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In search of light in the darkness: What can we learn from ethical, sustainable and green investments?

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Abstract

We analyse time-varying risk spillover and dependence to assess the systemic risk benefits of ethical, sustainable, and green investments. Our data comprise sustainable investments from ethical, environmental, social and governance (ESG), and green bonds. We investigate the link to major asset classes, including equity, commodity, and currency markets. We find evidence of close connection between the major asset classes and sustainable assets, except green bonds. We also explore the improvement in hedging efficiency from combining ethical and ESG investments with commodities and currencies over investment horizons. Our analysis based on systemic risk measures indicates that there is evidence of lower time-scale systemic risk connectedness in the case of commodities and currencies combined with ethical and ESG assets. These findings have significant implications for portfolio managers, policymakers, and market participants.

KEYWORDS

commodities, ethical investments, exchange rate, financial indices, sustainable investment, systemic risk

1 | INTRODUCTION

Ethical and sustainable assets are an emerging alternative to investment in conventional assets due to their ability to provide financial stability and the benefits of portfolio diversification. Ethical, environmental, social and governance (EESG) assets have grown rapidly over the past decade, with a growing number of firms and businesses transforming their operations and services in the direction of more ethical and sustainable practices. Furthermore, in the aftermath of global financial crisis of 2008–09, there was a seismic shift in the investment principles of many market participants

towards more ethical and sustainable investments. EESG is becoming an essential part of portfolios because market participants are becoming more aware of unethical business practices and climate change, and want their investments to have a positive impact. The sustainability assets under management have increased substantially, and their growth is likely to be sustained due to market participants' growing awareness of EESG issues. Therefore, it is important to evaluate the systemic risk contribution of EESG assets to identify their systemic importance, from investment allocation, risk management, regulatory, and academic viewpoints. This analysis aims to provide relevant

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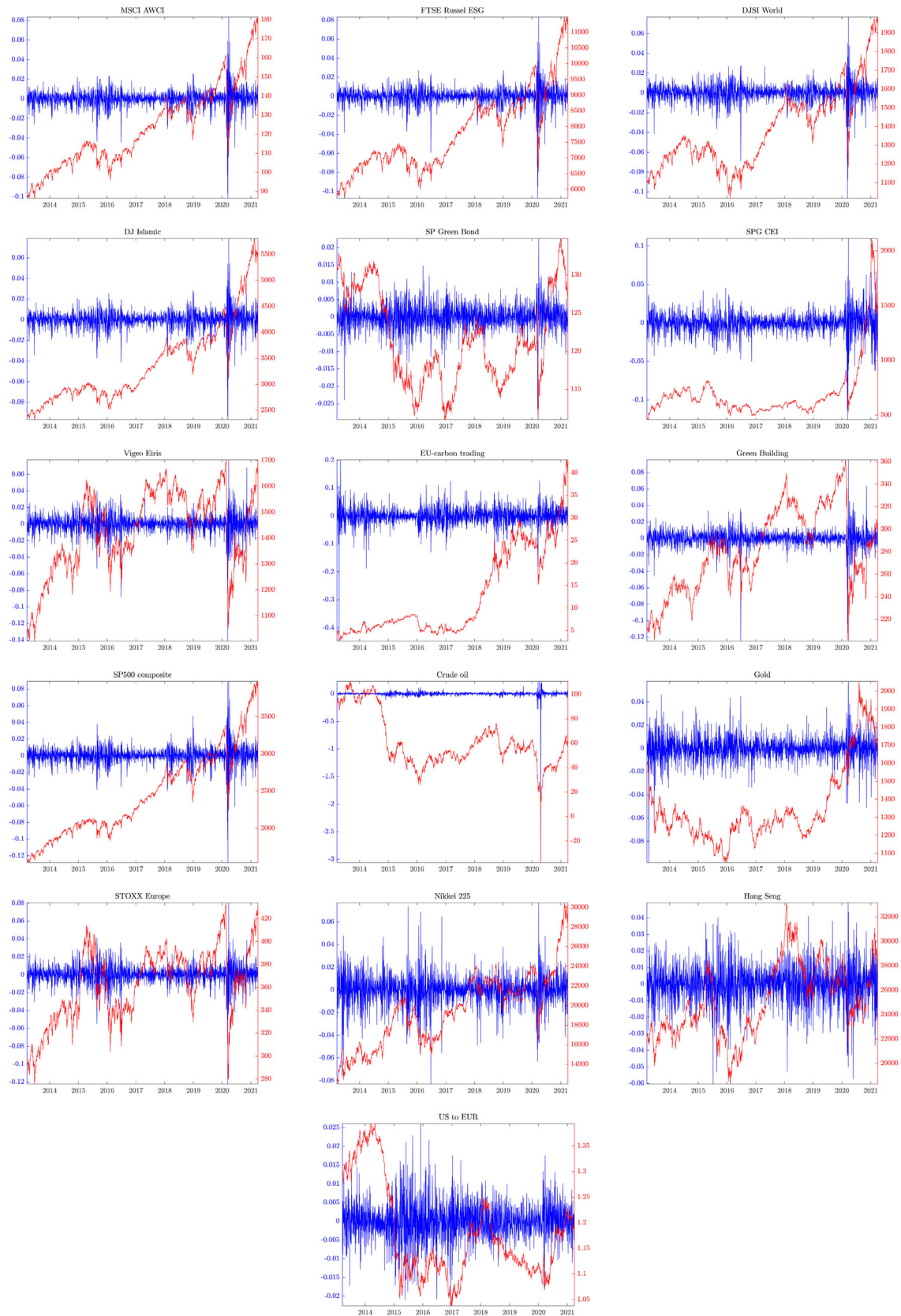


FIGURE 1 Development price and return series for all the underlying assets [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com/terms-and-conditions)]

TABLE 1 Descriptive statistics and stochastic properties

	Mean	SD	SR	Max	Min	Skew	Kurt	JB	Q (23)	Q ² (23)	ARCH (23)
MSCI World ESG	8.848	0.142	0.553	0.084	-0.101	-1.418	27.740	0.000	328.5***	2857.8***	810.3***
FTSE Good Global	8.103	0.144	0.493	0.084	-0.107	-1.497	27.249	0.000	275.9***	2323.5***	710.2***
DJSI World	7.043	0.144	0.418	0.077	-0.106	-1.449	23.339	0.000	219.6***	1806.5***	620.7***
DJ Islamic	10.195	0.142	0.650	0.079	-0.096	-1.206	22.919	0.000	262.6***	2585.6***	820.9***
S&P Green Bond	-0.388	0.056	-0.248	0.023	-0.030	-0.626	9.703	0.000	54.1***	642.6***	326.5***
S&P Clean Energy	14.574	0.223	0.608	0.110	-0.125	-0.766	14.661	0.000	148.6***	2069.5***	620.6***
Euronext Vigeo	5.660	0.179	0.260	0.078	-0.141	-1.462	21.410	0.000	72.7***	680.3***	313.6***
EEX-EU CO2 Emissions	30.532	0.501	0.589	0.202	-0.447	-1.515	25.798	0.000	96.8***	167.8***	405.3***
S&P Green Building	4.394	0.168	0.202	0.096	-0.125	-1.983	32.809	0.000	192.4***	1054.3***	384.8***
S&P500	11.449	0.171	0.612	0.090	-0.128	-1.058	25.602	0.000	452.2***	3328.6***	898.5***
Crude oil	-52.898	1.243	-0.434	0.224	-3.060	-30.999	1161.392	0.000	298.2***	66.0***	66.8***
Gold	0.749	0.158	-0.016	0.058	-0.098	-0.557	11.647	0.000	30.9***	162.7***	135.2***
STOXX	4.545	0.167	0.212	0.081	-0.122	-1.203	17.510	0.000	66.5***	911.2***	424.5***
Nikkei	10.331	0.207	0.450	0.077	-0.083	-0.291	8.233	0.000	45.4***	622.2***	244.2***
Hang Seng	3.070	0.177	0.117	0.049	-0.060	-0.375	5.544	0.000	13.6***	416.7***	188.0***
US to EUR	-1.119	0.077	-0.276	0.026	-0.023	0.028	5.405	0.000	38.0***	397.2***	153.9***

Note: This table reports the summary statistics and stochastic properties of all the series. We present the mean annualized figures of mean and standard deviation. SR corresponds to the Sharpe ratio and JB represents the p-values from the Jarque-Bera normality test. Q (23), Q² (23), and ARCH (23) present the test-statistics of serial correlation on returns and squared returns, and conditional heteroscedasticity with 23 lags, respectively. *** and ** represents the rejected of null-hypothesis of no autocorrelation and conditional homoscedasticity at 1% and 5% threshold level.

knowledge to market participants, regulatory agencies, and academics by evaluating the connectedness dynamics of EESG assets with conventional asset classes.

Ethical business practices, climate concerns, human rights, and management structures are becoming an integral part of investment allocation decisions. Market participants are diverting their resources and investment from conventional assets to sustainable assets. For instance, some oil and gas producers are responding to climate change by diverting their investments from fossil fuel to renewable energy. Similarly, market participants are considering the ethical, social, and environmental behaviour of firms before making asset allocation decisions. In portfolio management decisions, EESG measures allow the market participants to achieve high long-run returns while contributing to ethical, environmental, and societal outcomes by influencing the EESG behaviour of firms.

EESG assets exhibit less volatility than conventional assets, primarily due to less leverage, more socially responsible investing (SRI), abstention from unethical business practices and decisions, and enhanced activities to reduce environmental concerns (Balcilar et al., 2015). Furthermore, the consideration

of EESG-related factors restricts companies from taking unnecessary risks, thereby increasing stakeholder value by focusing on long-term sustainable operations and services. EESG-based regulations and criteria have reduced excessive risk-taking by management, speculative investments, interest-rate swaps, and other similar behaviours, thus adding values to stakeholder groups.

Despite the rapid growth of EESG-related investments, there is only limited literature that examines the inclusion of EESG-related assets in portfolios to attain diversification and risk management benefits. Prior literature on EESG investment looks mainly at the risk-adjusted performance of EESG compliant firms with conventional assets (e.g., Ashwin Kumar et al., 2016; Atan et al., 2018; Garefalakis & Dimitras, 2020; Maiti, 2021; Sassen et al., 2016) or the interconnectedness of EESG assets and conventional assets (e.g., Hkiri et al., 2017; Kenourgios et al., 2016; Narayan & Bannigidadmath, 2017; Rizvi et al., 2015). However, these studies fails to provide a comprehensive overview of interconnectedness dynamics over various frequency horizons.

Previous several studies investigated the ethical, sustainable, and green investments with conventional asset classes (stock, currency, commodity, etc.) using the

directionality approach (Shahbaz et al. (2021), Hammoudeh et al., (2020)), volatility modelling approach (Tolliver et al. (2020), Dutta et al. (2020), Pham (2016)),

directionality vs. dependence in the different horizons (Yahya et al., (2020), Elie et al. (2019)), Wavelet-based dependence and causality (Ferrer et al. (2021), Lee et al.

TABLE 2 DCC-student-t copula parameters

		Panel A: Student-t copula parameters				Panel B: AIC of different copulas			
		ρ	DoF	α	β	Student-t	Gaussian	Clayton	SJC
Panel A: S&P500	MSCI World ESG	0.923***	5.822***	0.037***	0.940***	-4143.6	-4052.4	-3496.4	-3479.7
	FTSE Good Global	0.850***	7.756***	0.041***	0.939***	-2883.1	-2833.9	-2429.4	-2445.6
	DJSI World	0.775***	8.804***	0.034***	0.939***	-2026.0	-1995.6	-1706.7	-1963.2
	DJ Islamic	0.903***	6.236***	0.051***	0.917***	-3739.7	-3652.1	-3202.8	-3209.1
	S&P Green Bond	-0.062***	13.811***	0.038***	0.901***	-35.1	-25.4	6.1	35.9
	S&P Clean Energy	0.526***	6.851***	0.018***	0.953***	-742.9	-696.5	-644.0	-730.7
	Euronext Vigeo	0.546***	9.709***	0.030***	0.880***	-753.4	-736.4	-643.1	-742.0
	EEX-EU CO2 Emissions	0.125***	17.004***	0.009***	0.985***	-57.5	-52.9	5.7	-38.6
	S&P Green Building	0.524***	13.386***	0.024***	0.959***	-720.6	-710.2	-633.8	-479.7
Panel B: Crude oil	MSCI World ESG	0.258***	16.534***	0.024*	0.883***	-156.4	-151.0	5.6	-143.0
	FTSE Good Global	0.257***	15.890***	0.029**	0.862***	-156.3	-151.1	5.6	-151.4
	DJSI World	0.264***	18.586**	0.034***	0.827***	-163.9	-160.3	5.6	-158.1
	DJ Islamic	0.274***	14.860***	0.027**	0.845***	-177.4	-170.2	5.6	-170.7
	S&P Green Bond	0.016***	22.090*	0.043	0.542*	-6.7	-5.0	6.0	12.6
	S&P Clean Energy	0.239***	14.981***	0.009**	0.985***	-141.1	-134.0	5.6	-137.9
	Euronext Vigeo	0.178***	35.835**	0.032*	0.911***	-89.9	-90.5	5.7	-82.0
	EEX-EU CO2 Emissions	0.208***	133.692	0.008	0.983***	-97.9	-99.8	5.7	-87.1
	S&P Green Building	0.169***	14.684***	0.028**	0.842***	-173.0	-67.2	5.7	-143.0
Panel C: Gold	MSCI World ESG	-0.120***	7.441***	0.031***	0.915***	-72.7	-43.9	6.0	53.2
	FTSE Good Global	-0.003	5.217***	0.033***	0.912***	-78.2	-18.3	6.0	10.7
	DJSI World	0.025***	4.995***	0.030***	0.913***	-85.5	-20.4	6.0	-0.4
	DJ Islamic	0.020***	5.571***	0.030***	0.907***	-66.6	-16.3	6.0	3.3
	S&P Green Bond	0.490***	9.491***	0.030**	0.921***	-626.0	-597.3	5.3	-608.9
	S&P Clean Energy	0.035***	7.254***	0.027***	0.918***	-41.6	-11.5	6.0	3.2
	Euronext Vigeo	-0.177***	8.918***	0.020***	0.958***	-97.1	-73.9	6.1	69.8
	EEX-EU CO2 Emissions	-0.031***	18.904**	0.012*	0.975***	-11.4	-8.3	6.0	31.1
	S&P Green Building	0.082***	6.450***	0.025**	0.887***	-64.1	-19.1	5.9	-15.0
Panel D: STOXX	MSCI World ESG	0.757***	9.101***	0.052***	0.888***	-1833.5	-1808.8	-1471.1	-1769.6
	FTSE Good Global	0.745***	8.166***	0.044***	0.930***	-1781.6	-1743.8	-1447.7	-1741.4
	DJSI World	0.765***	7.088***	0.053***	0.913***	-1997.1	-1938.0	-1738.3	-1913.3
	DJ Islamic	0.656***	8.421***	0.039***	0.920***	-1233.5	-1201.2	-1051.2	-1204.8
	S&P Green Bond	-0.170***	6.683***	0.035***	0.951***	-195.9	-147.1	6.1	65.7
	S&P Clean Energy	0.482***	8.120***	0.036***	0.931***	-633.7	-600.8	-551.7	-609.9
	Euronext Vigeo	0.958***	7.316***	0.073***	0.912***	-5503.5	-5441.8	-4604.9	-4032.2
	EEX-EU CO2 Emissions	0.144***	16.506**	0.010**	0.983***	-65.4	-60.8	5.7	-50.9
	S&P Green Building	0.548***	11.315***	0.047***	0.922***	-840.0	-821.9	-666.9	-779.7

TABLE 2 (Continued)

		Panel A: Student-t copula parameters				Panel B: AIC of different copulas			
		ρ	DoF	α	β	Student-t	Gaussian	Clayton	SJC
Panel E: Nikkei	MSCI World ESG	0.387***	19.312***	0.044	0.000	-338.8	-335.6	5.5	-330.5
	FTSE Good Global	0.373***	16.888**	0.019	0.825***	-319.8	-304.2	5.6	-310.0
	DJSI World	0.332***	15.859**	0.014	0.927***	-248.0	-236.5	5.6	-244.0
	DJ Islamic	0.314***	26.691	0.039	0.000	-213.7	-213.2	5.6	-211.7
	S&P Green Bond	-0.054***	16.560***	0.014***	0.972***	-20.0	-14.6	6.0	36.7
	S&P Clean Energy	0.254***	14.180***	0.010**	0.969***	-146.9	-139.5	5.7	-148.6
	Euronext Vigeo	0.316***	34.009	0.031	0.038	-213.8	-214.1	5.6	-220.2
	EEX-EU CO2 Emissions	0.033***	73.545***	0.021**	0.861***	-1.3	-0.7	5.9	7.9
	S&P Green Building	0.315***	18.759	0.012**	0.960***	-222.1	-219.4	5.6	-219.8
Panel F: Hang Seng	MSCI World ESG	0.358***	199.931	0.032	0.001	-281.8	-283.9	5.3	-250.8
	FTSE Good Global	0.402***	51.52	0.017**	0.946***	-372.7	-373.9	5.2	-333.7
	DJSI World	0.410***	35.856**	0.022**	0.942***	-395.6	-396.0	5.1	-359.0
	DJ Islamic	0.399***	137.334	0.03	0.573	-358.4	-360.3	5.2	-321.2
	S&P Green Bond	0.029***	14.506***	0.033**	0.901***	-20.4	-13.5	5.9	10.4
	S&P Clean Energy	0.396***	28.444	0.025***	0.957***	-394.3	-393.8	5.1	-372.9
	Euronext Vigeo	0.373***	20.110**	0.020**	0.949***	-326.2	-323.5	5.2	-315.8
	EEX-EU CO2 Emissions	0.061***	161.4	0.014	0.967	-13.5	-15.4	5.8	1.5
	S&P Green Building	0.375***	26.695	0.033***	0.918***	-339.7	-339.1	5.1	-314.4
Panel G: US 2 EURO	MSCI World ESG	-0.056***	7.954***	0.034**	0.920***	-58.5	-30.7	6.1	32.5
	FTSE Good Global	0.193***	5.603***	0.035***	0.932***	-162.6	-112.6	5.6	-121.1
	DJSI World	0.239***	4.803***	0.040***	0.930***	-234.2	-166.5	5.5	-184.0
	DJ Islamic	0.129***	6.954***	0.030**	0.930***	-88.0	-53.7	5.7	-51.0
	S&P Green Bond	0.864***	10.163***	0.024**	0.971***	-3050.7	-3022.2	-2340.7	-2266.0
	S&P Clean Energy	0.109***	11.769***	0.029*	0.927***	-56.1	-44.5	5.7	-30.2
	Euronext Vigeo	-0.133***	6.213***	0.039***	0.939***	-155.1	-105.7	6.3	52.3
	EEX-EU CO2 Emissions	0.051***	17.134**	0.024	0.787***	-8.5	-4.4	5.8	3.0
	S&P Green Building	0.210***	9.632***	0.055***	0.899***	-159.5	-138.3	5.5	-133.7

Note: This table reports the parameters DCC-Student-t copula and the AIC values of various symmetric and asymmetric models. ***, **, and * indicate the significance at the 1%, 5%, and 10% level.

(2021)) and structural VAR (Reboredo and Ugolini (2020), Reboredo et al., (2020)) and potential macroeconomic and financial driver using panel regression analysis(Gianfrate et al., (2019), Jiang et al. (2020)).

In this paper, we contributes to the literature on EESG in the following ways. We evaluate the connectedness and systemic uncertainty exposure of nine key EESG related assets to asymmetric shocks in conventional assets. To our knowledge, this kind of study has not been conducted before. Understanding the asymmetric impact of positive and negative shocks from conventional assets on EESG investment has significant implications for portfolio allocation and risk

management decisions. Furthermore, our analysis yields significant insights for policymakers and regulators, in addition to helping investors devise strategies to decouple the impact of uncertainty shocks from conventional assets to EESG assets.

