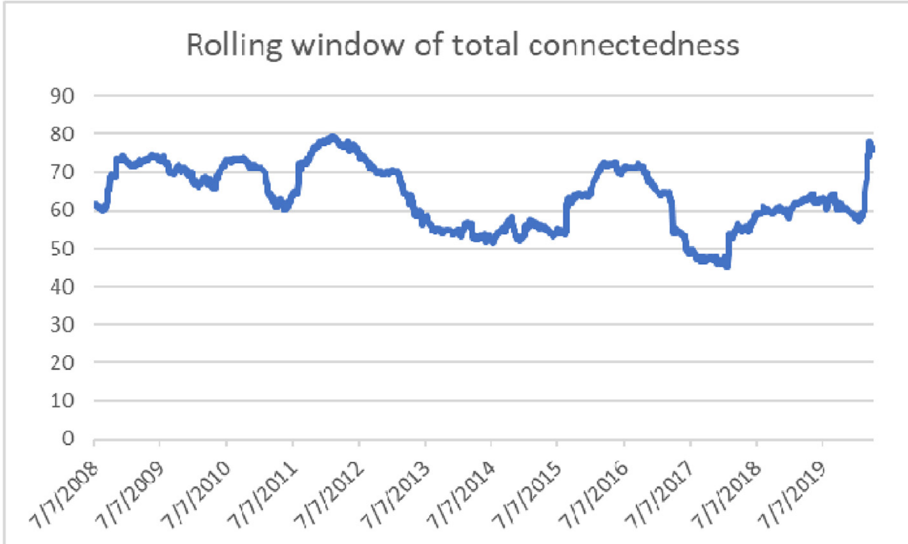
Fig. 2. Net pairwise directional connectedness.

connectedness over the period 7/7/2008–04/15/2020. The size of the rolling window is based on the trade-off between having enough data points for estimation and the time period to analyze the dynamic movement.[5]

The total connectedness among the markets during the sample period is depicted in Fig. 3 and reveals some intriguing patterns. The total connectedness' distribution is quite low for the period covered, showing that the markets' interaction is relatively stable over time.

Moreover, total connectedness remains at a high level throughout 2008–2020, indicating that this interaction is strong. However, two big cycles can be identified that prove that connectedness is gravely affected by political turmoil; the first one from 2011 to 2013 and the second one from 2015 to 2017. During the first big cycle, total connectedness rose from 60% (June 2011) to 80% (February 2012) and after its peak, started to decrease and come back to a static course. The aforementioned time period coincides with the deepening of the European debt crisis and the bailout programs requested by many countries in order to cope with their large deficits (e.g. Greece, Portugal) or their banking system solvency (e.g. Spain). This kept the volatility of the financial markets high, as well as their connectedness, until the beginning of 2012. The second cycle starts at mid-2015 and maintains its upward trend until early 2016. One of the main reasons for this increase in connectedness during the

[5] We performed alternative robustness tests for window size, lag size and forecast horizon and the results (available upon request) show, qualitatively, similar patterns.



Note: In this figure, the total connectedness between MSCI ESG Leaders Indices and the macroeconomic and financial variables is displayed. The spillovers are estimated using a 9-month rolling sample window.

Fig. 3. Rolling total connectedness.

aforementioned period maybe attributed to the inability of the Greek government to come to an agreement with its creditors in June 2015 and the enforcement of capital controls in the domestic banking system. The imposition of capital controls by a government that was elected on the promise to act otherwise, in order to prevent an uncontrolled bank run and a possible collapse of the banking system, put the sustainability of the Eurozone at stake and resulted in the boost of connectedness from 53% (June 2015) to 72% (March 2016).

Besides the aforementioned two big cycles, it is evident that total connectedness also exhibited an unprecedented rise of approximately 30% during February–April of 2020. This increasing trend is attributable to the outbreak of the COVID-19 pandemic. The loss of value of all major stock market indices due to the coronavirus pandemic triggered shocks across the financial markets, the ESG included, and boosted connectedness among the latter from 58% to 76% within a period of two months. Finally, Fig. 3 depicts some other smaller cycles, however no significant fluctuations in the total directional connectedness is observed during these cycles.