In addition, we propose a wavelet-based asymmetric copulas and systemic risk approach (Adrian & Brunnermeier, 2016) to explore the asymmetric impact of conventional asset shocks on EESG assets. The wavelets enable us to decompose the underlying return series into a set of subsequent wavelets corresponding to short-, medium-, and long-run trends. By utilizing wavelet-based approaches, we capture the

TABLE 3 Value-at-risk for the original and decomposed series for the pre-COVID period

	Undecomposed series					Short-run trend				
	Mean	Median	Max	Min	Std dev	Mean	Median	Max	Min	Std dev
MSCI World ESG	-1.151	-1.009	-0.332	-4.219	0.509	-0.651	-0.566	-0.167	-2.748	0.321
FTSE Good Global	-1.133	-1.033	-0.441	-4.474	0.449	-0.666	-0.592	-0.207	-3.267	0.311
DJSI World	-1.214	-1.126	-0.487	-4.628	0.441	-0.718	-0.656	-0.275	-3.650	0.313
DJ Islamic	-1.169	-1.063	-0.459	-3.660	0.477	-0.664	-0.584	-0.192	-2.467	0.324
S&P Green Bond	-0.521	-0.504	-0.317	-0.853	0.100	-0.333	-0.315	-0.152	-0.919	0.103
S&P Clean Energy	-1.799	-1.722	-0.899	-3.834	0.492	-1.019	-0.935	-0.347	-3.534	0.400
Euronext Vigeo	-1.526	-1.388	-0.622	-6.648	0.655	-0.937	-0.835	-0.290	-4.776	0.461
EEX-EU CO2 Emissions	-4.375	-4.056	-1.780	-19.397	1.745	-3.099	-2.727	-0.913	-27.338	1.690
S&P Green Building	-1.303	-1.215	-0.647	-6.927	0.489	-0.758	-0.688	-0.295	-6.253	0.355
S&P500	-1.389	-1.194	-0.485	-4.869	0.650	-0.845	-0.712	-0.233	-3.696	0.466
Crude oil	-3.341	-3.073	-1.719	-11.896	1.048	-2.237	-1.940	-0.646	-10.092	1.138
Gold	-1.444	-1.381	-0.867	-2.478	0.334	-0.958	-0.870	-0.427	-4.409	0.371
STOXX	-1.461	-1.320	-0.556	-6.083	0.639	-0.906	-0.798	-0.265	-4.042	0.448
Nikkei	-2.037	-1.830	-0.749	-6.763	0.833	-1.242	-1.105	-0.398	-6.030	0.593
Hang Seng	-1.861	-1.805	-1.067	-3.663	0.428	-1.080	-1.005	-0.549	-3.080	0.335
US 2 EUR	-0.783	-0.748	-0.400	-1.455	0.229	-0.489	-0.449	-0.166	-1.320	0.180
	Medium-run trend					Long-run trend				
	Mean	Median	Max	Min	Std dev	Mean	Median	Max	Min	Std dev
MSCI World ESG	-0.314	-0.269	-0.020	-1.365	0.207	-0.230	-0.170	0.000	-0.817	0.208
FTSE Good Global	-0.310	-0.261	-0.016	-1.391	0.219	-0.229	-0.178	-0.001	-0.797	0.204
DJSI World	-0.346	-0.294	-0.015	-1.305	0.228	-0.120	-0.097	-0.015	-0.385	0.083
DJ Islamic	-0.332	-0.288	-0.013	-1.086	0.224	-0.318	-0.278	-0.001	-0.991	0.241
S&P Green Bond	-0.137	-0.119	-0.008	-0.445	0.085	-0.112	-0.096	-0.014	-0.328	0.077
S&P Clean Energy	-0.631	-0.525	-0.035	-2.826	0.444	-0.840	-0.640	-0.001	-3.359	0.720
Euronext Vigeo	-0.439	-0.380	-0.043	-1.663	0.281	-0.194	-0.163	-0.025	-0.596	0.138
EEX-EU CO2 Emissions	-1.329	-1.073	-0.048	-7.481	1.037	-0.872	-0.715	-0.002	-2.275	0.656
S&P Green Building	-0.408	-0.336	-0.041	-2.574	0.310	-1.219	-1.045	-0.006	-3.841	0.946
S&P500	-0.310	-0.259	-0.021	-1.571	0.208	-0.087	-0.068	-0.009	-0.342	0.076
Crude oil	-1.083	-0.775	-0.028	-18.798	1.596	-1.775	-0.979	-0.002	-10.198	2.339
Gold	-0.446	-0.396	-0.056	-1.437	0.259	-0.452	-0.370	-0.001	-1.538	0.365
STOXX	-0.381	-0.335	-0.018	-1.227	0.240	-0.269	-0.227	-0.001	-0.719	0.205
Nikkei	-0.535	-0.435	-0.048	-2.326	0.377	-0.255	-0.243	0.000	-0.690	0.171
Hang Seng	-0.476	-0.425	-0.057	-1.338	0.277	-0.443	-0.393	-0.001	-1.241	0.328
US 2 EUR	-0.213	-0.189	-0.012	-0.726	0.135	-0.191	-0.147	-0.001	-0.630	0.163

Note: This table reports the summary statistics of the VaR estimates for the short-, medium-, and long-term horizons. The VaR is estimated based on the conditional variances from the ARMA(1,0)-EGARCH(1,1) framework.

heterogeneous preferences of investors who tend to invest over varying frequency horizons. Earlier studies are constrained from evaluating connectedness dynamics over short-run horizon. However, the literature

shows that the investment horizon tends to depend on the preferences of the market participants (Barunik & Vacha, 2018; Bekiros & Marcellino, 2013; Berger, 2015; Shahzad et al., 2021; Yahya et al., 2019). Therefore, in

TABLE 4 Value-at-risk for the original and decomposed series for the during-COVID period

	Undecomposed series					Short-run trend				
	Mean	Median	Max	Min	Std dev	Mean	Median	Max	Min	Std dev
MSCI World ESG	-1.887	-1.370	-0.536	-10.746	1.566	-1.061	-0.774	-0.260	-6.596	0.894
FTSE Good Global	-1.803	-1.350	-0.586	-9.276	1.390	-1.042	-0.790	-0.346	-7.063	0.857
DJSI World	-1.717	-1.321	-0.606	-8.284	1.230	-0.996	-0.766	-0.277	-6.481	0.772
DJ Islamic	-1.890	-1.529	-0.596	-9.706	1.383	-1.089	-0.843	-0.228	-6.546	0.850
S&P Green Bond	-0.613	-0.550	-0.394	-1.406	0.201	-0.358	-0.328	-0.174	-1.051	0.138
S&P Clean Energy	-3.406	-2.938	-1.004	-11.299	1.762	-1.824	-1.551	-0.477	-6.712	1.011
Euronext Vigeo	-2.290	-1.842	-0.876	-10.036	1.495	-1.382	-1.130	-0.501	-7.369	0.867
EEX-EU CO2 Emissions	-4.569	-4.193	-2.884	-10.258	1.287	-3.171	-2.952	-1.378	-8.965	1.207
S&P Green Building	-2.087	-1.700	-0.665	-8.441	1.379	-1.039	-0.848	-0.355	-4.109	0.660
S&P500	-2.326	-1.733	-0.723	-12.733	1.838	-1.385	-1.034	-0.292	-9.338	1.138
Crude oil	-13.941	-3.675	-2.224	-475.093	47.668	-5.290	-2.275	-0.880	-195.084	14.908
Gold	-1.872	-1.817	-1.119	-2.996	0.431	-1.121	-0.994	-0.459	-3.983	0.503
STOXX	-1.999	-1.648	-0.770	-9.432	1.304	-1.254	-1.050	-0.429	-6.857	0.815
Nikkei	-2.174	-1.841	-1.195	-7.029	0.996	-1.304	-1.139	-0.460	-9.025	0.726
Hang Seng	-2.199	-2.130	-1.275	-4.716	0.606	-1.260	-1.150	-0.623	-4.410	0.468
US 2 EUR	-0.734	-0.739	-0.425	-1.068	0.164	-0.456	-0.438	-0.229	-1.060	0.140
	Medium-run trend					Long-run trend				
	Mean	Median	Max	Min	Std dev	Mean	Median	Max	Min	Std dev
MSCI World ESG	-0.511	-0.323	-0.025	-2.568	0.542	-0.164	-0.122	-0.002	-0.534	0.120
FTSE Good Global	-0.550	-0.376	-0.046	-2.687	0.565	-0.246	-0.177	-0.003	-0.606	0.189
DJSI World	-0.556	-0.356	-0.057	-2.729	0.577	-0.120	-0.123	-0.030	-0.252	0.046
DJ Islamic	-0.547	-0.371	-0.019	-2.641	0.549	-0.410	-0.361	-0.015	-0.839	0.252
S&P Green Bond	-0.200	-0.129	-0.014	-0.860	0.195	-0.152	-0.166	-0.038	-0.218	0.055
S&P Clean Energy	-0.803	-0.417	-0.076	-4.266	0.981	-1.354	-1.420	-0.007	-2.619	0.756
Euronext Vigeo	-0.746	-0.497	-0.032	-3.409	0.728	-0.191	-0.188	-0.038	-0.558	0.100
EEX-EU CO2 Emissions	-1.585	-1.328	-0.228	-5.564	1.147	-0.427	-0.355	-0.013	-1.224	0.348
S&P Green Building	-0.639	-0.300	-0.040	-3.853	0.873	-1.332	-1.188	-0.050	-2.766	0.763
S&P500	-0.516	-0.347	-0.017	-2.500	0.532	-0.069	-0.049	-0.015	-0.193	0.042
Crude oil	-4.084	-1.073	-0.130	-36.533	8.234	-2.642	-1.569	-0.051	-9.799	2.522
Gold	-0.417	-0.348	-0.030	-1.348	0.297	-0.689	-0.760	-0.021	-0.985	0.260
STOXX	-0.629	-0.407	-0.051	-3.126	0.667	-0.198	-0.127	-0.009	-0.488	0.143
Nikkei	-0.681	-0.521	-0.080	-2.744	0.554	-0.154	-0.130	-0.007	-0.457	0.104
Hang Seng	-0.645	-0.628	-0.054	-1.871	0.377	-0.408	-0.326	-0.011	-0.859	0.286
US 2 EUR	-0.146	-0.120	-0.011	-0.565	0.114	-0.249	-0.271	-0.010	-0.420	0.111

Note: This table reports the summary statistics of the VaR estimates for the short-, medium-, and long-term horizons. The VaR is estimated based on the conditional variances from the ARMA(1,0)-EGARCH(1,1) framework.

this study, we will provide a comprehensive overview of the variation in symmetric and asymmetric connectedness and spillovers among the underlying assets over various investment time horizons (Al-Yahyaee

et al., 2020). Finally, we present several dynamic portfolio diversification and risk management strategies based on investments in conventional assets, along with EESG-based assets that may enable market

TABLE 5 Conditional value-at-risk for the original and decomposed series for pre-COVID period

	Undecomposed					Short-run trend					Medium-run trend					Long-run trend								
	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std						
Panel A: S&P500																								
MSCI World ESG	-1.849	-1.680	0.606	-1.201	-1.098	0.392	-0.378	-0.332	0.208	-0.244	-0.185	0.207	-1.849	-1.680	0.606	-1.201	-1.098	0.392	-0.378	-0.332	0.208	-0.244	-0.185	0.207
FTSE Good Global	-1.965	-1.850	0.513	-1.390	-1.301	0.372	-0.376	-0.328	0.219	-0.186	-0.148	0.149	-1.965	-1.850	0.513	-1.390	-1.301	0.372	-0.376	-0.328	0.219	-0.186	-0.148	0.149
DJISI World	-2.188	-2.092	0.477	-1.557	-1.486	0.356	-0.424	-0.375	0.219	-0.117	-0.100	0.062	-2.188	-2.092	0.477	-1.557	-1.486	0.356	-0.424	-0.375	0.219	-0.117	-0.100	0.062
DJ Islamic	-1.908	-1.783	0.565	-1.265	-1.164	0.409	-0.408	-0.363	0.230	-0.275	-0.243	0.187	-1.908	-1.783	0.565	-1.265	-1.164	0.409	-0.408	-0.363	0.230	-0.275	-0.243	0.187
S&P Green Bond	-1.522	-1.524	0.015	-0.889	-0.895	0.035	-0.320	-0.309	0.051	-0.132	-0.120	0.058	-1.522	-1.524	0.015	-0.889	-0.895	0.035	-0.320	-0.309	0.051	-0.132	-0.120	0.058
S&P Clean Energy	-2.221	-2.180	0.257	-1.492	-1.446	0.219	-0.538	-0.478	0.252	-0.278	-0.221	0.205	-2.221	-2.180	0.257	-1.492	-1.446	0.219	-0.538	-0.478	0.252	-0.278	-0.221	0.205
Euronext Vigeo	-2.252	-2.164	0.418	-1.514	-1.456	0.260	-0.465	-0.423	0.202	-0.113	-0.101	0.053	-2.252	-2.164	0.418	-1.514	-1.456	0.260	-0.465	-0.423	0.202	-0.113	-0.101	0.053
EEX-EU CO2	-2.098	-2.061	0.199	-1.241	-1.213	0.124	-0.389	-0.361	0.112	-0.178	-0.156	0.092	-2.098	-2.061	0.199	-1.241	-1.213	0.124	-0.389	-0.361	0.112	-0.178	-0.156	0.092
S&P Green Build	-2.321	-2.253	0.379	-1.434	-1.389	0.231	-0.434	-0.387	0.199	-0.498	-0.433	0.357	-2.321	-2.253	0.379	-1.434	-1.389	0.231	-0.434	-0.387	0.199	-0.498	-0.433	0.357
Panel B: Crude oil																								
MSCI World ESG	-4.462	-4.337	0.448	-3.239	-3.164	0.285	-0.823	-0.802	0.096	-3.987	-3.148	2.913	-4.462	-4.337	0.448	-3.239	-3.164	0.285	-0.823	-0.802	0.096	-3.987	-3.148	2.913
FTSE Good Global	-4.493	-4.396	0.432	-3.284	-3.215	0.288	-0.836	-0.810	0.118	-3.446	-2.864	2.320	-4.493	-4.396	0.432	-3.284	-3.215	0.288	-0.836	-0.810	0.118	-3.446	-2.864	2.320
DJISI World	-4.526	-4.445	0.406	-3.287	-3.229	0.292	-0.869	-0.840	0.127	-2.487	-2.181	1.074	-4.526	-4.445	0.406	-3.287	-3.229	0.292	-0.869	-0.840	0.127	-2.487	-2.181	1.074
DJ Islamic	-4.570	-4.467	0.463	-3.195	-3.126	0.280	-0.770	-0.757	0.065	-3.389	-3.106	1.698	-4.570	-4.467	0.463	-3.195	-3.126	0.280	-0.770	-0.757	0.065	-3.389	-3.106	1.698
S&P Green Bond	-3.854	-3.850	0.025	-2.704	-2.709	0.026	-0.319	-0.373	0.247	-1.669	-1.610	0.284	-3.854	-3.850	0.025	-2.704	-2.709	0.026	-0.319	-0.373	0.247	-1.669	-1.610	0.284
S&P Clean Energy	-4.710	-4.665	0.283	-3.250	-3.196	0.258	-0.781	-0.762	0.079	-2.907	-2.480	1.536	-4.710	-4.665	0.283	-3.250	-3.196	0.258	-0.781	-0.762	0.079	-2.907	-2.480	1.536
Euronext Vigeo	-4.530	-4.427	0.489	-3.290	-3.223	0.304	-0.910	-0.878	0.153	-2.103	-1.882	0.973	-4.530	-4.427	0.489	-3.290	-3.223	0.304	-0.910	-0.878	0.153	-2.103	-1.882	0.973
EEX-EU CO2	-5.147	-5.042	0.578	-3.471	-3.376	0.431	-0.721	-0.716	0.022	-2.805	-2.521	1.184	-5.147	-5.042	0.578	-3.471	-3.376	0.431	-0.721	-0.716	0.022	-2.805	-2.521	1.184
S&P Green Build	-4.401	-4.341	0.332	-3.304	-3.252	0.262	-0.615	-0.632	0.075	-8.848	-7.687	6.319	-4.401	-4.341	0.332	-3.304	-3.252	0.262	-0.615	-0.632	0.075	-8.848	-7.687	6.319
Panel C: Gold																								
MSCI World ESG	-1.654	-1.649	0.018	-3.239	-3.164	0.285	-0.340	-0.332	0.035	-0.210	-0.181	0.100	-1.654	-1.649	0.018	-3.239	-3.164	0.285	-0.340	-0.332	0.035	-0.210	-0.181	0.100
FTSE Good Global	-1.677	-1.670	0.032	-3.284	-3.215	0.288	-0.341	-0.332	0.040	-0.191	-0.171	0.083	-1.677	-1.670	0.032	-3.284	-3.215	0.288	-0.341	-0.332	0.040	-0.191	-0.171	0.083
DJISI World	-1.784	-1.770	0.067	-3.287	-3.229	0.292	-0.348	-0.338	0.042	-0.166	-0.152	0.049	-1.784	-1.770	0.067	-3.287	-3.229	0.292	-0.348	-0.338	0.042	-0.166	-0.152	0.049
DJ Islamic	-1.797	-1.779	0.083	-3.195	-3.126	0.280	-0.347	-0.339	0.043	-0.328	-0.297	0.188	-1.797	-1.779	0.083	-3.195	-3.126	0.280	-0.347	-0.339	0.043	-0.328	-0.297	0.188
S&P Green Bond	-2.083	-2.060	0.142	-2.704	-2.709	0.026	-0.346	-0.335	0.052	-0.227	-0.203	0.118	-2.083	-2.060	0.142	-2.704	-2.709	0.026	-0.346	-0.335	0.052	-0.227	-0.203	0.118
S&P Clean Energy	-1.646	-1.642	0.022	-3.250	-3.196	0.258	-0.366	-0.351	0.062	-0.327	-0.271	0.204	-1.646	-1.642	0.022	-3.250	-3.196	0.258	-0.366	-0.351	0.062	-0.327	-0.271	0.204
Euronext Vigeo	-1.544	-1.548	0.020	-3.290	-3.223	0.304	-0.344	-0.336	0.035	-0.093	-0.094	0.005	-1.544	-1.548	0.020	-3.290	-3.223	0.304	-0.344	-0.336	0.035	-0.093	-0.094	0.005
EEX-EU CO2	-1.724	-1.712	0.065	-3.471	-3.376	0.431	-0.360	-0.344	0.063	0.085	0.054	0.132	-1.724	-1.712	0.065	-3.471	-3.376	0.431	-0.360	-0.344	0.063	0.085	0.054	0.132
S&P Green Build	-1.772	-1.758	0.078	-3.304	-3.252	0.262	-0.338	-0.329	0.038	0.002	-0.013	0.078	-1.772	-1.758	0.078	-3.304	-3.252	0.262	-0.338	-0.329	0.038	0.002	-0.013	0.078

TABLE 5 (Continued)

		Undecomposed			Short-run trend			Medium-run trend			Long-run trend		
Panel D: STOXX	MSCI World ESG	-2.076	-1.941	0.484	-1.308	-1.245	0.237	-0.452	-0.403	0.224	-0.395	-0.302	0.321
	FTSE Good Global	-2.084	-1.986	0.437	-1.332	-1.268	0.263	-0.462	-0.412	0.230	-0.368	-0.297	0.283
	DJISI World	-2.134	-2.043	0.456	-1.340	-1.283	0.287	-0.500	-0.445	0.241	-0.226	-0.194	0.115
	DJ Islamic	-2.229	-2.131	0.444	-1.321	-1.269	0.210	-0.525	-0.478	0.242	-0.407	-0.365	0.254
	S&P Green Bond	-1.409	-1.416	0.039	-0.943	-0.953	0.052	-0.255	-0.259	0.021	-0.072	-0.074	0.010
	S&P Clean Energy	-2.181	-2.144	0.234	-1.463	-1.424	0.188	-0.540	-0.488	0.217	-0.369	-0.296	0.259
	Euronext Vigeo	-1.758	-1.631	0.600	-1.129	-1.035	0.426	-0.440	-0.389	0.244	-0.162	-0.138	0.105
	EEX-EU CO2	-2.226	-2.184	0.233	-1.410	-1.372	0.172	-0.460	-0.426	0.136	-0.309	-0.267	0.178
	S&P Green Build	-2.270	-2.198	0.400	-1.448	-1.398	0.253	-0.501	-0.449	0.221	-0.957	-0.827	0.706
			-2.669	-2.577	0.332	-1.537	-1.525	0.044	-0.524	-0.478	0.211	-0.372	-0.287
Panel E: Nikkei	MSCI World ESG	-2.628	-2.561	0.299	-1.559	-1.547	0.048	-0.539	-0.491	0.221	-0.220	-0.188	0.126
	FTSE Good Global	-2.682	-2.626	0.281	-1.585	-1.574	0.053	-0.561	-0.512	0.216	-0.131	-0.122	0.030
	DJISI World	-2.543	-2.488	0.251	-1.557	-1.546	0.045	-0.562	-0.519	0.217	-0.155	-0.147	0.050
	DJ Islamic	-2.065	-2.068	0.014	-1.408	-1.410	0.010	-0.373	-0.373	0.000	-0.078	-0.080	0.009
	S&P Green Bond	-2.772	-2.741	0.195	-1.604	-1.592	0.059	-0.590	-0.542	0.198	-0.176	-0.155	0.076
	S&P Clean Energy	-2.696	-2.621	0.354	-1.624	-1.607	0.077	-0.586	-0.537	0.233	-0.166	-0.149	0.075
	Euronext Vigeo	-2.491	-2.468	0.129	-1.456	-1.453	0.014	-0.471	-0.450	0.084	-0.462	-0.393	0.288
	EEX-EU CO2	-2.757	-2.701	0.308	-1.707	-1.681	0.132	-0.530	-0.487	0.183	-0.403	-0.357	0.251
	S&P Green Build												
			-2.344	-2.267	0.276	-1.340	-1.324	0.063	-0.452	-0.422	0.136	-0.338	-0.269
Panel F: Hang Seng	MSCI World ESG	-2.319	-2.264	0.245	-1.337	-1.320	0.069	-0.451	-0.418	0.149	-0.303	-0.252	0.203
	FTSE Good Global	-2.400	-2.347	0.265	-1.358	-1.339	0.097	-0.480	-0.444	0.160	-0.208	-0.180	0.096
	DJISI World	-2.375	-2.314	0.277	-1.345	-1.329	0.068	-0.486	-0.452	0.171	-0.348	-0.314	0.201
	DJ Islamic	-2.129	-2.122	0.043	-1.164	-1.165	0.009	-0.450	-0.433	0.079	-0.147	-0.140	0.033
	S&P Green Bond	-2.366	-2.336	0.184	-1.438	-1.415	0.111	-0.499	-0.463	0.154	-0.348	-0.282	0.236
	S&P Clean Energy	-2.481	-2.407	0.350	-1.491	-1.457	0.152	-0.466	-0.438	0.136	-0.256	-0.229	0.119
	Euronext Vigeo	-2.273	-2.247	0.143	-1.269	-1.259	0.046	-0.459	-0.434	0.103	-0.168	-0.156	0.051
	EEX-EU CO2	-2.541	-2.485	0.311	-1.477	-1.444	0.167	-0.421	-0.395	0.108	-0.877	-0.763	0.620
	S&P Green Build												
			-0.775	-0.777	0.008	-0.520	-0.526	0.024	-0.106	-0.112	0.027	0.079	0.053
Panel G: US to EUR	MSCI World ESG	-0.889	-0.870	0.083	-0.594	-0.588	0.026	-0.126	-0.128	0.011	-0.068	-0.064	0.020
	FTSE Good Global	-0.925	-0.905	0.089	-0.600	-0.594	0.030	-0.128	-0.130	0.008	-0.089	-0.086	0.032
	DJISI World	-0.908	-0.890	0.079	-0.578	-0.574	0.015	-0.125	-0.127	0.012	-0.083	-0.081	0.027
	DJ Islamic												

(Continues)

TABLE 5 (Continued)

	Undecomposed		Short-run trend		Medium-run trend		Long-run trend				
S&P Green Bond	-1.112	-1.075	0.182	-0.660	-0.634	0.137	-0.224	-0.199	0.112	-0.074	-0.069
S&P Clean Energy	-0.866	-0.857	0.049	-0.593	-0.588	0.023	-0.148	-0.146	0.007	-0.071	-0.070
Euronext Vigeo	-0.670	-0.685	0.065	-0.492	-0.502	0.039	-0.100	-0.107	0.031	0.002	-0.006
EEX-EU CO2	-0.901	-0.891	0.049	-0.555	-0.555	0.004	-0.167	-0.162	0.020	-0.016	-0.020
S&P Green Build	-0.882	-0.862	0.086	-0.591	-0.584	0.031	-0.135	-0.136	0.005	-0.194	-0.173

Note: This paper presents the summary statistics of the conditional VaR (CoVaR) between EESG assets and the conventional assets for the original and decomposed return series.

participants to achieve portfolio diversification and risk management potential over a range of investment horizons.

Our findings indicate that with some exceptions, the EESG assets exhibit significantly positive asymmetric connectedness and risk exposure with the financial indices. This implies that the financial indices and the EESG assets are closely integrated, that is, EESG assets exhibit homogeneous characteristics with respect to these indices. However, we do find weak-to-moderate negative dependence between financial indices and S&P Green Bonds, suggesting portfolio diversification and risk management potential for market participants. Furthermore, our results indicate a weak negative to moderately positive connection for commodities and exchange rates, implying a greater opportunity to realize risk management and diversification benefits. Our findings indicate that gold can serve as a safe haven for market participants that invest in EESG assets. These findings are supported by the systemic risk measure, indicating a significantly lower systemic risk contribution for commodities and currencies with EESG assets. In terms of optimal portfolio weights, our findings generally point to a higher proportion of capital to be invested in EESG assets compared to the conventional assets in our sample to capture diversification benefits. Finally, hedging is expensive for EESG assets and financial indices and there is significantly lower improvement in hedging efficiency for these assets. For the commodities and exchange rates, however, it is much less costly to hedge a long position in EESG and hedging efficiency indicates a significant reduction in uncertainty.

The rest of the paper is structured as follows. Section 2 describes the methodological framework. Section 3 presents the data and stochastic properties. Section 3.3 discusses the empirical findings and their implications. Section 4 concludes.

2 | METHODOLOGY

In this section, we describe our methodological framework.

2.1 | Wavelet transform

Since the market have heterogeneous preferences in regard to investment horizon, we use wavelet transform analysis to decompose the underlying return series into a set of subsequent wavelets, corresponding to short-, medium-, and long-term horizons. The resulting output of decomposition allow us to uncover

TABLE 6 Conditional value-at-risk for the original and decomposed series for during-COVID period

	Undecomposed					Short-run trend					Medium-run trend					Long-run trend				
	Mean	Median	Std	Mean	Std	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std			
Panel A: S&P500																				
MSCI World ESG	-2.727	-2.111	1.867	-1.703	1.352	-0.576	-0.387	1.093	-1.703	-1.352	1.093	-0.576	-0.387	1.093	-0.179	-0.137	0.120			
FTSE Good Global	-2.730	-2.212	1.588	-1.841	-1.538	-0.616	-0.442	1.027	-1.841	-1.538	1.027	-0.616	-0.442	1.027	-0.198	-0.147	0.139			
DJISI World	-2.732	-2.303	1.329	-1.872	-1.611	-0.627	-0.434	0.876	-1.872	-1.611	0.876	-0.627	-0.434	0.876	-0.117	-0.119	0.034			
DJ Islamic	-2.761	-2.334	1.636	-1.802	-1.491	-0.629	-0.448	1.073	-1.802	-1.491	1.073	-0.629	-0.448	1.073	-0.345	-0.307	0.196			
S&P Green Bond	-1.508	-1.518	0.029	-0.880	-0.891	-0.358	-0.315	0.047	-0.880	-0.891	0.047	-0.358	-0.315	0.047	-0.162	-0.172	0.041			
S&P Clean Energy	-3.061	-2.816	0.921	-1.932	-1.783	-0.635	-0.416	0.553	-1.932	-1.783	0.553	-0.635	-0.416	0.553	-0.424	-0.443	0.216			
Euronext Vigeo	-2.740	-2.454	0.954	-1.765	-1.622	-0.686	-0.508	0.489	-1.765	-1.622	0.489	-0.686	-0.508	0.489	-0.112	-0.111	0.038			
EEX-EU CO2	-2.120	-2.077	0.147	-1.246	-1.230	-0.416	-0.389	0.089	-1.246	-1.230	0.089	-0.416	-0.389	0.089	-0.115	-0.105	0.049			
S&P Green Build	-2.927	-2.627	1.067	-1.617	-1.492	-0.583	-0.364	0.430	-1.617	-1.492	0.430	-0.583	-0.364	0.430	-0.541	-0.487	0.288			
Panel B: Crude oil																				
MSCI World ESG	-5.111	-4.656	1.380	-3.604	-3.348	-0.915	-0.827	0.794	-3.604	-3.348	0.794	-0.915	-0.827	0.794	-3.066	-2.470	1.684			
FTSE Good Global	-5.138	-4.701	1.339	-3.633	-3.399	-0.966	-0.872	0.795	-3.633	-3.399	0.795	-0.966	-0.872	0.795	-3.629	-2.847	2.157			
DJISI World	-4.990	-4.625	1.133	-3.547	-3.331	-0.987	-0.875	0.720	-3.547	-3.331	0.720	-0.987	-0.875	0.720	-2.491	-2.526	0.592			
DJ Islamic	-5.268	-4.918	1.341	-3.564	-3.350	-0.832	-0.781	0.736	-3.564	-3.350	0.736	-0.832	-0.781	0.736	-4.032	-3.688	1.777			
S&P Green Bond	-3.877	-3.861	0.050	-2.698	-2.706	-0.137	-0.341	0.035	-2.698	-2.706	0.035	-0.137	-0.341	0.035	-1.817	-1.869	0.203			
S&P Clean Energy	-5.636	-5.366	1.015	-3.769	-3.593	-0.812	-0.743	0.652	-3.769	-3.593	0.652	-0.812	-0.743	0.652	-4.003	-4.144	1.614			
Euronext Vigeo	-5.102	-4.766	1.117	-3.584	-3.417	-1.077	-0.942	0.572	-3.584	-3.417	0.572	-1.077	-0.942	0.572	-2.080	-2.060	0.700			
EEX-EU CO2	-5.212	-5.087	0.426	-3.489	-3.433	-0.726	-0.721	0.308	-3.489	-3.433	0.308	-0.726	-0.721	0.308	-2.003	-1.871	0.629			
S&P Green Build	-4.934	-4.671	0.937	-3.511	-3.369	-0.559	-0.641	0.488	-3.511	-3.369	0.488	-0.559	-0.641	0.488	-9.602	-8.644	5.097			
Panel C: Gold																				
MSCI World ESG	-1.654	-1.649	0.018	-3.239	-3.164	-0.340	-0.332	0.285	-3.239	-3.164	0.285	-0.340	-0.332	0.285	-0.210	-0.181	0.100			
FTSE Good Global	-1.677	-1.670	0.032	-3.284	-3.215	-0.341	-0.332	0.288	-3.284	-3.215	0.288	-0.341	-0.332	0.288	-0.191	-0.171	0.083			
DJISI World	-1.784	-1.770	0.067	-3.287	-3.229	-0.348	-0.338	0.292	-3.287	-3.229	0.292	-0.348	-0.338	0.292	-0.166	-0.152	0.049			
DJ Islamic	-1.797	-1.779	0.083	-3.195	-3.126	-0.347	-0.339	0.280	-3.195	-3.126	0.280	-0.347	-0.339	0.280	-0.328	-0.297	0.188			
S&P Green Bond	-2.083	-2.060	0.142	-2.704	-2.709	-0.346	-0.335	0.026	-2.704	-2.709	0.026	-0.346	-0.335	0.026	-0.227	-0.203	0.118			
S&P Clean Energy	-1.646	-1.642	0.022	-3.250	-3.196	-0.366	-0.351	0.258	-3.250	-3.196	0.258	-0.366	-0.351	0.258	-0.327	-0.271	0.204			
Euronext Vigeo	-1.544	-1.548	0.020	-3.290	-3.223	-0.344	-0.336	0.304	-3.290	-3.223	0.304	-0.344	-0.336	0.304	-0.093	-0.094	0.005			
EEX-EU CO2	-1.724	-1.712	0.065	-3.471	-3.376	-0.360	-0.344	0.431	-3.471	-3.376	0.431	-0.360	-0.344	0.431	0.085	0.054	0.132			
S&P Green Build	-1.772	-1.758	0.078	-3.304	-3.252	-0.338	-0.329	0.262	-3.304	-3.252	0.262	-0.338	-0.329	0.262	0.002	-0.013	0.078			

(Continues)

TABLE 6 (Continued)

		Undecomposed			Short-run trend			Medium-run trend			Long-run trend		
Panel D: STOXX	MSCI World ESG	-2.778	-2.286	1.491	-1.611	-1.399	0.660	-0.666	-0.462	0.588	-0.293	-0.227	0.186
	FTSE Good Global	-2.736	-2.295	1.352	-1.650	-1.436	0.725	-0.715	-0.532	0.593	-0.390	-0.294	0.263
	DJISI World	-2.656	-2.245	1.273	-1.595	-1.384	0.706	-0.723	-0.510	0.612	-0.227	-0.231	0.063
	DJ Islamic	-2.900	-2.564	1.287	-1.597	-1.437	0.553	-0.758	-0.567	0.592	-0.503	-0.452	0.266
	S&P Green Bond	-1.373	-1.398	0.078	-0.931	-0.946	0.070	-0.240	-0.257	0.047	-0.067	-0.065	0.007
	S&P Clean Energy	-2.945	-2.722	0.838	-1.843	-1.714	0.476	-0.624	-0.435	0.480	-0.554	-0.578	0.273
	Euronext Vigeo	-2.459	-2.048	1.370	-1.540	-1.307	0.801	-0.707	-0.491	0.632	-0.159	-0.157	0.076
	EEX-EU CO2	-2.252	-2.202	0.172	-1.417	-1.395	0.123	-0.493	-0.460	0.150	-0.189	-0.169	0.094
	S&P Green Build	-2.911	-2.594	1.127	-1.648	-1.511	0.470	-0.666	-0.423	0.624	-1.041	-0.934	0.570
Panel E: Nikkei	MSCI World ESG	-3.151	-2.813	1.023	-1.594	-1.554	0.124	-0.725	-0.533	0.552	-0.279	-0.219	0.170
	FTSE Good Global	-3.074	-2.773	0.926	-1.617	-1.578	0.132	-0.782	-0.606	0.569	-0.229	-0.187	0.117
	DJISI World	-3.003	-2.750	0.784	-1.632	-1.593	0.131	-0.761	-0.571	0.548	-0.131	-0.132	0.017
	DJ Islamic	-2.922	-2.733	0.728	-1.616	-1.582	0.117	-0.770	-0.599	0.532	-0.174	-0.164	0.053
	S&P Green Bond	-2.053	-2.061	0.028	-1.406	-1.409	0.013	-0.373	-0.373	0.000	-0.073	-0.072	0.007
	S&P Clean Energy	-3.410	-3.224	0.700	-1.722	-1.682	0.148	-0.667	-0.494	0.437	-0.231	-0.238	0.080
	Euronext Vigeo	-3.109	-2.867	0.808	-1.698	-1.656	0.145	-0.840	-0.634	0.603	-0.164	-0.163	0.054
	EEX-EU CO2	-2.506	-2.478	0.095	-1.457	-1.455	0.010	-0.491	-0.471	0.093	-0.267	-0.235	0.153
	S&P Green Build	-3.251	-3.007	0.870	-1.812	-1.740	0.246	-0.666	-0.466	0.515	-0.433	-0.395	0.203
Panel F: Hang Seng	MSCI World ESG	-2.743	-2.463	0.849	-1.420	-1.364	0.174	-0.581	-0.458	0.355	-0.262	-0.213	0.138
	FTSE Good Global	-2.685	-2.437	0.760	-1.420	-1.364	0.190	-0.614	-0.496	0.383	-0.319	-0.251	0.188
	DJISI World	-2.703	-2.465	0.740	-1.444	-1.373	0.239	-0.628	-0.487	0.405	-0.208	-0.211	0.053
	DJ Islamic	-2.792	-2.583	0.802	-1.434	-1.383	0.177	-0.650	-0.515	0.418	-0.424	-0.383	0.211
	S&P Green Bond	-2.168	-2.141	0.086	-1.162	-1.164	0.011	-0.508	-0.443	0.181	-0.164	-0.170	0.024
	S&P Clean Energy	-2.968	-2.793	0.661	-1.663	-1.587	0.282	-0.559	-0.425	0.340	-0.516	-0.538	0.248
	Euronext Vigeo	-2.889	-2.650	0.798	-1.638	-1.555	0.287	-0.615	-0.495	0.353	-0.253	-0.251	0.085
	EEX-EU CO2	-2.289	-2.258	0.105	-1.271	-1.265	0.033	-0.485	-0.459	0.114	-0.134	-0.128	0.027
	S&P Green Build	-3.039	-2.793	0.876	-1.609	-1.519	0.311	-0.501	-0.383	0.303	-0.951	-0.857	0.500
Panel G: US to EUR	MSCI World ESG	-0.734	-0.744	0.028	-0.483	-0.496	0.040	-0.098	-0.112	0.041	-0.046	-0.045	0.003
	FTSE Good Global	-0.950	-0.900	0.153	-0.594	-0.582	0.044	-0.141	-0.140	0.003	-0.054	-0.051	0.010
	DJISI World	-0.951	-0.904	0.147	-0.606	-0.591	0.053	-0.143	-0.142	0.004	-0.061	-0.062	0.007
	DJ Islamic	-0.961	-0.923	0.146	-0.562	-0.557	0.017	-0.132	-0.134	0.008	-0.088	-0.083	0.028

TABLE 6 (Continued)

	Undecomposed		Short-run trend		Medium-run trend		Long-run trend				
S&P Green Bond	-1.190	-1.107	0.263	-0.688	-0.651	0.167	-0.267	-0.201	0.184	-0.106	-0.113
S&P Clean Energy	-1.001	-0.967	0.130	-0.606	-0.595	0.041	-0.157	-0.148	0.021	-0.087	-0.090
Euronext Vigeo	-0.650	-0.672	0.075	-0.439	-0.457	0.062	-0.069	-0.091	0.064	-0.045	-0.045
EEX-EU CO2	-0.901	-0.891	0.035	-0.517	-0.518	0.006	-0.146	-0.145	0.004	-0.035	-0.037
S&P Green Build	-0.952	-0.910	0.151	-0.594	-0.581	0.044	-0.153	-0.145	0.021	-0.213	-0.194

Note: This paper presents the summary statistics of the conditional VaR (CoVaR) between EESG assets and the conventional assets for the original and decomposed return series.

relationships, which is difficult to investigate in the scale-aggregated data. We use the maximal overlap discrete wavelet transform (MODWT), a modified version of discrete wavelet transform (DWT), which is immune to the pitfalls facing DWT. Following Percival and Walden (2000) and Gençay et al. (2001), let the u returns series be described as: $r_t : t = 1, 2, \dots, N$. We can decompose the r_t into a set of J frequencies by circularly filtering r_t by using the MODWT wavelet and scaling filters:

$$\tilde{W}_{j,t} = \sum_{l=0}^{L-1} \tilde{h}_l r_{t-l \bmod N} \text{ and } \tilde{V}_{j,t} = \sum_{l=0}^{L-1} \tilde{g}_l r_{t-l \bmod N}, \quad (1)$$

where, $\tilde{h}_{j,l}$ and $\tilde{g}_{j,l}$ are the wavelet and scaling filters, respectively, and L is the length of the filter. A real valued DWT wavelet filter h_l with length $L \in \mathbb{N}$ satisfies the following three properties:

$$\sum_{l=0}^{L-1} h_l = 0, \sum_{l=0}^{L-1} h_l^2 = 1, \text{ and } \sum_{l=0}^{L-1} h_l h_{l+2n} = 0, \forall n \in \mathbb{N} \quad (2)$$

These properties ensure that the filter has zero mean, unit energy, and is orthogonal to even shifts (Gençay et al., 2001; Percival & Walden, 2000). The DWT scaling filter is defined as the quadrature mirror filter of the DWT wavelet filter satisfying:

$$h_l = (-1)^l g_{L-1-l}, \text{ or } g_l = (-1)^{l+1} h_{L-1-l}, l = 0, \dots, L-1. \quad (3)$$

As we incorporate MODWT, the rescaled filters can be directly obtained from the DWT wavelet and scaling filters as follows:

$$\tilde{h}_{j,l} = \frac{h_{j,l}}{2^{j/2}} \text{ and } \tilde{g}_{j,l} = \frac{g_{j,l}}{2^{j/2}}, j = 0, \dots, J, \quad (4)$$

where J is the total number of levels. The selection of wavelet filter is fundamental for decomposing a series to obtain the wavelet coefficients. We chose Daubechies' (1992) least asymmetric wavelet filters in MODWT to extract wavelet and scaling coefficients due to their ability to capture the scale and time variations in the data.