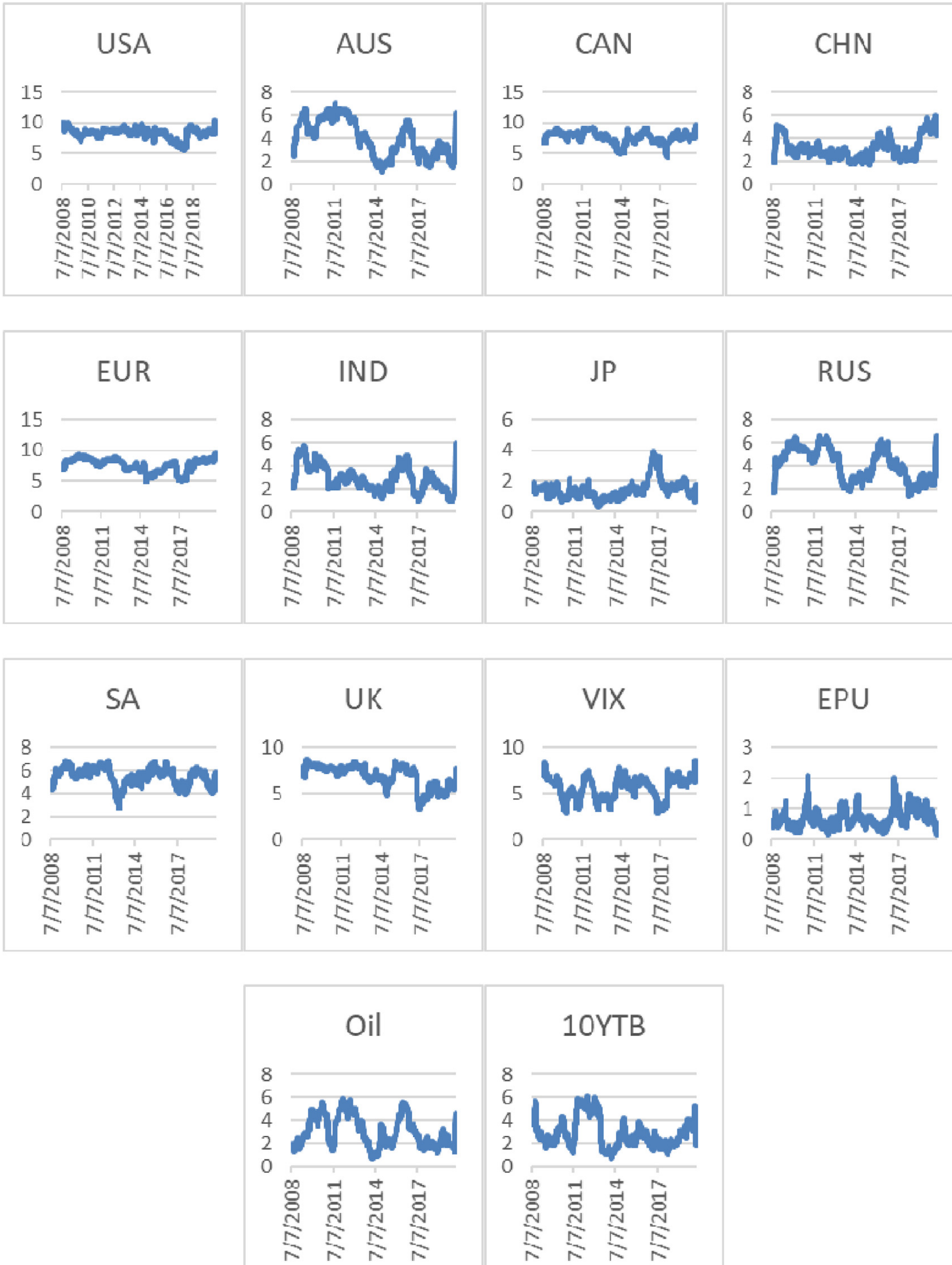
Figs. 4–6 present the time series of directional connectedness (to, from and net) separately for each market. The plots for directional connectedness "to" others are illustrated in Fig. 4, the plots for directional connectedness "from" others in Fig. 5 and for the "net" directional connectedness in Fig. 6.