2.2 | Time-varying copula

The copulas are effective in capturing connectedness structure among variables. We utilize both symmetric

TABLE 7 Delta conditional value-at-risk for the original and decomposed series for pre-COVID period

	Undecomposed					Short-run trend					Medium-run trend					Long-run trend				
	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std		
Panel A: S&P500																				
MSCI World ESG	-1.418	-1.249	0.606	-0.802	-0.698	0.392	-0.321	-0.275	0.208	-0.230	-0.171	0.207	-0.321	-0.275	0.208	-0.230	-0.171	0.207		
FTSE Good Global	-1.329	-1.214	0.513	-0.804	-0.714	0.372	-0.311	-0.263	0.219	-0.166	-0.129	0.149	-0.311	-0.263	0.219	-0.166	-0.129	0.149		
DJISI World	-1.340	-1.244	0.477	-0.828	-0.758	0.356	-0.339	-0.289	0.219	-0.087	-0.070	0.062	-0.339	-0.289	0.219	-0.087	-0.070	0.062		
DJ Islamic	-1.419	-1.294	0.565	-0.837	-0.736	0.409	-0.342	-0.297	0.230	-0.242	-0.211	0.187	-0.342	-0.297	0.230	-0.242	-0.211	0.187		
S&P Green Bond	0.077	0.075	0.015	0.114	0.108	0.035	-0.084	-0.073	0.051	-0.086	-0.074	0.058	-0.084	-0.073	0.051	-0.086	-0.074	0.058		
S&P Clean Energy	-0.965	-0.924	0.257	-0.554	-0.508	0.219	-0.357	-0.297	0.252	-0.238	-0.181	0.205	-0.357	-0.297	0.252	-0.238	-0.181	0.205		
Euronext Vigeo	-0.994	-0.906	0.418	-0.526	-0.468	0.260	-0.320	-0.278	0.202	-0.075	-0.063	0.053	-0.320	-0.278	0.202	-0.075	-0.063	0.053		
EEX-EU CO2	-0.484	-0.448	0.199	-0.227	-0.199	0.124	-0.143	-0.115	0.112	-0.121	-0.099	0.092	-0.143	-0.115	0.112	-0.121	-0.099	0.092		
S&P Green Build	-1.024	-0.956	0.379	-0.495	-0.450	0.231	-0.264	-0.218	0.199	-0.457	-0.392	0.357	-0.264	-0.218	0.199	-0.457	-0.392	0.357		
Panel B: Crude oil																				
MSCI World ESG	-1.048	-0.923	0.448	-0.583	-0.507	0.285	-0.149	-0.128	0.096	-3.242	-2.403	2.913	-0.149	-0.128	0.096	-3.242	-2.403	2.913		
FTSE Good Global	-1.120	-1.023	0.432	-0.623	-0.553	0.288	-0.167	-0.141	0.118	-2.582	-1.999	2.320	-0.167	-0.141	0.118	-2.582	-1.999	2.320		
DJISI World	-1.142	-1.061	0.406	-0.681	-0.623	0.292	-0.197	-0.168	0.127	-1.520	-1.214	1.074	-0.197	-0.168	0.127	-1.520	-1.214	1.074		
DJ Islamic	-1.163	-1.060	0.463	-0.574	-0.505	0.280	-0.096	-0.083	0.065	-2.202	-1.919	1.698	-0.096	-0.083	0.065	-2.202	-1.919	1.698		
S&P Green Bond	-0.130	-0.126	0.025	0.086	0.082	0.026	0.403	0.350	0.247	-0.420	-0.361	0.284	0.403	0.350	0.247	-0.420	-0.361	0.284		
S&P Clean Energy	-1.064	-1.019	0.283	-0.654	-0.600	0.258	-0.113	-0.094	0.079	-1.781	-1.354	1.536	-0.113	-0.094	0.079	-1.781	-1.354	1.536		
Euronext Vigeo	-1.165	-1.061	0.489	-0.616	-0.548	0.304	-0.242	-0.210	0.153	-1.368	-1.148	0.973	-0.242	-0.210	0.153	-1.368	-1.148	0.973		
EEX-EU CO2	-1.408	-1.302	0.578	-0.786	-0.691	0.431	-0.027	-0.022	0.022	-1.554	-1.270	1.184	-0.027	-0.022	0.022	-1.554	-1.270	1.184		
S&P Green Build	-0.899	-0.839	0.332	-0.561	-0.509	0.262	0.099	0.081	0.075	-8.105	-6.944	6.319	0.099	0.081	0.075	-8.105	-6.944	6.319		
Panel C: Gold																				
MSCI World ESG	-0.042	-0.037	0.018	-0.583	-0.507	0.285	-0.053	-0.046	0.035	-0.112	-0.083	0.100	-0.053	-0.046	0.035	-0.112	-0.083	0.100		
FTSE Good Global	-0.082	-0.075	0.032	-0.623	-0.553	0.288	-0.057	-0.048	0.040	-0.093	-0.072	0.083	-0.057	-0.048	0.040	-0.093	-0.072	0.083		
DJISI World	-0.189	-0.176	0.067	-0.681	-0.623	0.292	-0.066	-0.056	0.042	-0.070	-0.056	0.049	-0.066	-0.056	0.042	-0.070	-0.056	0.049		
DJ Islamic	-0.209	-0.190	0.083	-0.574	-0.505	0.280	-0.064	-0.055	0.043	-0.244	-0.212	0.188	-0.064	-0.055	0.043	-0.244	-0.212	0.188		
S&P Green Bond	-0.747	-0.724	0.142	0.086	0.082	0.026	-0.084	-0.073	0.052	-0.174	-0.150	0.118	-0.084	-0.073	0.052	-0.174	-0.150	0.118		
S&P Clean Energy	-0.081	-0.077	0.022	-0.654	-0.600	0.258	-0.088	-0.073	0.062	-0.237	-0.180	0.204	-0.088	-0.073	0.062	-0.237	-0.180	0.204		
Euronext Vigeo	0.048	0.043	0.020	-0.616	-0.548	0.304	-0.056	-0.048	0.035	0.007	0.006	0.005	-0.056	-0.048	0.035	0.007	0.006	0.005		
EEX-EU CO2	-0.159	-0.147	0.065	-0.786	-0.691	0.431	-0.080	-0.065	0.063	0.173	0.142	0.132	-0.080	-0.065	0.063	0.173	0.142	0.132		
S&P Green Build	-0.210	-0.196	0.078	-0.561	-0.509	0.262	-0.051	-0.042	0.038	0.101	0.086	0.078	-0.051	-0.042	0.038	0.101	0.086	0.078		

TABLE 7 (Continued)

		Undecomposed			Short-run trend			Medium-run trend			Long-run trend		
Panel D: STOXX	MSCI World ESG	-1.133	-0.998	0.484	-0.484	-0.422	0.237	-0.347	-0.297	0.224	-0.357	-0.265	0.321
	FTSE Good Global	-1.132	-1.034	0.437	-0.568	-0.504	0.263	-0.328	-0.277	0.230	-0.315	-0.244	0.283
	DJISI World	-1.283	-1.192	0.456	-0.668	-0.611	0.287	-0.374	-0.319	0.241	-0.162	-0.130	0.115
	DJ Islamic	-1.116	-1.018	0.444	-0.431	-0.379	0.210	-0.359	-0.312	0.242	-0.329	-0.287	0.254
	S&P Green Bond	0.205	0.199	0.039	0.170	0.161	0.052	0.034	0.029	0.021	0.015	0.013	0.010
	S&P Clean Energy	-0.878	-0.841	0.234	-0.478	-0.438	0.188	-0.309	-0.257	0.217	-0.301	-0.229	0.259
	Euronext Vigeo	-1.429	-1.302	0.600	-0.862	-0.768	0.426	-0.386	-0.335	0.244	-0.148	-0.124	0.105
	EEX-EU CO2	-0.568	-0.525	0.233	-0.314	-0.276	0.172	-0.172	-0.139	0.136	-0.234	-0.191	0.178
	S&P Green Build	-1.082	-1.010	0.400	-0.541	-0.491	0.253	-0.293	-0.242	0.221	-0.906	-0.776	0.706
Panel E: Nikkei	MSCI World ESG	-0.777	-0.684	0.332	-0.091	-0.079	0.044	-0.325	-0.279	0.211	-0.327	-0.242	0.294
	FTSE Good Global	-0.775	-0.708	0.299	-0.103	-0.092	0.048	-0.314	-0.265	0.221	-0.140	-0.108	0.126
	DJISI World	-0.790	-0.734	0.281	-0.124	-0.114	0.053	-0.335	-0.286	0.216	-0.043	-0.034	0.030
	DJ Islamic	-0.631	-0.575	0.251	-0.092	-0.080	0.045	-0.322	-0.280	0.217	-0.065	-0.057	0.050
	S&P Green Bond	0.072	0.070	0.014	0.031	0.030	0.010	0.000	0.000	0.000	0.014	0.012	0.009
	S&P Clean Energy	-0.734	-0.703	0.195	-0.149	-0.136	0.059	-0.281	-0.234	0.198	-0.088	-0.067	0.076
	Euronext Vigeo	-0.843	-0.768	0.354	-0.156	-0.139	0.077	-0.369	-0.320	0.233	-0.105	-0.088	0.075
	EEX-EU CO2	-0.315	-0.291	0.129	-0.026	-0.023	0.014	-0.107	-0.086	0.084	-0.378	-0.309	0.288
	S&P Green Build	-0.835	-0.779	0.308	-0.283	-0.257	0.132	-0.242	-0.200	0.183	-0.322	-0.276	0.251
Panel F: Hang Seng	MSCI World ESG	-0.645	-0.568	0.276	-0.128	-0.111	0.063	-0.210	-0.180	0.136	-0.267	-0.198	0.239
	FTSE Good Global	-0.636	-0.581	0.245	-0.148	-0.132	0.069	-0.211	-0.179	0.149	-0.225	-0.175	0.203
	DJISI World	-0.746	-0.693	0.265	-0.226	-0.207	0.097	-0.247	-0.211	0.160	-0.135	-0.108	0.096
	DJ Islamic	-0.695	-0.634	0.277	-0.138	-0.122	0.068	-0.254	-0.220	0.171	-0.261	-0.227	0.201
	S&P Green Bond	-0.226	-0.219	0.043	0.028	0.026	0.009	-0.129	-0.112	0.079	-0.049	-0.042	0.033
	S&P Clean Energy	-0.692	-0.663	0.184	-0.282	-0.259	0.111	-0.218	-0.182	0.154	-0.273	-0.208	0.236
	Euronext Vigeo	-0.832	-0.758	0.350	-0.309	-0.275	0.152	-0.216	-0.187	0.136	-0.167	-0.140	0.119
	EEX-EU CO2	-0.347	-0.321	0.143	-0.084	-0.074	0.046	-0.131	-0.106	0.103	-0.066	-0.054	0.051
	S&P Green Build	-0.841	-0.785	0.311	-0.357	-0.324	0.167	-0.143	-0.117	0.108	-0.795	-0.681	0.620
Panel G: US to EUR	MSCI World ESG	0.021	0.019	0.009	0.030	0.026	0.014	0.024	0.021	0.016	-0.005	-0.004	0.004
	FTSE Good Global	-0.128	-0.117	0.049	-0.034	-0.031	0.016	-0.002	-0.001	0.001	-0.012	-0.009	0.011
	DJISI World	-0.148	-0.137	0.053	-0.050	-0.046	0.021	-0.003	-0.002	0.002	-0.018	-0.015	0.013
	DJ Islamic	-0.127	-0.116	0.050	-0.014	-0.012	0.007	0.005	0.004	0.003	-0.035	-0.030	0.027

(Continues)

TABLE 7 (Continued)

	Undecomposed		Short-run trend		Medium-run trend		Long-run trend			
S&P Green Bond	-0.691	-0.670	0.131	-0.408	-0.386	0.124	-0.114	0.080	-0.060	-0.052
S&P Clean Energy	-0.137	-0.131	0.036	-0.041	-0.037	0.016	-0.011	0.009	-0.028	-0.021
Euronext Vigeo	0.079	0.072	0.033	0.067	0.059	0.033	0.039	0.025	-0.003	-0.002
EEX-EU CO2	-0.114	-0.105	0.047	0.014	0.012	0.008	-0.005	0.004	0.019	0.015
S&P Green Build	-0.145	-0.135	0.053	-0.050	-0.045	0.023	-0.010	0.007	-0.155	-0.133

Note: This paper presents the summary statistics of the Delta CoVaR (ΔCoVaR) between ESG assets and the conventional assets for the original and decomposed return series.

and asymmetric copula frameworks to assess the extreme nonlinear connectedness among the assets, which is generally common for the financial returns.¹ According to Sklar's (1959) theorem, the joint functional distribution for a copula may be written as:

$$F_{XY}(x, y) = C(u, v) \tag{5}$$

where $u = F_X(x)$ and $v = F_Y(y)$ represent the univariate functions for X and Y and $F_{XY}(x, y)$ represents to the joint distribution function. We may define the Student-t copula for the multivariate case as:

$$C_{d,\rho}(u_1, \dots, u_n) = t_{d,\rho}(t_d^{-1}(u_1), \dots, t_d^{-1}(u_n)) = \int_{-\infty}^{t_d^{-1}(u_1)} \dots \int_{-\infty}^{t_d^{-1}(u_n)} \frac{\Gamma\left(\frac{d+n}{2}\right) |\rho|^{-\frac{1}{2}}}{\Gamma\left(\frac{d}{2}\right) (\pi v)^{\frac{n}{2}}} \left(1 + \frac{1}{d} z^T \rho^{-1} z\right)^{-\frac{d+n}{2}} dz_1, \dots, dz_n, \tag{6}$$

where t_d^{-1} represents the inverse univariate t distribution with d corresponding to the asymmetric extreme dependence and $t_{d,\rho}$ corresponds to multivariate t distribution. We replace the linear dependence matrix with the DCC matrix of Engle (2002) that is defined as:

$$R_t = \text{diag}(\tilde{Q}_t)^{-\frac{1}{2}} Q_t \text{diag}(\tilde{Q}_t)^{-\frac{1}{2}}, \tag{7}$$

$$Q_t = \Delta \bar{R} + \alpha \epsilon_{t-1} \epsilon'_{t-1} + \beta Q_{t-1},$$

where $\Delta = 1 - \alpha - \beta$, \bar{Q} is the sample covariance of ϵ_t , \tilde{Q}_t corresponds the square root of diagonal elements of Q_t . Assessment of marginal distributional framework is a crucial requirement to estimating copula frameworks. Based on the lowest Akaike Information Criterion (AIC), we determine an ARMA(1,0)-EGARCH(1,1) as the optimal model to capture the dynamics among the evaluated series.² We specify the generalized form EGARCH (P,Q) as:

$$\log \sigma_t^2 = \kappa + \sum_{i=1}^P \beta_i \log \sigma_{t-i}^2 + \sum_{j=1}^Q \alpha_j \left[\frac{|\epsilon_{t-j}|}{\sigma_{t-j}} - E \left\{ \frac{|\epsilon_{t-j}|}{\sigma_{t-j}} \right\} \right] + \sum_{j=1}^Q \xi_j \left(\frac{\epsilon_{t-j}}{\sigma_{t-j}} \right), \tag{8}$$

where α_j and β_i represents to the ARCH and GARCH parameters, respectively, and ξ_j represents the asymmetric impact of positive and negative shocks.

TABLE 8 Delta conditional value-at-risk for the original and decomposed series for during-COVID period

	Undecomposed					Short-run trend					Medium-run trend					Long-run trend				
	Mean	Median	Std	Mean	Std	Mean	Median	Std	Mean	Std	Mean	Median	Std	Mean	Median	Std	Mean	Median	Std	
Panel A: S&P500																				
MSCI World ESG	-2.296	-1.680	1.867	-1.304	1.093	-0.952	-0.330	1.093	-0.519	1.093	-0.330	1.093	-0.330	-0.165	-0.123	0.545	-0.165	-0.123	0.545	
FTSE Good Global	-2.095	-1.577	1.588	-1.254	1.027	-0.952	-0.378	1.027	-0.552	1.027	-0.378	1.027	-0.378	-0.178	-0.127	0.563	-0.178	-0.127	0.563	
DJISI World	-1.884	-1.455	1.329	-1.144	0.876	-0.882	-0.349	0.876	-0.541	0.876	-0.349	0.876	-0.349	-0.087	-0.089	0.554	-0.087	-0.089	0.554	
DJ Islamic	-2.272	-1.845	1.636	-1.374	1.073	-1.063	-0.382	1.073	-0.564	1.073	-0.382	1.073	-0.382	-0.313	-0.275	0.565	-0.313	-0.275	0.565	
S&P Green Bond	0.091	0.082	0.029	0.122	0.047	0.112	-0.079	0.047	-0.122	0.047	-0.079	0.047	-0.116	-0.127	0.118	-0.116	-0.127	0.118		
S&P Clean Energy	-1.805	-1.560	0.921	-0.994	0.553	-0.845	-0.236	0.553	-0.455	0.553	-0.236	0.553	-0.384	-0.403	0.555	-0.384	-0.403	0.555		
Euronext Vigeo	-1.482	-1.196	0.954	-0.777	0.489	-0.634	-0.362	0.489	-0.541	0.489	-0.362	0.489	-0.074	-0.073	0.523	-0.074	-0.073	0.523		
EEX-EU CO2	-0.507	-0.464	0.147	-0.232	0.089	-0.216	-0.142	0.089	-0.170	0.089	-0.142	0.089	-0.058	-0.048	0.124	-0.058	-0.048	0.124		
S&P Green Build	-1.631	-1.331	1.067	-0.678	0.430	-0.553	-0.194	0.430	-0.413	0.430	-0.194	0.430	-0.500	-0.446	0.562	-0.500	-0.446	0.562		
Panel B: Crude oil																				
MSCI World ESG	-1.698	-1.242	1.380	-0.947	0.794	-0.692	-0.153	0.794	-0.241	0.794	-0.153	0.794	-0.321	-1.725	1.684	-0.321	-1.725	1.684		
FTSE Good Global	-1.765	-1.329	1.339	-0.972	0.795	-0.737	-0.203	0.795	-0.297	0.795	-0.203	0.795	-2.765	-1.982	2.157	-2.765	-1.982	2.157		
DJISI World	-1.605	-1.240	1.133	-0.941	0.720	-0.725	-0.202	0.720	-0.315	0.720	-0.202	0.720	-1.524	-1.559	0.592	-1.524	-1.559	0.592		
DJ Islamic	-1.861	-1.512	1.341	-0.942	0.736	-0.729	-0.107	0.736	-0.158	0.736	-0.107	0.736	-2.844	-2.500	1.777	-2.844	-2.500	1.777		
S&P Green Bond	-0.153	-0.137	0.050	0.093	0.035	0.085	0.381	0.035	0.585	0.035	0.381	0.035	-0.568	-0.620	0.203	-0.568	-0.620	0.203		
S&P Clean Energy	-1.990	-1.720	1.015	-1.173	0.652	-0.997	-0.074	0.652	-0.143	0.652	-0.074	0.652	-2.877	-3.018	1.614	-2.877	-3.018	1.614		
Euronext Vigeo	-1.736	-1.401	1.117	-0.910	0.572	-0.743	-0.274	0.572	-0.409	0.572	-0.274	0.572	-1.346	-1.326	0.700	-1.346	-1.326	0.700		
EEX-EU CO2	-1.472	-1.348	0.426	-0.805	0.308	-0.749	-0.027	0.308	-0.033	0.308	-0.027	0.308	-0.752	-0.620	0.629	-0.752	-0.620	0.629		
S&P Green Build	-1.432	-1.169	0.937	-0.768	0.488	-0.627	0.073	0.488	0.155	0.488	0.073	0.488	-8.859	-7.901	5.097	-8.859	-7.901	5.097		
Panel C: Gold																				
MSCI World ESG	-0.068	-0.049	0.055	-0.947	0.794	-0.692	-0.055	0.794	-0.086	0.794	-0.055	0.794	-0.080	-0.059	0.058	-0.080	-0.059	0.058		
FTSE Good Global	-0.129	-0.097	0.098	-0.972	0.795	-0.737	-0.069	0.795	-0.101	0.795	-0.069	0.795	-0.099	-0.071	0.077	-0.099	-0.071	0.077		
DJISI World	-0.266	-0.205	0.188	-0.941	0.720	-0.725	-0.067	0.720	-0.105	0.720	-0.067	0.720	-0.070	-0.072	0.027	-0.070	-0.072	0.027		
DJ Islamic	-0.334	-0.271	0.241	-0.942	0.736	-0.729	-0.071	0.736	-0.105	0.736	-0.071	0.736	-0.315	-0.277	0.197	-0.315	-0.277	0.197		
S&P Green Bond	-0.878	-0.789	0.285	0.093	0.035	0.085	-0.080	0.035	-0.123	0.035	-0.080	0.119	-0.236	-0.257	0.084	-0.236	-0.257	0.084		
S&P Clean Energy	-0.151	-0.131	0.077	-1.173	0.652	-0.997	-0.058	0.652	-0.112	0.652	-0.058	0.652	-0.383	-0.401	0.215	-0.383	-0.401	0.215		
Euronext Vigeo	0.071	0.057	0.046	-0.910	0.572	-0.743	-0.063	0.572	-0.094	0.572	-0.063	0.572	0.007	0.007	0.004	0.007	0.007	0.004		
EEX-EU CO2	-0.166	-0.152	0.048	-0.805	0.308	-0.749	-0.080	0.308	-0.096	0.308	-0.080	0.308	0.084	0.069	0.070	0.084	0.069	0.070		
S&P Green Build	-0.334	-0.273	0.219	-0.768	0.488	-0.627	-0.037	0.488	-0.079	0.488	-0.037	0.488	0.110	0.098	0.063	0.110	0.098	0.063		

(Continues)

TABLE 8 (Continued)