We start by looking into endogenous shocks at market level to explain the downward trend of the net spillover effects shown in Fig. 6. The downward spiral of US at the end of 2008 is related to the mitigation of the financial crisis' impact on the domestic economy. Furthermore, the rise of long-term interest rates by the Fed in 2015 reduced the spillover transmissions due to the sizeable price spillovers received by SRI from currency markets but transmitting negligible reverse effects, as highlighted by Reboredo and Ugolini (2019). Similarly, the drop in the net spillover effects transmitted by Europe at the end of 2014 is associated with ECB's announcement of quantitative easing program of a total amount of €1.1 trillion to spur inflation and growth, as quantitative easing programs produce significant spillovers only after their implementation (Umar et al., 2019; Papathanasiou et al., 2020; Riaz et al., 2019, 2020). In addition, the reduction of interest rates by the Bank of England and the subsequent announcement of £60 billion allocated for bond-purchasing may have contributed in the attenuation of the net spillover effects generated by the UK market from 2016 onwards. Finally, the VIX volatility index is identified as a significant transmitter of spillover effects to other markets for a sizable part of 2008–2020, indicating that ESG financial markets are greatly influenced by the level of uncertainty as calculated by the underlying index. On the other hand, the US economic policy uncertainty index, international crude oil price and the US 10-year Treasury bond yield are to greater extent net receivers of spillover effects for the major part of our sample period.

Another noticeable feature from Figs. 4–6 is that the "to" connectedness plots' variation is larger compared to the equivalent in the "from" connectedness plots. This difference is intuitive though because when a market large in depth and breadth receives a shock, it is expected that this shock will be transmitted and have an even larger spillover effect on other markets. Since the size of our sample markets vary, the directional connectedness "to" others also varies across markets over the rolling-sample windows in Fig. 4. On the other hand, while shocks transmitted to others by each market may be large, the magnitude of the shock received by each market will be comparatively smaller (Diebold and Yilmaz, 2014). Thus, the "from" connectedness plots in Fig. 5 are characterized by less variation in comparison to the "to" connectedness plots. Therefore, the variation in the plots for "net" connectedness is more affected by the variation in the plots for connectedness "to" others.

In order to further investigate the differences in the variations between the "to" and "from" directional connectedness, Fig. 7 depicts the quartiles of distribution of "to" and "from" directional connectedness. We incorporate the first and third quartile (Q1, Q3) of the distributions to have a distinct picture of the observed differences. As mentioned earlier, it is evident that the variation of the "from" directional connectedness is comparatively much lower than the variation of the "to" connectedness.

Overall, our empirical results of both Granger (1969) causality test and connectedness methodology reveal significant interactions between the MSCI ESG Leaders Indices and the global risk factors of our sample. Moreover, the spillover effects between the ESG markets have been consistent during the sample period, with a few exceptions during the Euro zone debt crisis, the Greek debt problem and the outbreak of the COVID-19 pandemic, where a boost of connectedness has been observed. The strongest degree of association is observed among USA, Canada,



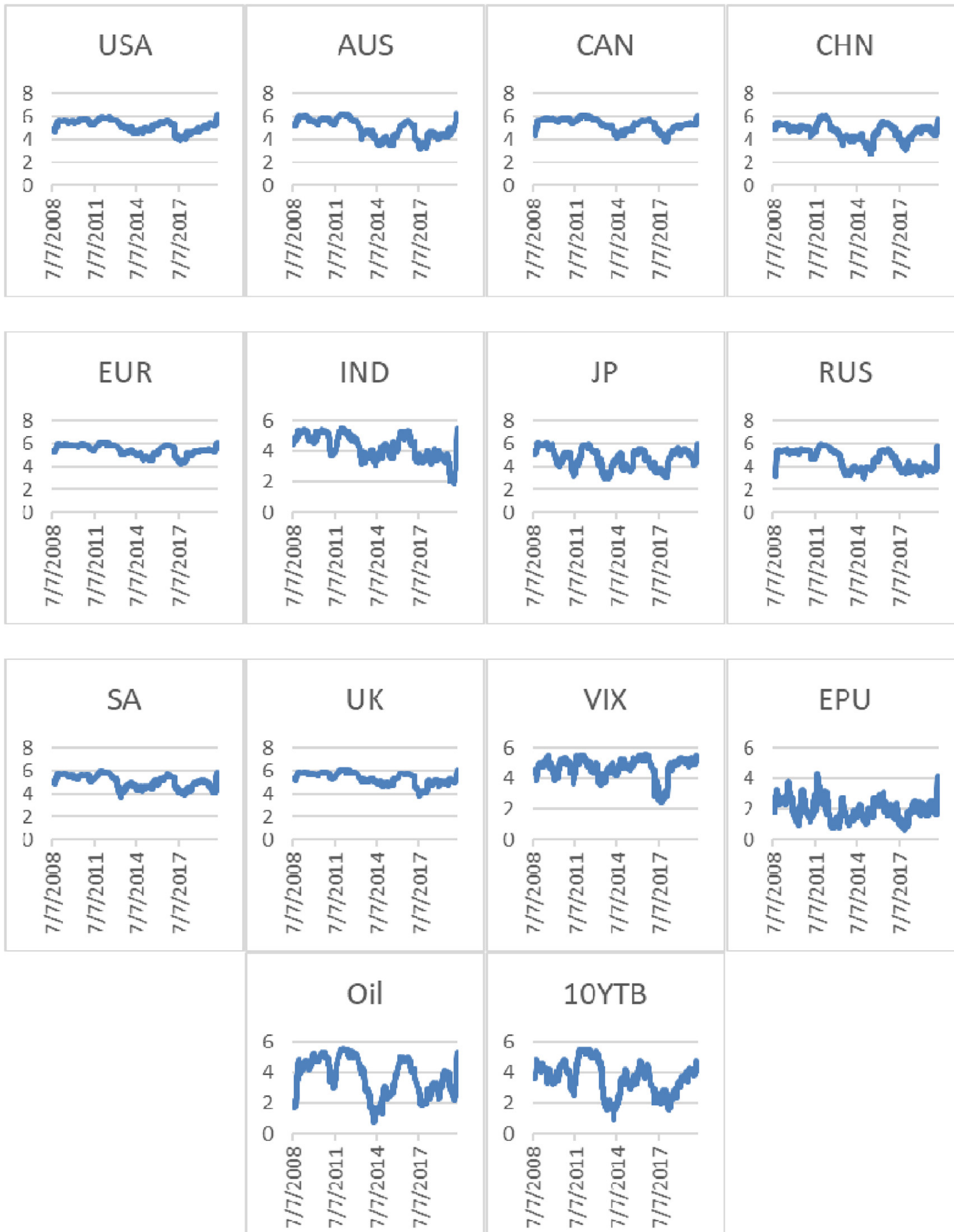
Note: This figure shows total directional connectedness from each market to others. The rolling estimation window width is 9 months.

Fig. 4. Rolling total directional connectedness "to" others.

Europe and the UK. These markets seem to operate as precursors of prospective fluctuations in the direction of other markets that adopt the ESG criteria. Shocks across ESG markets are also diffused via the VIX volatility index, which operates as the basic transmission channel among the selected macroeconomic and financial variables of our sample.

5. Conclusions

The rise of sustainable investing over the last two decades, together with its immense growth potential, have stimulated interest of academics, practitioners, and policy makers. It is important to analyze performance of ESG markets during major economic and financial shocks, especially during turbulent time-periods. This paper examines the co-