		Undecomposed			Short-run trend			Medium-run trend			Long-run trend		
Panel D: STOXX	MSCI World ESG	-1.834	-1.342	1.491	-0.787	-0.575	0.660	-0.560	-0.356	0.588	-0.256	-0.190	0.186
	FTSE Good Global	-1.783	-1.343	1.352	-0.886	-0.672	0.725	-0.581	-0.398	0.593	-0.337	-0.242	0.263
	DJISI World	-1.804	-1.394	1.273	-0.923	-0.712	0.706	-0.597	-0.384	0.612	-0.163	-0.167	0.063
	DJ Islamic	-1.787	-1.451	1.287	-0.708	-0.547	0.553	-0.591	-0.401	0.592	-0.426	-0.374	0.266
	S&P Green Bond	0.241	0.216	0.078	0.183	0.168	0.070	0.049	0.032	0.047	0.021	0.023	0.007
	S&P Clean Energy	-1.643	-1.420	0.838	-0.857	-0.728	0.476	-0.393	-0.203	0.480	-0.486	-0.510	0.273
	Euronext Vigeo	-2.130	-1.718	1.370	-1.274	-1.040	0.801	-0.653	-0.437	0.632	-0.145	-0.143	0.076
	EEX-EU CO2	-0.594	-0.544	0.172	-0.322	-0.299	0.123	-0.206	-0.172	0.150	-0.113	-0.093	0.094
S&P Green Build	-1.723	-1.406	1.127	-0.741	-0.604	0.470	-0.458	-0.216	0.624	-0.990	-0.883	0.570	
Panel E: Nikkei	MSCI World ESG	-1.259	-0.921	1.023	-0.148	-0.108	0.124	-0.526	-0.334	0.552	-0.234	-0.174	0.170
	FTSE Good Global	-1.221	-0.919	0.926	-0.161	-0.122	0.132	-0.557	-0.381	0.569	-0.150	-0.107	0.117
	DJISI World	-1.111	-0.858	0.784	-0.171	-0.132	0.131	-0.535	-0.344	0.548	-0.043	-0.044	0.017
	DJ Islamic	-1.010	-0.820	0.728	-0.150	-0.116	0.117	-0.531	-0.360	0.532	-0.084	-0.074	0.053
	S&P Green Bond	0.085	0.076	0.028	0.034	0.031	0.013	0.000	0.000	0.000	0.018	0.020	0.007
	S&P Clean Energy	-1.372	-1.186	0.700	-0.267	-0.227	0.148	-0.358	-0.185	0.437	-0.142	-0.150	0.080
	Euronext Vigeo	-1.256	-1.014	0.808	-0.230	-0.188	0.145	-0.623	-0.417	0.603	-0.104	-0.102	0.054
	EEX-EU CO2	-0.329	-0.301	0.095	-0.027	-0.025	0.010	-0.128	-0.107	0.093	-0.183	-0.151	0.153
S&P Green Build	-1.329	-1.085	0.870	-0.388	-0.316	0.246	-0.378	-0.178	0.515	-0.352	-0.314	0.203	
Panel F: Hang Seng	MSCI World ESG	-1.044	-0.764	0.849	-0.208	-0.152	0.174	-0.339	-0.215	0.355	-0.191	-0.142	0.138
	FTSE Good Global	-1.002	-0.754	0.760	-0.232	-0.176	0.190	-0.375	-0.256	0.383	-0.241	-0.173	0.188
	DJISI World	-1.048	-0.810	0.740	-0.312	-0.240	0.239	-0.395	-0.254	0.405	-0.136	-0.139	0.053
	DJ Islamic	-1.113	-0.904	0.802	-0.227	-0.176	0.177	-0.418	-0.283	0.418	-0.337	-0.296	0.211
	S&P Green Bond	-0.266	-0.239	0.086	0.030	0.027	0.011	-0.187	-0.122	0.181	-0.066	-0.072	0.024
	S&P Clean Energy	-1.295	-1.119	0.661	-0.507	-0.431	0.282	-0.278	-0.144	0.340	-0.442	-0.463	0.248
	Euronext Vigeo	-1.241	-1.001	0.798	-0.456	-0.372	0.287	-0.364	-0.244	0.353	-0.164	-0.162	0.085
	EEX-EU CO2	-0.363	-0.332	0.105	-0.086	-0.080	0.033	-0.157	-0.131	0.114	-0.032	-0.027	0.027
S&P Green Build	-1.339	-1.093	0.876	-0.489	-0.399	0.311	-0.223	-0.105	0.303	-0.869	-0.775	0.500	
Panel G: US to EUR	MSCI World ESG	0.034	0.025	0.028	0.048	0.035	0.040	0.039	0.025	0.041	-0.004	-0.003	0.003
	FTSE Good Global	-0.202	-0.152	0.153	-0.054	-0.041	0.044	-0.003	-0.002	0.003	-0.013	-0.009	0.010
	DJISI World	-0.208	-0.161	0.147	-0.069	-0.053	0.053	-0.004	-0.003	0.004	-0.019	-0.019	0.007
	DJ Islamic	-0.203	-0.165	0.146	-0.022	-0.017	0.017	0.008	0.005	0.008	-0.045	-0.039	0.028

TABLE 8 (Continued)

	Undecomposed		Short-run trend		Medium-run trend		Long-run trend				
S&P Green Bond	-0.813	-0.730	0.263	-0.438	-0.401	0.167	-0.190	-0.124	0.184	-0.082	-0.089
S&P Clean Energy	-0.256	-0.221	0.130	-0.073	-0.062	0.041	-0.017	-0.009	0.021	-0.045	-0.047
Euronext Vigeo	0.117	0.095	0.075	0.098	0.080	0.062	0.066	0.044	0.064	-0.002	-0.002
EEX-EU CO2	-0.119	-0.109	0.035	0.014	0.013	0.006	-0.006	-0.005	0.004	0.009	0.008
S&P Green Build	-0.230	-0.188	0.151	-0.069	-0.056	0.044	-0.015	-0.007	0.021	-0.170	-0.151

Note: This paper presents the summary statistics of the Delta CoVaR ($\Delta CoVaR$) between EESG assets and the conventional assets for the original and decomposed return series.

2.3 | Value-at-risk, CoVaR, and $\Delta CoVaR$

To estimate the downside risk and risk spillovers between an EESG asset and a conventional assets, we follow Adrian and Brunnermeier (2016) and estimate the value-at-risk (VaR), conditional value-at-risk (CoVaR), and delta conditional value-at-risk ($\Delta CoVaR$). The VaR estimates the maximum loss of an asset, basing on a tail probability of $\alpha\%$. The VaR is a broadly utilized measure to examine the downside risk of an underlying asset. Let $\{X_{1,t}, X_{2,t}\} : t=1,2,\dots,T$, be the continuously compounded stock returns of underlying assets 1 and 2, respectively, then the $VaR_{\alpha,t}^1$ for the first asset is estimated as the α -th quantile of the distribution of returns:

$$Pr(X_{1,t} \leq VaR_{\alpha,t}^1) = \alpha\%. \tag{9}$$

The CoVaR is the VaR of an EESG asset conditional on the extreme downward movements in some conventional assets and can be expressed as:

$$Pr(X_{1,t} \leq CoVaR_{\alpha,\beta,t}^{1|2} | X_{2,t} \leq VaR_{\beta,t}^2) = \alpha\%, \tag{10}$$

where $Pr(X_{2,t} \leq VaR_{\beta,t}^2) = \beta\%$ for a β -th quantile of $X_{2,t}$.

In addition, we also estimate the delta CoVaR ($\Delta CoVaR$) to assess the systemic risk contribution that is the difference between the VaR of an EESG stock returns conditional on the extreme movement of conventional assets' return and the VaR of the EESG returns conditional on the normal state (median values) of the conventional assets' return. The $\Delta CoVaR$ can be expressed as follows:

$$\Delta CoVaR_{\alpha,\beta,t}^{1|2} = (CoVaR_{\alpha,\beta,t}^{1|2} - CoVaR_{\alpha,50,t}^{1|2}), \tag{11}$$

where $CoVaR_{\alpha,50,t}^{1|2}$ satisfies $Pr(X_{1,t} \leq CoVaR_{\alpha,50,t}^{1|2} | X_{2,t} \leq VaR_{50,t}^2) = \alpha\%$, for the 50%-th quantile (or median) of the return distribution $X_{2,t}$. Adrian and Brunnermeier (2016) estimate the $CoVaR_{\alpha,\beta,t}^{1|2}$ by the quantile regression approach, which does not consider the temporal variations. Conversely, Girardi and Tolga Ergün (2013) employ a multivariate GARCH model to examine $CoVaR_{\alpha,\beta,t}^{1|2}$ by utilizing a dynamic correlation. Nevertheless, their approach relies on the selected bivariate distribution of $X_{1,t}$ and $X_{2,t}$, which can produce misspecification errors in the assessment of $CoVaR_{\alpha,\beta,t}^{1|2}$. Following Mainik and Schaanning (2014) and Karimalis and Nomikos (2018), we use copulas to evaluate $CoVaR_{\alpha,\beta,t}^{1|2}$. The copula approach

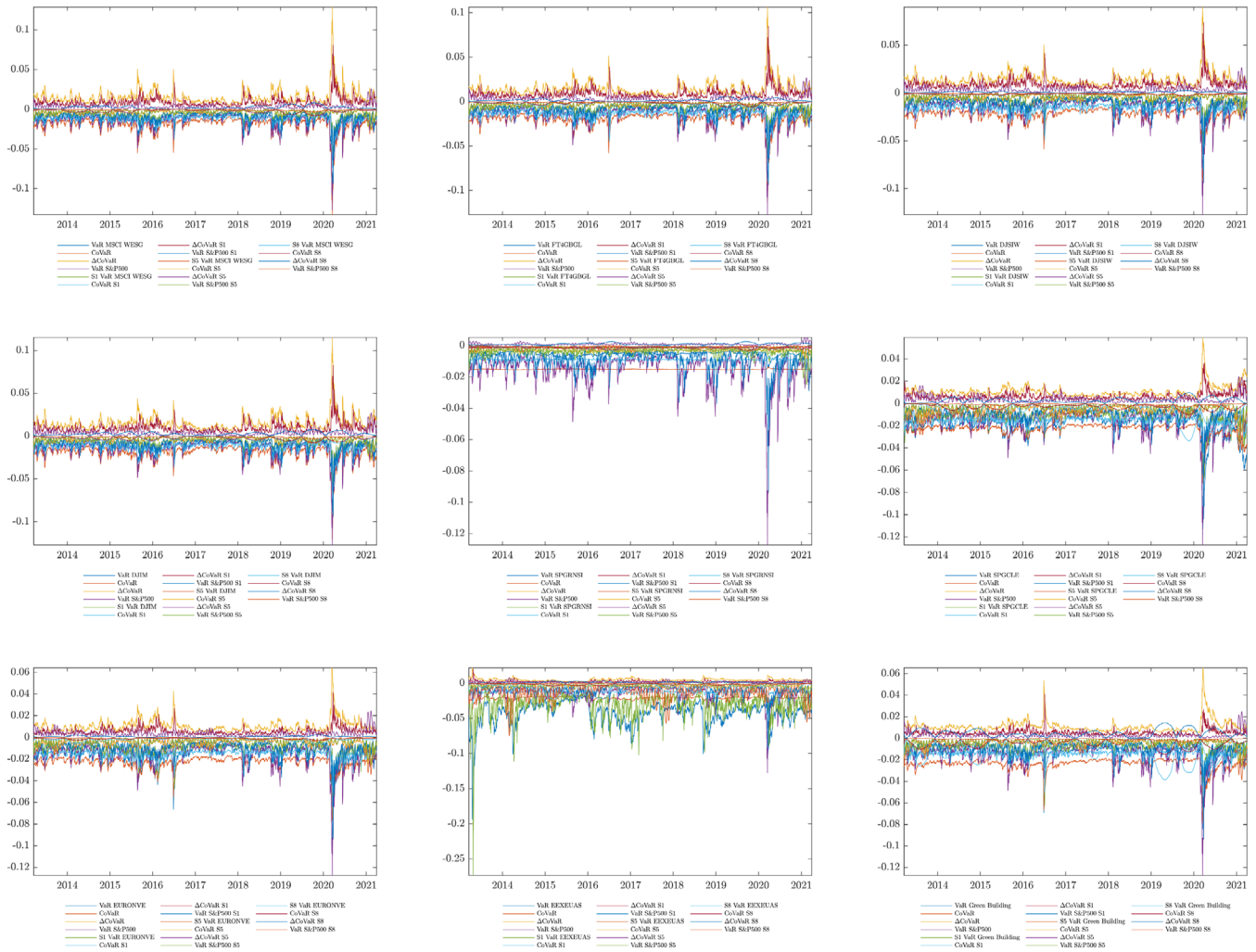


FIGURE 2 Development VaR, CoVaR, and delta CoVaR with S&P 500 [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com/doi/10.1002/for)]

provides the time-varying estimates of $CoVaR_{\alpha,\beta,t}^{1/2}$, and it is robust to the specification of the bivariate copula so that it avoids possible misspecification errors.

2.4 | Portfolio weights, hedge ratios and hedging effectiveness

To evaluate the portfolio diversification and risk management potential from the perspective of an investor's trading behaviour, we examine the variations in hedging effectiveness over several investment horizons by using wavelet-based copulas. For instance, an investor's choice may vary over different investment horizons (represented by frequencies), suggesting the preference for a particular frequency. Therefore, this approach captures the market trading mechanics and the heterogeneous behaviour of the market participants with varying frequencies.

Following Kroner and Ng (1998), we define the optimal portfolio weights as:

$$w_t^{SI} = \frac{h_t^I - h_t^{SI}}{h_t^S + h_t^I + 2 \times h_t^{SI}} \tag{12}$$

and,

$$w_t^{SI} = \begin{cases} 0, & \text{if } w_t^{SI} < 0 \\ w_t^{SI} & \text{if } 0 \leq w_t^{SI} \leq 1, \\ 1, & \text{if } w_t^{SI} > 1 \end{cases} \tag{13}$$

where, w_t^{SI} represents the weight of \$1 portfolio invested in EESG and $(1 - w_t^{SI})$ is the proportion of investment in conventional assets (financial indices, commodities, and currencies), h_t^I represents the conditional variance of conventional indices, h_t^{SI} corresponds to the conditional covariance between EESG and the conventional indices,

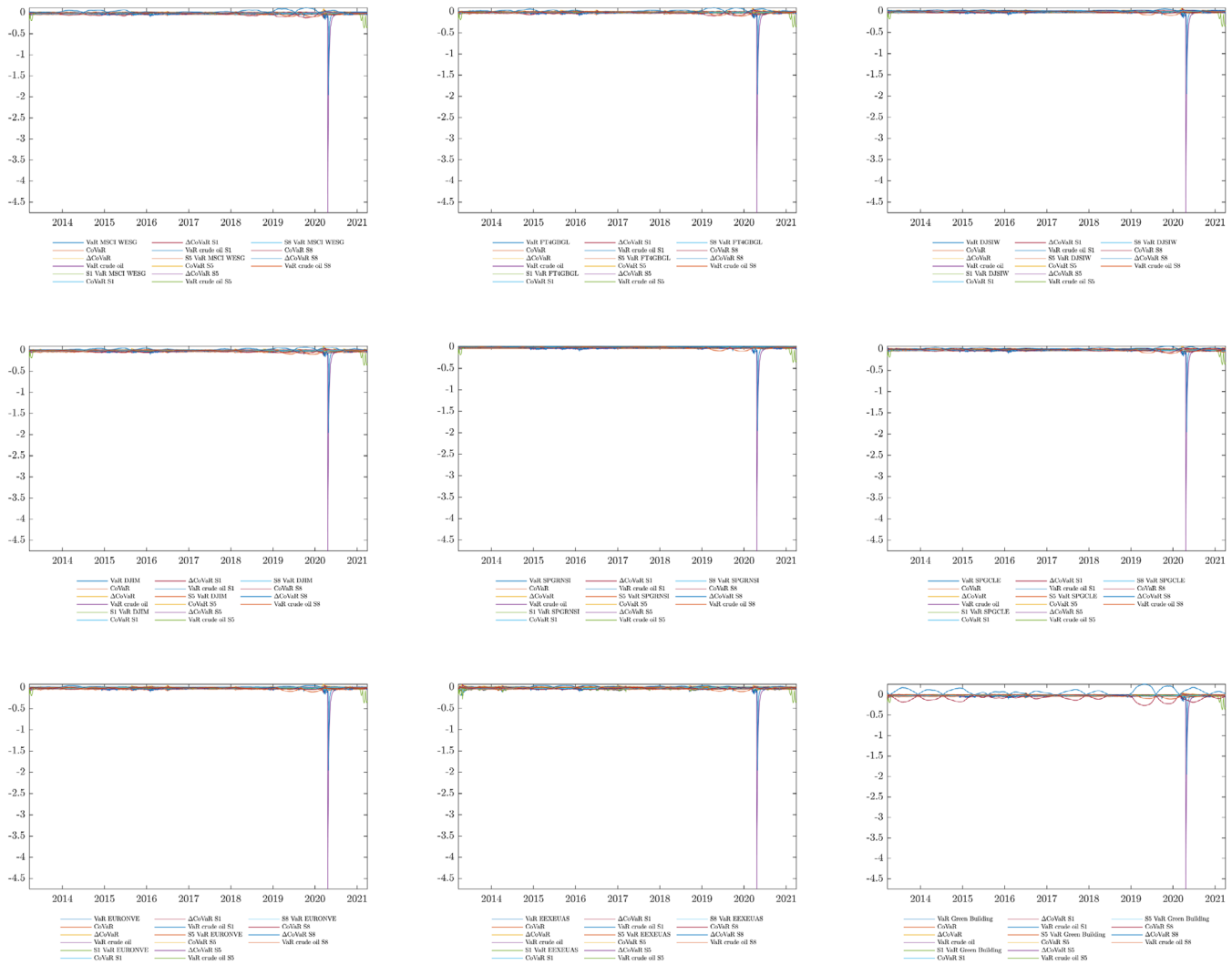


FIGURE 3 Development VaR, CoVaR, and delta CoVaR with crude oil [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com/terms-and-conditions)]

and h_t^S represents the conditional variances of each EESG.

Following Kroner and Sultan (1993), we estimate the optimal hedge ratios of a \$1 long position in EESG assets to be hedged with \$ β short position in conventional assets as:

$$\beta_t^{SI} = \frac{h_t^{SI}}{h_t^I} \tag{14}$$

We follow Ku et al. (2007) to evaluate the hedging effectiveness (HE) as:

$$HE = \frac{\text{Var}_{UH} - \text{Var}_H}{\text{Var}_{UH}} \tag{15}$$

where Var_{UH} indicates the variances of individual EESG assets and Var_H reflects the variance of the portfolio. The higher value of HE indicates the higher reduction of uncertainty and thereby favouring the employed portfolio strategy.

3 | DATA AND STOCHASTIC PROPERTIES

We utilize daily data from March 19, 2013 to March 31, 2021 of ethical and sustainable investment assets including MSCI Environmental, Social and Governance (MSCIWESG), FTSE4Good Index (FTSE4GLB), Dow Jones Sustainability Index (DJSIW), Dow Jones Ethical Equity Index (DJIM), S&P Green Bond Index (SPGRNSI), S&P Global Clean Energy Index

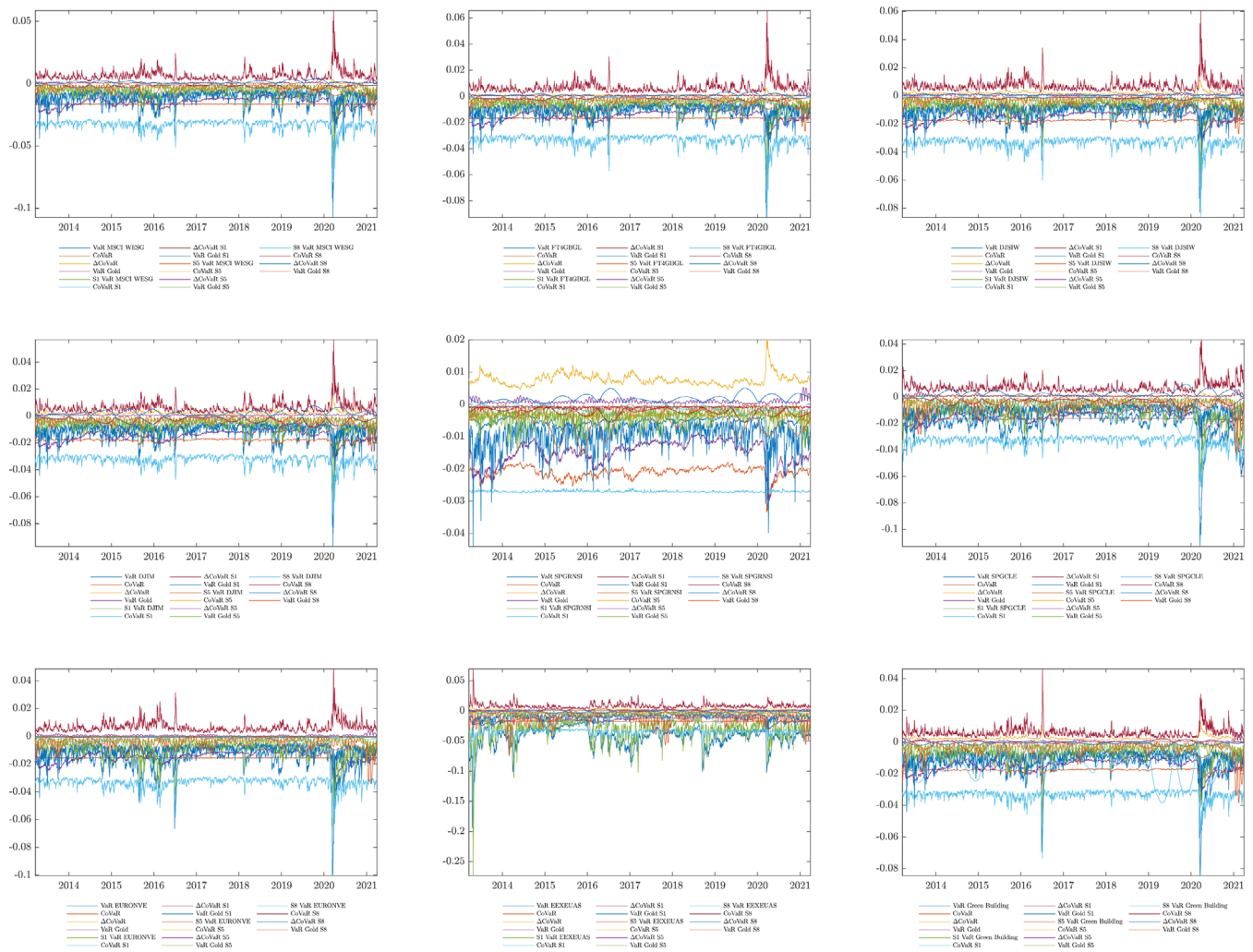


FIGURE 4 Development VaR, CoVaR, and delta CoVaR with gold [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com/terms-and-conditions)]

(SPGCLE), Vigeo Eiris (Vigeo), EU-Carbon trading–EEX-EU CO₂ Emissions (EEXEUAS), and S&P Green Building (SPGBUI). We evaluate the performance of these indices against the major financial indices (S&P 500 composite (S&P 500), STOXX Europe (STOXX), Nikkei 225 (Nikkei), Hang Seng), commodities (crude oil and gold), and exchange rate (USD to EUR). The data utilized in this study is collected from Thomson Reuters DataStream. The sample span is selected based on the data availability. For instance, the Vigeo Eiris has data available from November 2013. To evaluate the impact of COVID-19 on the investment allocation and risk management decisions, we divided the dataset into pre- and during-COVID period. This is of significant interest as to explore the dynamics of risk management and hedging potential of each ESG indexes against various major asset classes for various market participants. Figure 1 illustrates the development of price and return series for pre- and during-COVID period.

3.1 | Description of variables

The MSCI ESG Leaders (MSCIWESG) is an index of the highest Environmental, Social and Governance (ESG) rated companies in each sector of the parent index. The FTSE4Good Index (FTSE4GLB) is designed to estimate the performance of companies demonstrating ESG practices. The DJ sustainability index (DJSIW) tracks the stock performance of the world's leading companies in terms of economic, environmental, and social criteria. The DJ ethical equity index (DJIM) screens companies based on their number of Shariah (Islamic law) companies. The S&P Green Bond Index (SPGRNSI) tracks the global green bond market. The S&P Global Clean Energy Price Index (SPGCLE) provides liquid and tradable exposure to 30 companies from around the world that are involved in clean energy related businesses. The Vigeo Eiris Index stocks

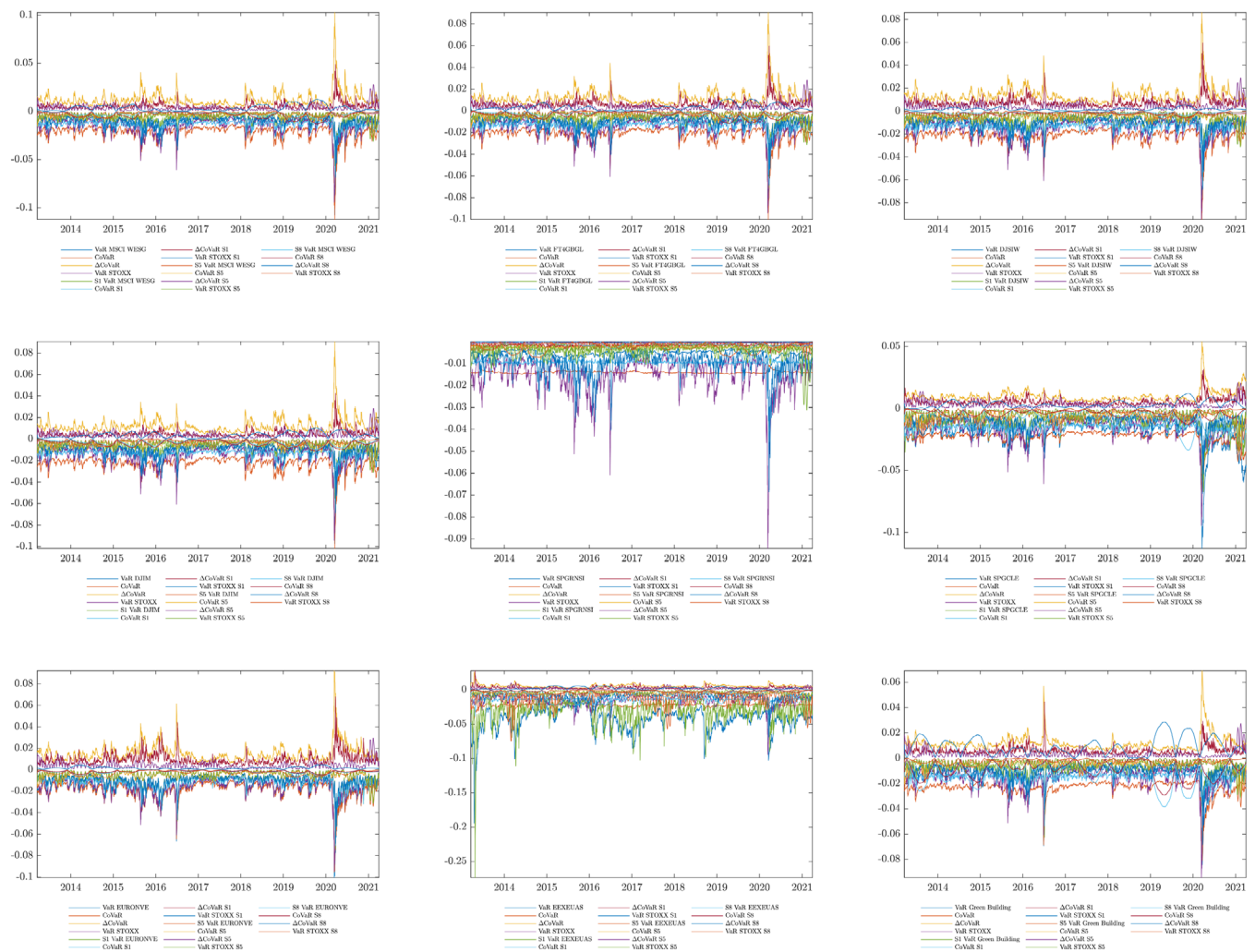


FIGURE 5 Development VaR, CoVaR, and delta CoVaR with STOXX [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com/terms-and-conditions)]

are the companies rated highest for control of corporate social responsibility risk and contribution to sustainable development. EU-Carbon trading – EEX-EU CO₂ Emissions is a cornerstone of the EU's policy to combat climate change and its key instrument for the cost-effective reduction of greenhouse gas emissions. Figure 1 shows the development of price and return series over the sample period.

3.2 | Descriptive statistics and stochastic properties

We estimate the continuously compounded return for each asset in our sample as the logarithmic difference between two consecutive prices at t and $t-1$ as $r_{i,t} = \ln(P_{i,t}/P_{i,t-1})$.³ Table 1 reports the summary statistics and stochastic properties for all the variables in our sample. The average annualized returns ranges from

–52.89% for crude oil to 30.53% for the EEXEUAS; the annualized standard deviation ranges from 124.3% for crude oil to 5.6% for SPGRNSI. In terms of reward-to-risk measure (Sharpe, 1994), crude oil (–0.434) provides the lowest reward in terms of risk taken; the S&P 500 offers the highest.⁴ The distribution of return for nearly all the assets exhibits negative skewness, except for US to EUR, and the value of kurtosis larger than 4 for all assets. Taken together, our findings indicate that all the return series demonstrate skewed and leptokurtic distributions, indicating that the distributions exhibit fat tails and are asymmetric characteristics. The formal Jarque-Bera (JB) normality test upholds the non-Gaussian pattern and strongly rejects the null of normality for all the assets in our sample. The Ljung-Box test-statistics with 23 lags on returns and squared returns are significant at the 1% threshold, indicating that both the return and squared return series are serially correlated. The ARCH test with 23 lags are significant at the 1% threshold, indicating

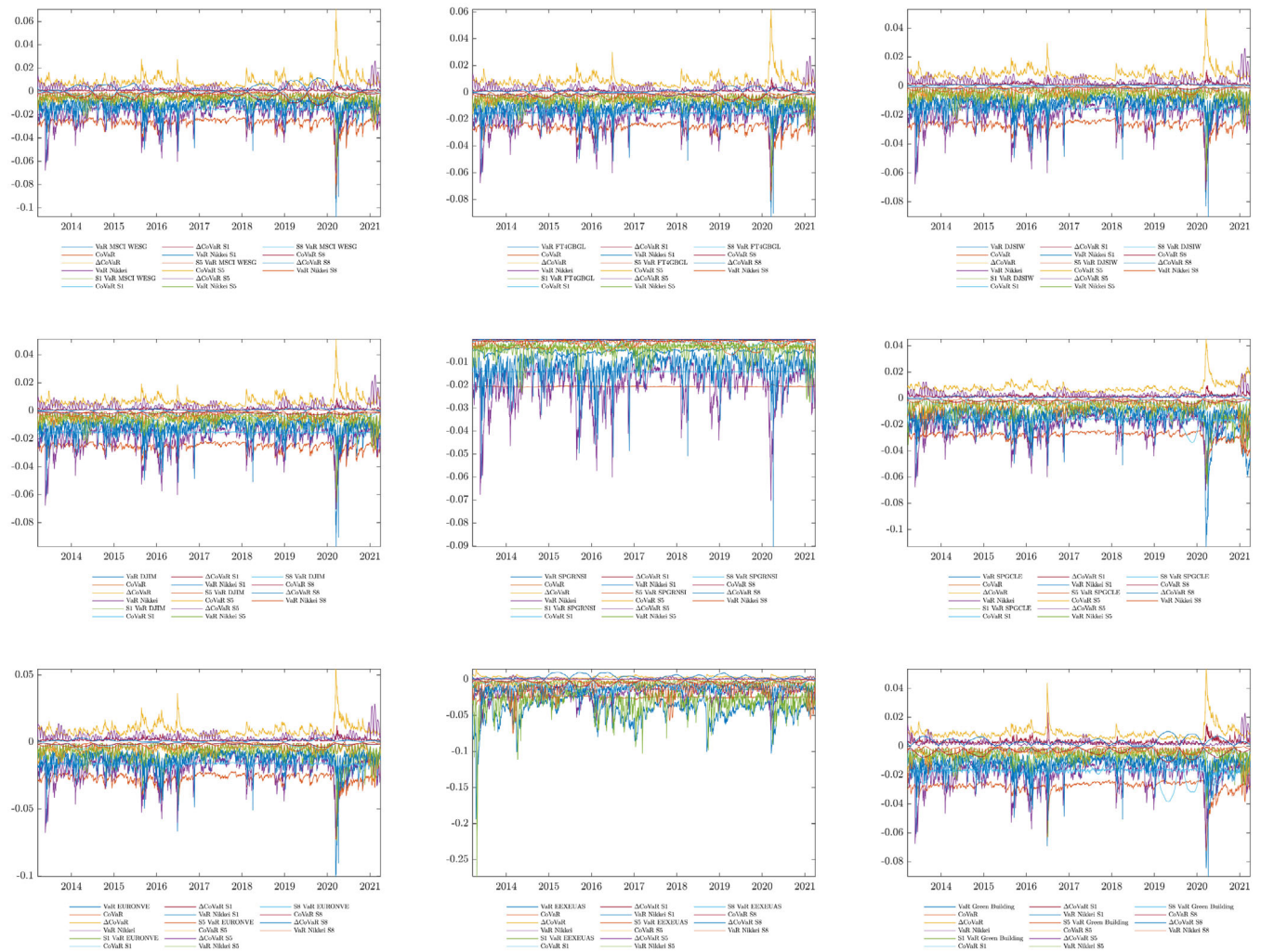


FIGURE 6 Development VaR, CoVaR, and delta CoVaR with Nikkei [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com/terms-and-conditions)]

the rejection of null-hypothesis of homoscedasticity for all commodities, thus favouring the utilization of GARCH-type framework to capture the underlying stylized facts, for instance, clustering of volatilities and time-varying dynamics.

3.3 | Empirical analysis and results

We follow a two-step procedure proposed by Joe (1998) to estimate copulas. The first step of this procedure consists of estimation of univariate marginal distribution frameworks for both the undecomposed and the decomposed return series.⁵ Based on the filtered returns from the ARMA(1,0)-EGARCH(1,1) specification, we evaluate the connectedness structure between each of the ethical, environmental, sustainable, and governance assets (EESG) with that of the major financial markets, commodities, and currencies by utilizing various symmetric

and asymmetric time-varying copula frameworks. Based on the filtered returns from the EGARCH framework, we examine the connectedness structure between the EESG in the second step of this procedure by estimating various copula frameworks.

Panels A and B of Table 2 summarizes the estimated parameters from the best-suited copula framework (time-varying Student-t copula) and the AIC values of different copula frameworks, respectively.⁶ The best-suited copula framework is selected based on the lowest AIC values (Panel B of Table 2). From Panel A, for the relationship of S&P500 with the underlying ethical and sustainable investment assets, we report significantly strong and positive connectedness for most of the underlying assets. The dependence parameter ρ is strongly significant at the 1% threshold and ranges from -6.2% to 92.3% for the SPGRNSI and MSCIWESG, respectively. Overall, the connectedness structure of EESG assets with S&P500 are characterized from weakly negative to strongly positive

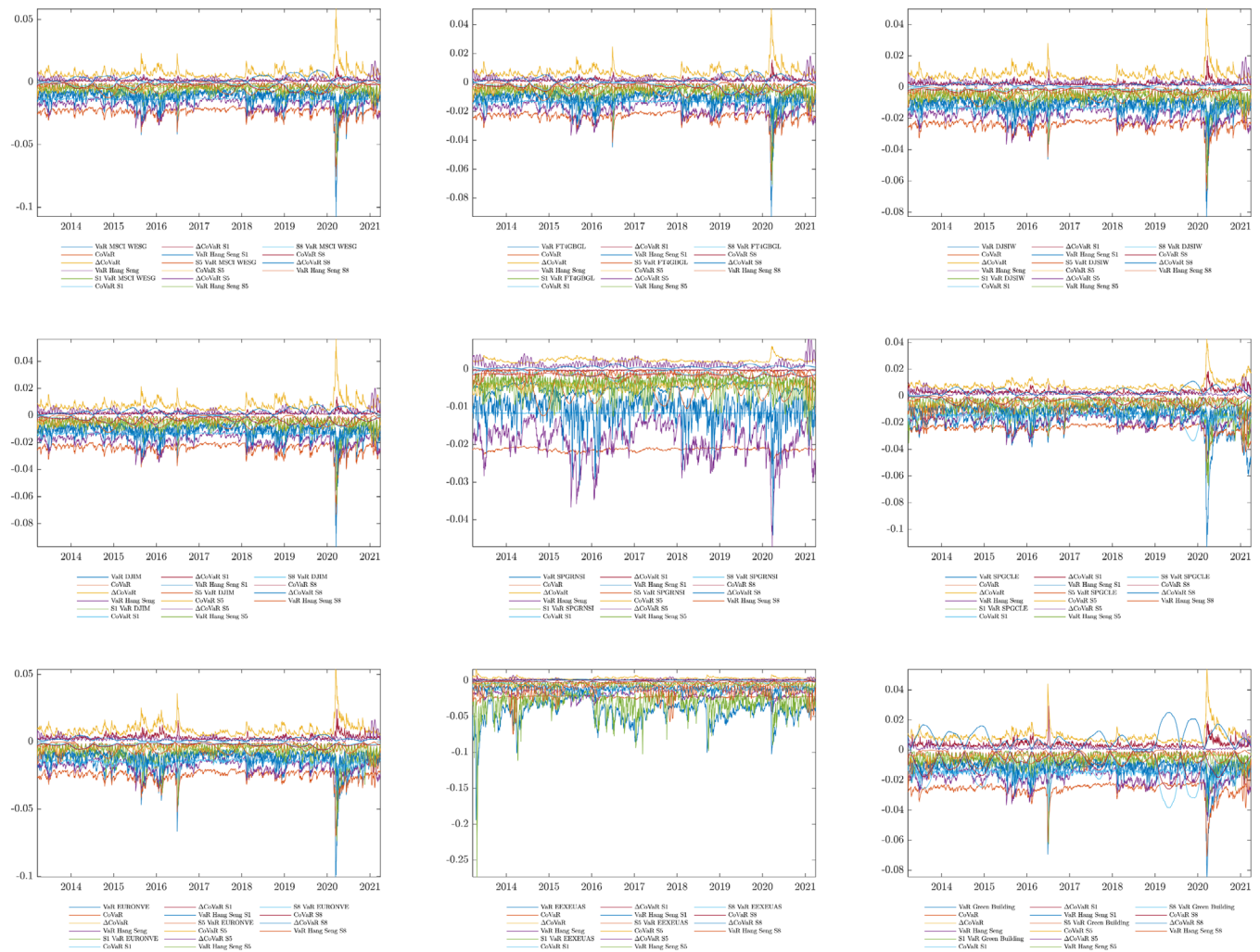


FIGURE 7 Development VaR, CoVaR, and delta CoVaR with hang Seng [Colour figure can be viewed at wileyonlinelibrary.com]

dependence. The degrees of freedom (DoF) parameters are low and strongly significant between S&P500 and for nearly all the EESG assets in our sample. This indicates the potential for joint extreme movements and tail dependence of these EESG assets with S&P500. Furthermore, the parameter capturing the asymmetric impact of positive and negative shocks on the conditional connectedness, α , is strongly significant for most of the EESG assets indicating that the negative and positive shocks exhibit an asymmetric impact on the conditional connectedness parameter. The parameter β is strongly significantly at the 1% threshold indicating that the connectedness structure is time-varying for these assets. Overall, these findings indicate that the S&P500 and the underlying EESG assets are strongly positively dependent and that there is strong information connectedness between these assets, except for SPGRNSI. Similar results are reported in Panel D (STOXX), Panel E (Nikkei), and Panel F (Hang Seng). This indicate that the

underlying EESG assets behaves in a similar fashion with other developed financial markets.

In contrast to the financial markets, the copula estimates between crude oil and EESG assets indicate significant weak to moderately positive connectedness structure. Specifically, the dependence parameter varies from 1.6% to 27.4% for the SPGRNSI and DJIM, respectively. The DoF parameters are significant for nearly all the underlying EESG assets indicating the flow of extreme co-movements for these assets. Whereas, for some of the EESG assets, the parameter is high and significant indicating that the Student-t distribution converges to the standard normal distribution. The parameter α is significant for most of the EESG assets indicating the asymmetric impact of positive and negative shocks on the conditional dependence. The parameter β is strongly significant at the 1% threshold for all the EESG assets suggesting that the time-varying connectedness structure for these assets. In general, the weak negative to moderately



FIGURE 8 Development VaR, CoVaR, and delta CoVaR with US to EURO [Colour figure can be viewed at wileyonlinelibrary.com]

positive connectedness structure between crude oil and the underlying EESG assets indicate the potential to attain risk management and diversification benefits.