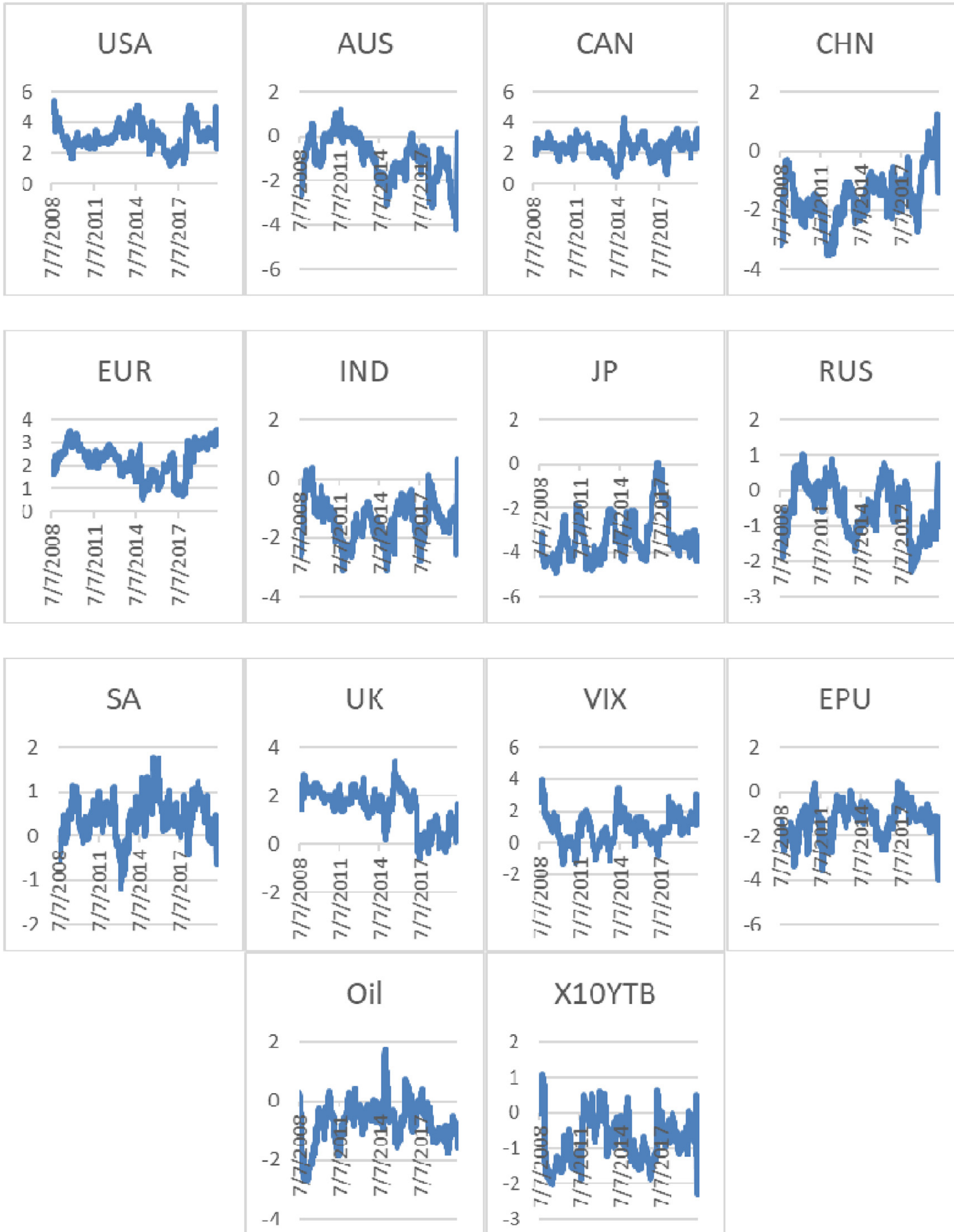


Note: This figure shows total directional connectedness from other markets to each market. The rolling estimation window width is 9 months.

Fig. 5. Rolling total directional connectedness "from" others.

movement and transmissions between ESG indices and a set of influential macroeconomic and financial variables for the period ranging from 10/1/2007–04/15/2020. MSCI ESG Leaders Indices are selected for the ten most significant ESG markets worldwide. We employ four global risk factors; the VIX volatility index, the US Economic Policy Uncertainty index, the WTI crude oil price and changes in the US 10-year Treasury bond yield. We employ a two-fold methodology. Firstly, we use the Granger (1969) causality approach to evaluate the causality between the employed variables. Subsequently, the connectedness between these variables is assessed by using the Diebold and Yilmaz (2012) methodology. This approach enables us to estimate the magnitude and the direction of spillovers across the various variables, as well as to identify any transmission channels.