From the copula between gold and the underlying EESG assets, we observe weak negative and statistically significant dependence structure for most of the assets. The level of dependence varies from -17.7% to 49.0% for Vigeo and SPGRNSI, respectively. However, the DoF parameters are small and significant for all the underlying EESG assets indicating the strong potential for extreme co-movements among the assets. In addition, the parameters α and β are significant for all the assets, suggesting asymmetric impact of positive and negative shocks and time-varying conditional connectedness pattern. Similarly, for the copula between exchange rate (US2EUR) and underlying EESG assets, we report weak negative (-13.3% for Vigeo) to strong positive dependence (86.4% for SPGRNSI). The DoF, α , and β parameters are all significant for all the EESG assets

indicating potential for tail dependence, asymmetric shocks, and persistency in conditional dependence among the assets.

In general, estimation of copula frameworks indicate evidence of weak negative to strong positive connectedness among the assets the undecomposed series. Specifically, the EESG assets exhibit strong positive co-movement with the four major financial indices (S&P500, STOXX, Nikkei, and Hang Seng), with exception of S&P Green Bond which demonstrate neutral to weak negative dependence with the four financial indices. Regarding commodities and exchange rate, we observe primarily weak negative to weak positive connectedness among the assets. This may primarily be attributed to the significant increase in investments in the EESG assets in recent years. Over the last decade, the issuance of sustainable debt has shown exponential growth, increased by more than 9200% from \$5 billion in 2012 to \$465

billion in 2019 (Rutigliano, 2020), leading investors to divert their resources from traditional conventional indexes to more sustainable investment. These findings are in accordance with Abu-Alkheil et al.

(2017), Dewandaru et al. (2014), Mensi et al. (2015), and Yilmaz et al. (2015) who reported an increased dependence between the financial and Islamic indexes.

TABLE 9 Statistics of unhedged and hedged portfolios for return series for pre-COVID

		Portfolio Hedge Hedging			Std dev		Skewness		Kurtosis	
		Weight	Ratio	Effectiveness	Hedged	Unhedged	Hedged	Unhedged	Hedged	Unhedged
Panel A: S&P500	MSCI World ESG	0.907	0.774	0.012	0.007	0.007	-0.764	-0.757	6.810	6.938
	FTSE Good Global	0.750	0.748	0.055	0.007	0.007	-0.684	-0.840	6.183	8.262
	DJSI World	0.598	0.733	0.129	0.007	0.007	-0.644	-0.818	5.934	9.024
	DJ Islamic	0.829	0.792	0.028	0.007	0.007	-0.699	-0.669	6.274	6.223
	S&P Green Bond	0.795	-0.034	0.238	0.003	0.003	-0.594	-0.329	7.746	5.858
	S&P Clean Energy	0.224	0.779	0.515	0.007	0.010	-0.476	-0.216	5.765	4.893
	Euronext Vigeo	0.358	0.667	0.366	0.007	0.009	-0.668	-0.739	6.006	9.427
	EEX-EU CO2	0.081	0.374	0.891	0.008	0.032	-0.625	-1.705	5.859	28.953
	S&P Green Build	0.471	0.572	0.300	0.006	0.008	-0.813	-2.362	7.453	35.454
Panel B: Crude oil	MSCI World ESG	0.961	0.083	0.019	0.006	0.007	-0.619	-0.757	7.791	6.938
	FTSE Good Global	0.959	0.085	0.019	0.007	0.007	-0.749	-0.840	8.490	8.262
	DJSI World	0.955	0.093	0.021	0.007	0.007	-0.757	-0.818	9.144	9.024
	DJ Islamic	0.963	0.091	0.017	0.007	0.007	-0.604	-0.669	6.593	6.223
	S&P Green Bond	0.975	0.003	0.024	0.003	0.003	-0.329	-0.329	5.905	5.858
	S&P Clean Energy	0.844	0.120	0.102	0.010	0.010	-0.261	-0.216	5.358	4.893
	Euronext Vigeo	0.879	0.077	0.084	0.009	0.009	-0.535	-0.739	10.142	9.427
	EEX-EU CO2	0.362	0.284	0.549	0.017	0.032	0.096	-1.705	7.504	28.953
	S&P Green Build	0.908	0.064	0.059	0.007	0.008	-2.024	-2.362	30.690	35.454
Panel C: Gold	MSCI World ESG	0.722	0.189	0.190	0.006	0.007	-0.517	-0.757	7.376	6.938
	FTSE Good Global	0.700	0.195	0.206	0.006	0.007	-0.522	-0.840	7.478	8.262
	DJSI World	0.670	0.211	0.228	0.006	0.007	-0.535	-0.818	7.418	9.024
	DJ Islamic	0.706	0.209	0.198	0.006	0.007	-0.531	-0.669	7.655	6.223
	S&P Green Bond	0.890	0.006	0.107	0.003	0.003	-0.288	-0.329	6.239	5.858
	S&P Clean Energy	0.428	0.280	0.456	0.008	0.010	-0.625	-0.216	10.031	4.893
	Euronext Vigeo	0.542	0.180	0.383	0.007	0.009	-0.550	-0.739	8.959	9.427
	EEX-EU CO2	0.077	0.616	0.858	0.009	0.032	-0.843	-1.705	14.890	28.953
	S&P Green Build	0.618	0.143	0.310	0.006	0.008	-0.623	-2.362	9.632	35.454
Panel D: STOXX	MSCI World ESG	0.679	0.196	0.217	0.006	0.007	-0.737	-0.757	7.018	6.938
	FTSE Good Global	0.649	0.204	0.244	0.006	0.007	-0.837	-0.840	8.447	8.262
	DJSI World	0.611	0.223	0.273	0.006	0.007	-0.826	-0.818	9.055	9.024
	DJ Islamic	0.655	0.220	0.233	0.006	0.007	-0.710	-0.669	6.533	6.223
	S&P Green Bond	0.845	0.007	0.151	0.003	0.003	-0.509	-0.329	8.245	5.858
	S&P Clean Energy	0.359	0.308	0.526	0.007	0.010	-0.549	-0.216	7.344	4.893
	Euronext Vigeo	0.475	0.176	0.440	0.007	0.009	-0.633	-0.739	8.524	9.427
	EEX-EU CO2	0.080	0.757	0.862	0.008	0.032	-0.712	-1.705	8.476	28.953
	S&P Green Build	0.549	0.154	0.377	0.006	0.008	-1.507	-2.362	20.042	35.454

(Continues)

TABLE 9 (Continued)

		Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis	
Panel E: Nikkei	MSCI World ESG	0.837	0.140	0.096	0.006	0.007	-0.922	-0.757	7.435	6.938
	FTSE Good Global	0.817	0.146	0.111	0.006	0.007	-1.043	-0.840	9.048	8.262
	DJSI World	0.792	0.160	0.128	0.007	0.007	-1.065	-0.818	10.305	9.024
	DJ Islamic	0.821	0.158	0.105	0.006	0.007	-0.876	-0.669	6.944	6.223
	S&P Green Bond	0.916	0.005	0.081	0.003	0.003	-0.397	-0.329	6.428	5.858
	S&P Clean Energy	0.567	0.217	0.328	0.009	0.010	-0.698	-0.216	7.564	4.893
	Euronext Vigeo	0.666	0.127	0.266	0.008	0.009	-1.007	-0.739	11.578	9.427
	EEX-EU CO2	0.144	0.516	0.782	0.012	0.032	-0.841	-1.705	8.543	28.953
	S&P Green Build	0.726	0.109	0.214	0.007	0.008	-2.259	-2.362	31.993	35.454
Panel F: Hang Seng	MSCI World ESG	0.795	0.157	0.127	0.006	0.007	-0.888	-0.757	8.219	6.938
	FTSE Good Global	0.777	0.162	0.139	0.006	0.007	-0.855	-0.840	8.195	8.262
	DJSI World	0.750	0.178	0.158	0.007	0.007	-0.783	-0.818	7.638	9.024
	DJ Islamic	0.786	0.173	0.128	0.006	0.007	-0.773	-0.669	7.316	6.223
	S&P Green Bond	0.909	0.006	0.088	0.003	0.003	-0.398	-0.329	6.443	5.858
	S&P Clean Energy	0.504	0.238	0.382	0.008	0.010	-0.339	-0.216	5.258	4.893
	Euronext Vigeo	0.614	0.147	0.312	0.007	0.009	-0.678	-0.739	7.223	9.427
	EEX-EU CO2	0.111	0.563	0.820	0.010	0.032	-0.322	-1.705	4.777	28.953
	S&P Green Build	0.683	0.123	0.250	0.007	0.008	-1.095	-2.362	11.993	35.454
Panel G: US to EUR	MSCI World ESG	0.347	0.385	0.536	0.004	0.007	-0.453	-0.757	7.740	6.938
	FTSE Good Global	0.315	0.397	0.568	0.004	0.007	-0.269	-0.840	6.704	8.262
	DJSI World	0.274	0.429	0.604	0.004	0.007	-0.128	-0.818	5.922	9.024
	DJ Islamic	0.322	0.428	0.552	0.004	0.007	-0.300	-0.669	6.225	6.223
	S&P Green Bond	0.664	0.012	0.329	0.003	0.003	-0.189	-0.329	5.205	5.858
	S&P Clean Energy	0.114	0.557	0.793	0.005	0.010	0.005	-0.216	5.214	4.893
	Euronext Vigeo	0.212	0.361	0.719	0.004	0.009	-0.056	-0.739	6.187	9.427
	EEX-EU CO2	0.018	1.302	0.952	0.005	0.032	0.017	-1.705	5.371	28.953
	S&P Green Build	0.253	0.292	0.674	0.004	0.008	-0.156	-2.362	6.145	35.454

Note: This table reports the summary statistics of the unhedged and hedged portfolio. Weights are estimated using Equation 10 and indicate the proportion of investment in the ESG and conventional assets. The hedge ratio (HR) is estimated using Equation 14 and reflect the β to be long/short in the ESG. Hedging effectiveness (HE) is calculated by utilizing Equation 15 and indicate the performance of hedged portfolio over the unhedged portfolio.

3.4 | VaR, CoVaR and delta CoVaR

Based on the time-varying Student-t copula framework, the optimal framework, we estimate the VaR, CoVaR, and Δ CoVaR for each of the underlying series in our dataset. In addition, we provide the robustness checks for these measures over various investment horizons. Given heterogeneous investor's behaviour and time-horizon of investment, we transform the return series into the short-, medium-, and long-term horizons that correspond to variations over 2–4 days, 32–64 days, and 256–512 days, respectively. We then estimate the VaR, CoVaR, and Δ CoVaR for each subsequent wavelet.

Tables 3 and 4 provides the summary statistics of the VaR estimates for various investment horizons for the pre- and during-COVID period, respectively. Estimations of VaR for the undecomposed return series indicate that the EESG assets, in general, provide lower risk for the undertaken investment. The mean daily VaR of EESG assets ranges from -0.52% to -4.37% and -0.61% to -4.57% for SPGRNSI and EEXEUAS for the pre- and during-COVID, respectively. Whereas, the average VaR of the conventional assets ranges from -0.783% to -3.34% and -0.73% to -13.94% for US2EUR and crude oil for the pre- and during-COVID subsamples, respectively. This may be attributed to the investors' sentiments

and trust in the management of the organization in abstaining from the unethical practices and towards a sustainable growth model. For example, over the post-crisis period, the investments in ethical and

sustainable assets have substantially increased (GSIA, 2018), indicating a diversion of resources and investment towards heterogeneous operations and services offer by EESG and ethical assets. The mean

TABLE 10 Statistics of unhedged and hedged portfolios for return series for during-COVID

		Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis	
		Weight	Ratio	Effectiveness	Hedged	Unhedged	Hedged	Unhedged	Hedged	Unhedged
Panel A: S&P500	MSCI World ESG	0.974	0.755	0.004	0.011	0.016	-1.217	-1.216	14.670	14.676
	FTSE Good Global	0.926	0.755	0.008	0.011	0.016	-1.284	-1.310	14.661	14.945
	DJSI World	0.868	0.676	0.031	0.010	0.015	-1.443	-1.474	15.412	15.926
	DJ Islamic	0.859	0.777	0.024	0.011	0.016	-1.133	-1.123	13.241	13.353
	S&P Green Bond	0.863	-0.006	0.153	0.004	0.005	-1.294	-1.178	13.539	12.864
	S&P Clean Energy	0.154	0.993	0.591	0.012	0.026	-1.512	-0.866	14.525	7.661
	Euronext Vigeo	0.430	0.620	0.320	0.011	0.018	-1.969	-1.631	17.885	16.220
	EEX-EU CO2	0.096	0.795	0.814	0.012	0.031	-1.905	-0.431	18.956	7.414
	S&P Green Build	0.481	0.556	0.291	0.010	0.019	-1.664	-1.132	17.398	14.193
Panel B: Crude oil	MSCI World ESG	0.952	0.096	0.023	0.011	0.016	-2.835	-1.216	20.262	14.676
	FTSE Good Global	0.957	0.097	0.019	0.011	0.016	-3.141	-1.310	23.018	14.945
	DJSI World	0.967	0.094	0.013	0.010	0.015	-2.881	-1.474	20.794	15.926
	DJ Islamic	0.946	0.100	0.027	0.011	0.016	-2.456	-1.123	17.227	13.353
	S&P Green Bond	0.982	0.002	0.020	0.004	0.005	-2.765	-1.178	24.375	12.864
	S&P Clean Energy	0.724	0.178	0.192	0.018	0.026	-4.035	-0.866	35.336	7.661
	Euronext Vigeo	0.893	0.108	0.060	0.013	0.018	-4.946	-1.631	47.767	16.220
	EEX-EU CO2	0.479	0.273	0.415	0.023	0.031	-12.765	-0.431	204.122	7.414
	S&P Green Build	0.923	0.079	0.042	0.012	0.019	-7.689	-1.132	98.087	14.193
Panel C: Gold	MSCI World ESG	0.670	0.252	0.240	0.008	0.016	0.038	-1.216	10.652	14.676
	FTSE Good Global	0.657	0.254	0.247	0.008	0.016	-0.013	-1.310	10.253	14.945
	DJSI World	0.681	0.241	0.220	0.008	0.015	0.026	-1.474	10.669	15.926
	DJ Islamic	0.642	0.258	0.259	0.008	0.016	-0.008	-1.123	9.717	13.353
	S&P Green Bond	0.913	0.004	0.086	0.004	0.005	-1.063	-1.178	11.225	12.864
	S&P Clean Energy	0.273	0.431	0.604	0.011	0.026	-0.029	-0.866	6.790	7.661
	Euronext Vigeo	0.512	0.273	0.387	0.009	0.018	0.162	-1.631	9.370	16.220
	EEX-EU CO2	0.074	0.645	0.826	0.012	0.031	-0.160	-0.431	6.846	7.414
	S&P Green Build	0.569	0.206	0.343	0.009	0.019	0.350	-1.132	9.753	14.193
Panel D: STOXX	MSCI World ESG	0.614	0.232	0.269	0.009	0.016	-1.673	-1.216	16.702	14.676
	FTSE Good Global	0.598	0.239	0.282	0.009	0.016	-1.648	-1.310	16.454	14.945
	DJSI World	0.625	0.231	0.256	0.009	0.015	-1.657	-1.474	16.499	15.926
	DJ Islamic	0.585	0.248	0.295	0.009	0.016	-1.586	-1.123	15.960	13.353
	S&P Green Bond	0.879	0.005	0.120	0.004	0.005	-1.517	-1.178	14.758	12.864
	S&P Clean Energy	0.217	0.471	0.661	0.011	0.026	-1.855	-0.866	16.507	7.661
	Euronext Vigeo	0.423	0.258	0.460	0.010	0.018	-1.750	-1.631	17.029	16.220
	EEX-EU CO2	0.071	0.752	0.840	0.011	0.031	-1.713	-0.431	15.795	7.414
	S&P Green Build	0.494	0.210	0.413	0.009	0.019	-1.566	-1.132	16.907	14.193

(Continues)

TABLE 10 (Continued)

		Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis	
Panel E: Nikkei	MSCI World ESG	0.685	0.215	0.214	0.009	0.016	-0.283	-1.216	11.282	14.676
	FTSE Good Global	0.672	0.220	0.222	0.009	0.016	-0.368	-1.310	11.380	14.945
	DJSI World	0.694	0.213	0.202	0.009	0.015	-0.653	-1.474	13.132	15.926
	DJ Islamic	0.664	0.224	0.230	0.009	0.016	-0.351	-1.123	10.779	13.353
	S&P Green Bond	0.910	0.005	0.089	0.004	0.005	-1.320	-1.178	11.845	12.864
	S&P Clean Energy	0.270	0.417	0.605	0.012	0.026	-0.492	-0.866	9.588	7.661
	Euronext Vigeo	0.507	0.244	0.385	0.010	0.018	-0.418	-1.631	10.821	16.220
	EEX-EU CO2	0.099	0.647	0.802	0.013	0.031	-0.654	-0.431	11.562	7.414
	S&P Green Build	0.567	0.193	0.347	0.009	0.019	-0.760	-1.132	13.730	14.193
Panel F: Hang Seng	MSCI World ESG	0.677	0.230	0.227	0.008	0.016	-0.616	-1.216	7.382	14.676
	FTSE Good Global	0.665	0.233	0.233	0.008	0.016	-0.619	-1.310	7.060	14.945
	DJSI World	0.686	0.223	0.211	0.008	0.015	-0.713	-1.474	7.545	15.926
	DJ Islamic	0.656	0.236	0.241	0.009	0.016	-0.609	-1.123	6.701	13.353
	S&P Green Bond	0.915	0.004	0.084	0.004	0.005	-1.347	-1.178	12.635	12.864
	S&P Clean Energy	0.270	0.423	0.605	0.011	0.026	-0.509	-0.866	5.141	7.661
	Euronext Vigeo	0.507	0.255	0.387	0.010	0.018	-0.367	-1.631	5.771	16.220
	EEX-EU CO2	0.084	0.637	0.814	0.012	0.031	-0.609	-0.431	5.576	7.414
	S&P Green Build	0.564	0.198	0.347	0.009	0.019	-0.477	-1.132	7.073	14.193
Panel G: US to EUR	MSCI World ESG	0.179	0.702	0.712	0.004	0.016	-0.308	-1.216	5.196	14.676
	FTSE Good Global	0.157	0.707	0.734	0.004	0.016	-0.259	-1.310	4.737	14.945
	DJSI World	0.157	0.669	0.730	0.004	0.015	-0.245	-1.474	4.786	15.926
	DJ Islamic	0.152	0.717	0.740	0.004	0.016	-0.433	-1.123	5.460	13.353
	S&P Green Bond	0.576	0.010	0.418	0.003	0.005	-0.374	-1.178	7.169	12.864
	S&P Clean Energy	0.012	1.204	0.931	0.004	0.026	-0.002	-0.866	4.434	7.661
	Euronext Vigeo	0.079	0.762	0.847	0.004	0.018	-0.073	-1.631	4.439	16.220
	EEX-EU CO2	0.000	1.791	0.977	0.004	0.031	0.019	-0.431	4.412	7.414
	S&P Green Build	0.113	0.570	0.815	0.004	0.019	-0.020	-1.132	4.498	14.193

Note: This table reports the summary statistics of the unhedged and hedged portfolio. Weights are estimated using Equation 10 and indicate the proportion of investment in the ESG and conventional assets. The hedge ratio (HR) is estimated using Equation 14 and reflect the β to be long/short in the ESG. Hedging effectiveness (HE) is calculated by utilizing Equation 15 and indicate the performance of hedged portfolio over the unhedged portfolio.

VaR of the short-run trend follows the similar structure as that of the undecomposed return series for both the pre- and during-COVID subsamples. Like the undecomposed series, the VaR estimates of the EESG assets are lower than the traditional financial indices. It is noteworthy that the VaR has significantly reduced over the short-run trend for both subsamples. The VaR structure for the medium-run trend closely follows the undecomposed and short-run trend for both subsamples. However, in the long run, the mean VaR of the traditional financial indexes are lower than the EESG assets indicating a

lower risk for the investment in the traditional assets over the long-term horizon for both subsamples.