Our empirical results show significant transmissions between the selected ESG indices throughout our sample period from 10/1/2007–04/15/2020. These findings are consistent with the results of



Note: This figure shows rolling net directional connectedness for each market. The rolling estimation window width is 9 months.

Fig. 6. Rolling "net" directional connectedness.

Akhtaruzzaman and Shamsuddin (2016) who also document significant international contagion through financial/non-financial firms. Interestingly, the spillover effects observed remained consistent during the sample period, with the exception of a rise in connectedness during three periods characterized by the European sovereign debt crisis, the Greek systemic problem and the outbreak of the coronavirus pandemic. These findings suggest that the markets that abide by the ESG criteria are closely linked, with a sizable increase in their connectedness during turmoil periods. Major ESG markets like the US, Canada, Europe and the UK are significant net contributors to other markets, whereas Japan, China and India are net receivers. Our findings are in accordance with the findings of Akhtaruzzaman et al. (2019) who document the US market as a significant contributor of spillover. However, contrary to Akhtaruzzaman et al. (2019) findings, we document that China as a net receiver rather than a net transmitter. Among the global risk factors, our results indicate that the VIX index act as the primary transmission channel of

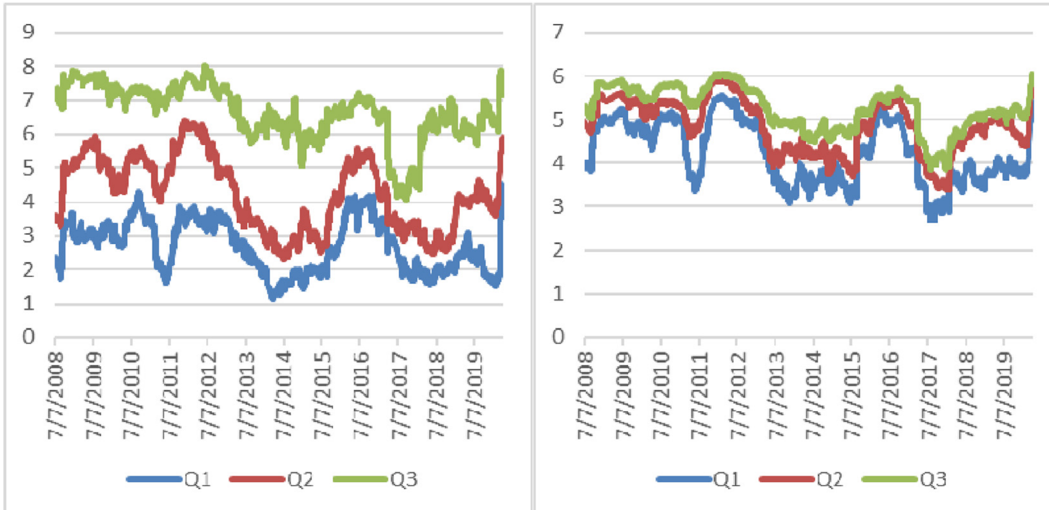


Fig. 7. Rolling distribution of total directional connectedness.

spillover effects between the global ESG markets.

This study may have important implications for various market participants. Investors and portfolio managers interested in ESG indices can benefit from the results on connectedness for investment and portfolio decisions. Our conclusions indicate that portfolio diversification benefits using ESG investments tend to diminish during turbulent periods. Thus, investors should incorporate other types of assets in their portfolios for diversification and optimal risk-return objectives. Therefore, investors may use alternative hedging instruments to protect them against the risks transmitted between ESG markets. The policy makers and regulators should also be cognizant of the high risk of contagion between ESG markets during turbulent time periods, in their attempt to achieve international financial stability, as the decoupling hypothesis of socially responsible investing does not seem to hold. Finally, future research should focus on the diversification properties of ESG assets in the context of a portfolio and risk management analysis by constructing ESG portfolios along with other conventional and alternative asset classes.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors would like to thank the Editors and three anonymous referees of this journal for their helpful comments. Any unintended errors or omissions are our own doing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.econmod.2020.08.007.

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