The VaR provides an estimate of the maximum expected loss of an asset, given a tail probability. Therefore, we utilize the CoVaR and ΔCoVaR to evaluate how the systemic risk of an EESG asset depends on some extreme event of conventional assets. In addition, the preferences of the investors tend to differ over frequency horizons (represented by frequencies), indicating their preferences for a particular frequency. Therefore, to capture the heterogeneity of investment patterns caused by economic shocks, we estimate the CoVaR and ΔCoVaR

for short-, medium-, and long-term trends. This process allows us to capture diverse trading horizons due to stock market fluctuations and cycles of different lengths. Therefore, a shock with a stronger short-term (long-term)

impact is expected to exhibit higher power in high (low) frequency, indicating short-term (long-term) systemic connectedness when transmitted to other assets. For instance, a permanent variation in the expectation of an

TABLE 11 Statistics of unhedged and hedged portfolios for short-run trend for pre-COVID

		Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis	
		Weight	Ratio	Effectiveness	Hedged	Unhedged	Hedged	Unhedged	Hedged	Unhedged
Panel A: S&P500	MSCI World ESG	0.868	0.730	0.031	0.003	0.004	-0.057	-0.042	5.299	5.425
	FTSE Good Global	0.740	0.672	0.090	0.003	0.004	-0.088	-0.147	5.064	6.188
	DJSI World	0.625	0.640	0.169	0.003	0.005	-0.095	-0.185	4.705	6.446
	DJ Islamic	0.822	0.740	0.042	0.003	0.004	-0.102	-0.106	5.295	5.230
	S&P Green Bond	0.784	-0.058	0.291	0.001	0.002	0.133	0.068	5.290	4.278
	S&P Clean Energy	0.330	0.625	0.470	0.004	0.007	-0.074	-0.033	4.806	4.198
	Euronext Vigeo	0.408	0.520	0.405	0.004	0.006	0.009	-0.120	4.636	7.583
	EEX-EU CO2	0.089	0.415	0.886	0.004	0.022	-0.004	0.423	5.979	11.732
	S&P Green Build	0.529	0.440	0.313	0.003	0.005	-0.045	-0.010	6.009	17.215
Panel B: Crude oil	MSCI World ESG	0.941	0.089	0.054	0.003	0.004	-0.063	-0.042	5.550	5.425
	FTSE Good Global	0.937	0.085	0.060	0.003	0.004	-0.149	-0.147	6.739	6.188
	DJSI World	0.928	0.089	0.069	0.004	0.005	-0.166	-0.185	7.111	6.446
	DJ Islamic	0.943	0.099	0.046	0.003	0.004	-0.078	-0.106	5.156	5.230
	S&P Green Bond	0.961	-0.002	0.081	0.002	0.002	0.035	0.068	4.461	4.278
	S&P Clean Energy	0.822	0.112	0.144	0.005	0.007	0.089	-0.033	4.973	4.198
	Euronext Vigeo	0.851	0.072	0.145	0.004	0.006	0.301	-0.120	11.616	7.583
	EEX-EU CO2	0.364	0.336	0.551	0.009	0.022	0.060	0.423	6.186	11.732
	S&P Green Build	0.889	0.058	0.109	0.004	0.005	-0.256	-0.010	12.527	17.215
Panel C: Gold	MSCI World ESG	0.665	-0.095	0.404	0.002	0.004	-0.073	-0.042	4.297	5.425
	FTSE Good Global	0.669	-0.016	0.353	0.003	0.004	-0.069	-0.147	4.758	6.188
	DJSI World	0.645	-0.001	0.369	0.003	0.005	-0.020	-0.185	4.607	6.446
	DJ Islamic	0.669	-0.016	0.351	0.003	0.004	-0.059	-0.106	4.833	5.230
	S&P Green Bond	0.962	0.155	0.031	0.002	0.002	0.024	0.068	4.363	4.278
	S&P Clean Energy	0.481	0.029	0.509	0.003	0.007	-0.074	-0.033	4.570	4.198
	Euronext Vigeo	0.530	-0.154	0.542	0.003	0.006	0.060	-0.120	4.325	7.583
	EEX-EU CO2	0.138	-0.191	0.879	0.004	0.022	0.088	0.423	4.842	11.732
	S&P Green Build	0.624	0.066	0.357	0.003	0.005	0.016	-0.010	6.108	17.215
Panel D: STOXX	MSCI World ESG	0.806	0.497	0.080	0.003	0.004	0.053	-0.042	5.684	5.425
	FTSE Good Global	0.786	0.530	0.086	0.003	0.004	-0.124	-0.147	6.643	6.188
	DJSI World	0.762	0.607	0.090	0.004	0.005	-0.167	-0.185	7.022	6.446
	DJ Islamic	0.745	0.450	0.123	0.003	0.004	0.006	-0.106	5.097	5.230
	S&P Green Bond	0.814	-0.069	0.300	0.001	0.002	0.099	0.068	5.003	4.278
	S&P Clean Energy	0.407	0.510	0.414	0.004	0.007	-0.105	-0.033	5.437	4.198
	Euronext Vigeo	0.434	0.982	0.112	0.005	0.006	-0.078	-0.120	7.522	7.583
	EEX-EU CO2	0.096	0.666	0.860	0.004	0.022	-0.001	0.423	7.098	11.732
	S&P Green Build	0.625	0.466	0.217	0.003	0.005	-0.374	-0.010	10.266	17.215

(Continues)

TABLE 11 (Continued)

		Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis	
Panel E: Nikkei	MSCI World ESG	0.777	0.061	0.213	0.003	0.004	-0.142	-0.042	7.764	5.425
	FTSE Good Global	0.769	0.070	0.216	0.003	0.004	-0.233	-0.147	9.433	6.188
	DJSI World	0.739	0.062	0.249	0.003	0.005	-0.200	-0.185	9.686	6.446
	DJ Islamic	0.756	0.039	0.247	0.003	0.004	-0.197	-0.106	7.617	5.230
	S&P Green Bond	0.902	-0.001	0.137	0.002	0.002	-0.074	0.068	5.033	4.278
	S&P Clean Energy	0.583	0.107	0.381	0.004	0.007	-0.158	-0.033	6.465	4.198
	Euronext Vigeo	0.632	0.073	0.348	0.004	0.006	-0.085	-0.120	10.609	7.583
	EEX-EU CO2	0.183	0.026	0.815	0.005	0.022	0.053	0.423	7.333	11.732
S&P Green Build	0.728	0.116	0.237	0.003	0.005	0.635	-0.010	19.941	17.215	
Panel F: Hang Seng	MSCI World ESG	0.767	0.123	0.186	0.003	0.004	-0.087	-0.042	5.357	5.425
	FTSE Good Global	0.767	0.150	0.178	0.003	0.004	-0.114	-0.147	4.948	6.188
	DJSI World	0.742	0.176	0.191	0.003	0.005	-0.069	-0.185	4.932	6.446
	DJ Islamic	0.762	0.142	0.185	0.003	0.004	-0.145	-0.106	5.093	5.230
	S&P Green Bond	0.895	-0.006	0.150	0.002	0.002	0.083	0.068	4.502	4.278
	S&P Clean Energy	0.546	0.283	0.339	0.004	0.007	-0.066	-0.033	4.566	4.198
	Euronext Vigeo	0.611	0.248	0.291	0.004	0.006	-0.078	-0.120	5.625	7.583
	EEX-EU CO2	0.141	0.184	0.837	0.005	0.022	-0.086	0.423	4.355	11.732
S&P Green Build	0.728	0.227	0.195	0.003	0.005	-0.033	-0.010	4.888	17.215	
Panel G: US to EUR	MSCI World ESG	0.399	-0.115	0.635	0.002	0.004	0.018	-0.042	6.157	5.425
	FTSE Good Global	0.359	0.243	0.564	0.002	0.004	-0.006	-0.147	5.239	6.188
	DJSI World	0.309	0.331	0.590	0.002	0.005	0.045	-0.185	5.041	6.446
	DJ Islamic	0.375	0.134	0.582	0.002	0.004	0.039	-0.106	5.226	5.230
	S&P Green Bond	0.912	0.615	0.026	0.002	0.002	0.052	0.068	4.174	4.278
	S&P Clean Energy	0.186	0.242	0.768	0.002	0.007	0.051	-0.033	4.769	4.198
	Euronext Vigeo	0.270	-0.256	0.775	0.002	0.006	0.002	-0.120	5.396	7.583
	EEX-EU CO2	0.045	-0.002	0.957	0.002	0.022	0.148	0.423	4.761	11.732
S&P Green Build	0.276	0.335	0.634	0.002	0.005	0.063	-0.010	4.734	17.215	

Note: See notes Table 6.

investor regarding the soundness of an individual underlying asset may be better reflected by the long-term systemic risk and connectedness structure than by short-term ones. In accordance with the theoretical assertion, Bandi and Tamoni (2017), Baruník and Křehlík (2018), and Cogley (2001) argue that the time-preferences of investors' consumption and the resultant consumption growth have distinct cyclical components that produce shocks with heterogeneous frequency responses.

Tables 5 and 6 reports the descriptive statistics of the CoVaR estimates for various investment horizons for the pre- and during-COVID subsamples, respectively. For the undecomposed series over both subsamples, the mean CoVaR for the EESG and the financial indices are significantly higher than they are for the commodity and

forex markets. This is because the EESG assets exhibit homogeneous properties to those of the financial indices and heterogeneous characteristics with the commodity and forex market. Furthermore, it implies that these financial indices are more sensitive to uncertainty shocks from the EESG assets, indicating a seismic change in the investment principles of the market participants towards a more positive kind of EESG investing. However, the highest CoVaR estimates are observed for crude oil over both subsamples. For the pre-COVID period, it can be argued that the crude oil exhibit unfavorability towards sustainability, resulting an increased estimates of CoVaR. Whereas, for the latter subsample, the significant decline in crude oil futures prices to subzero level during the pandemic led to a significantly higher estimates of

CoVaR. The CoVaR between gold and EESG assets indicates significantly lower CoVaR estimates over both subsamples. This may be attributed to the flight-to-safety

phenomenon, indicating that the market participants are embedding the EESG-related uncertainties with a safer asset. In contrast, the lowest estimates of CoVaR are

TABLE 12 Statistics of unhedged and hedged portfolios for short-run trend during-COVID period

		Portfolio Hedge Hedging			Std dev		Skewness		Kurtosis	
		Weight	Ratio	Effectiveness	Hedged	Unhedged	Hedged	Unhedged	Hedged	Unhedged
Panel A: S&P500	MSCI World ESG	0.926	0.718	0.019	0.006	0.013	-0.282	-0.260	16.200	16.103
	FTSE Good Global	0.858	0.664	0.043	0.005	0.013	-0.215	-0.188	15.807	15.763
	DJSI World	0.827	0.562	0.068	0.005	0.012	-0.074	-0.038	16.017	15.890
	DJ Islamic	0.804	0.752	0.058	0.006	0.013	-0.282	-0.274	14.696	14.539
	S&P Green Bond	0.866	-0.025	0.210	0.002	0.003	0.445	-0.033	7.244	4.571
	S&P Clean Energy	0.293	0.786	0.509	0.006	0.018	-0.419	0.234	14.693	8.983
	Euronext Vigeo	0.466	0.488	0.379	0.005	0.013	0.380	0.722	12.387	10.482
	EEX-EU CO2	0.133	0.605	0.810	0.006	0.023	-0.044	-0.014	7.289	5.009
	S&P Green Build	0.638	0.393	0.237	0.005	0.011	0.158	0.072	12.980	10.445
Panel B: Crude oil	MSCI World ESG	0.920	0.098	0.073	0.005	0.013	-0.291	-0.260	14.196	16.103
	FTSE Good Global	0.924	0.098	0.071	0.005	0.013	0.014	-0.188	13.866	15.763
	DJSI World	0.929	0.091	0.068	0.005	0.012	0.072	-0.038	14.638	15.890
	DJ Islamic	0.916	0.111	0.070	0.005	0.013	-0.338	-0.274	12.796	14.539
	S&P Green Bond	0.971	0.000	0.071	0.002	0.003	0.248	-0.033	4.603	4.571
	S&P Clean Energy	0.721	0.155	0.229	0.008	0.018	0.550	0.234	11.331	8.983
	Euronext Vigeo	0.835	0.093	0.156	0.007	0.013	0.636	0.722	9.092	10.482
	EEX-EU CO2	0.442	0.311	0.464	0.011	0.023	0.422	-0.014	10.552	5.009
	S&P Green Build	0.914	0.073	0.080	0.005	0.011	0.126	0.072	10.634	10.445
Panel C: Gold	MSCI World ESG	0.569	-0.076	0.469	0.003	0.013	-0.104	-0.260	8.123	16.103
	FTSE Good Global	0.580	0.002	0.424	0.004	0.013	0.076	-0.188	8.715	15.763
	DJSI World	0.597	0.016	0.402	0.003	0.012	0.065	-0.038	9.502	15.890
	DJ Islamic	0.555	0.005	0.443	0.004	0.013	-0.096	-0.274	7.433	14.539
	S&P Green Bond	0.955	0.128	0.042	0.002	0.003	0.073	-0.033	4.775	4.571
	S&P Clean Energy	0.307	0.034	0.666	0.005	0.018	-0.048	0.234	4.964	8.983
	Euronext Vigeo	0.448	-0.123	0.595	0.004	0.013	0.132	0.722	7.025	10.482
	EEX-EU CO2	0.142	0.011	0.862	0.005	0.023	-0.245	-0.014	4.961	5.009
	S&P Green Build	0.580	0.056	0.397	0.004	0.011	-0.224	0.072	8.525	10.445
Panel D: STOXX	MSCI World ESG	0.685	0.541	0.139	0.005	0.013	0.107	-0.260	13.076	16.103
	FTSE Good Global	0.706	0.565	0.123	0.005	0.013	0.404	-0.188	12.582	15.763
	DJSI World	0.787	0.587	0.073	0.005	0.012	0.218	-0.038	13.275	15.890
	DJ Islamic	0.627	0.503	0.196	0.005	0.013	0.071	-0.274	12.444	14.539
	S&P Green Bond	0.879	-0.023	0.206	0.002	0.003	-0.374	-0.033	6.916	4.571
	S&P Clean Energy	0.264	0.675	0.538	0.006	0.018	0.651	0.234	11.446	8.983
	Euronext Vigeo	0.331	1.036	0.185	0.006	0.013	0.903	0.722	10.568	10.482
	EEX-EU CO2	0.100	0.639	0.829	0.006	0.023	0.554	-0.014	8.152	5.009
	S&P Green Build	0.656	0.449	0.184	0.005	0.011	0.628	0.072	11.254	10.445
Panel E: Nikkei	MSCI World ESG	0.636	0.116	0.333	0.004	0.013	0.240	-0.260	9.748	16.103

(Continues)

TABLE 12 (Continued)

		Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis	
	FTSE Good Global	0.643	0.130	0.320	0.004	0.013	0.258	-0.188	9.148	15.763
	DJSI World	0.662	0.114	0.304	0.004	0.012	0.345	-0.038	8.407	15.890
	DJ Islamic	0.611	0.103	0.365	0.004	0.013	0.182	-0.274	8.618	14.539
	S&P Green Bond	0.903	-0.005	0.140	0.002	0.003	0.353	-0.033	5.154	4.571
	S&P Clean Energy	0.342	0.197	0.603	0.005	0.018	-0.096	0.234	7.008	8.983
	Euronext Vigeo	0.497	0.153	0.452	0.005	0.013	0.108	0.722	6.014	10.482
	EEX-EU CO2	0.165	0.099	0.833	0.006	0.023	-0.226	-0.014	4.688	5.009
	S&P Green Build	0.633	0.186	0.301	0.004	0.011	0.100	0.072	7.158	10.445
Panel F: Hang Seng	MSCI World ESG	0.647	0.198	0.289	0.004	0.013	0.857	-0.260	10.243	16.103
	FTSE Good Global	0.660	0.229	0.268	0.004	0.013	0.879	-0.188	9.992	15.763
	DJSI World	0.682	0.231	0.241	0.004	0.012	0.823	-0.038	10.223	15.890
	DJ Islamic	0.627	0.230	0.298	0.004	0.013	0.631	-0.274	8.377	14.539
	S&P Green Bond	0.915	0.005	0.130	0.002	0.003	-0.188	-0.033	5.714	4.571
	S&P Clean Energy	0.331	0.432	0.548	0.006	0.018	0.554	0.234	9.054	8.983
	Euronext Vigeo	0.496	0.352	0.384	0.005	0.013	0.686	0.722	9.989	10.482
	EEX-EU CO2	0.148	0.265	0.823	0.006	0.023	0.293	-0.014	7.726	5.009
	S&P Green Build	0.648	0.322	0.238	0.004	0.011	0.098	0.072	10.542	10.445
Panel G: US to EUR	MSCI World ESG	0.248	-0.169	0.770	0.002	0.013	0.062	-0.260	4.599	16.103
	FTSE Good Global	0.206	0.284	0.733	0.002	0.013	0.011	-0.188	3.980	15.763
	DJSI World	0.212	0.346	0.713	0.002	0.012	-0.036	-0.038	4.031	15.890
	DJ Islamic	0.204	0.147	0.762	0.002	0.013	0.021	-0.274	4.111	14.539
	S&P Green Bond	0.832	0.679	0.043	0.002	0.003	-0.071	-0.033	3.964	4.571
	S&P Clean Energy	0.061	0.429	0.914	0.002	0.018	-0.018	0.234	3.342	8.983
	Euronext Vigeo	0.143	-0.129	0.868	0.002	0.013	-0.249	0.722	3.955	10.482
	EEX-EU CO2	0.031	0.132	0.974	0.002	0.023	0.041	-0.014	3.373	5.009
	S&P Green Build	0.179	0.402	0.743	0.002	0.011	0.126	0.072	3.797	10.445

Note: See notes Table 6.

observed for the exchange rate, indicating a significantly lower responsiveness of US to EUR exchange rate to risk shocks in the EESG indices.

The CoVaR estimates for the short-, medium-, and long-run trends closely follows the structure of the undecomposed series over both subsamples. Notably, the estimates of CoVaR significantly as the investment horizon becomes longer, indicating a decreased sensitivity to risk shocks over both subsamples. Overall, these findings indicate that the risk spillover from the EESG assets to financial indices are significantly higher than the commodities and the forex markets, implying similarity to the financial indices and difference from the commodity and currency markets.

Tables 7 and 8 presents the summary statistics of the Delta CoVaR ($\Delta CoVaR$) for the undecomposed and

the decomposed return series for the pre and during-COVID subsamples, respectively. The $\Delta CoVaR$ is estimated as the difference between the VaR of an underlying EESG returns conditional on the extreme movement of financial indices, commodities, and currencies, and the VaR of the underlying EESG returns conditional on the median values (normal state) of financial indices, commodities, and currencies return. The $\Delta CoVaR$ provides an estimate of systemic risk contribution of an EESG asset to the other assets in our sample. Similar to the CoVaR estimates, the $\Delta CoVaR$ of the major financial indexes are significantly higher than that of commodity and currency markets over both subsamples. These findings are consistent with our prior expectations of the similarities to major financial indices, indicating that the EESG assets are systemically more

important in financial markets. The lower estimates of $\Delta CoVaR$ in the case of commodities and currencies indicate the heterogeneous properties of EESG with these assets. The higher systemic risk connectedness of EESG to the financial indices are consistent with Hkiri et al.

(2017); Jain et al. (2019); Kenourgios et al. (2016); Rizvi et al. (2015); Umar et al. (2020); Yilmaz et al. (2015); Abu-Alkheil et al. (2017). They report significantly greater connectedness and cointegration between the conventional financial indices and the EESG assets.

TABLE 13 Statistics of unhedged and hedged portfolios for medium-run trend

		Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis	
		Weight	Ratio	Effectiveness	Hedged	Unhedged	Hedged	Unhedged	Hedged	Unhedged
Panel A: S&P500	MSCI World ESG	0.535	0.945	0.189	0.000	0.001	0.060	0.096	3.238	3.240
	FTSE Good Global	0.576	0.873	0.169	0.000	0.001	0.076	0.061	3.008	2.960
	DJSI World	0.471	0.882	0.261	0.000	0.001	0.078	0.036	2.950	2.730
	DJ Islamic	0.577	0.891	0.168	0.000	0.001	0.090	0.110	3.217	3.032
	S&P Green Bond	0.748	-0.003	0.331	0.000	0.001	0.187	0.073	5.895	3.453
	S&P Clean Energy	0.254	1.227	0.556	0.000	0.003	0.224	-0.042	3.908	4.042
	Euronext Vigeo	0.375	0.951	0.456	0.000	0.002	-0.018	-0.108	3.349	3.196
	EEX-EU CO2	0.159	1.619	0.790	0.000	0.006	-0.057	0.236	4.460	6.930
	S&P Green Build	0.432	0.901	0.392	0.000	0.002	-0.010	-0.176	3.993	4.863
Panel B: Crude oil	MSCI World ESG	0.789	0.161	0.232	0.000	0.001	-0.182	0.096	4.285	3.240
	FTSE Good Global	0.800	0.162	0.217	0.000	0.001	-0.347	0.061	4.752	2.960
	DJSI World	0.778	0.168	0.239	0.000	0.001	-0.330	0.036	4.642	2.730
	DJ Islamic	0.790	0.151	0.209	0.000	0.001	-0.011	0.110	3.538	3.032
	S&P Green Bond	0.911	-0.011	0.206	0.000	0.001	-0.207	0.073	5.626	3.453
	S&P Clean Energy	0.654	0.272	0.319	0.000	0.003	0.126	-0.042	3.874	4.042
	Euronext Vigeo	0.727	0.212	0.293	0.000	0.002	-0.781	-0.108	9.472	3.196
	EEX-EU CO2	0.422	0.411	0.549	0.000	0.006	-0.251	0.236	6.493	6.930
	S&P Green Build	0.745	0.102	0.274	0.000	0.002	-1.156	-0.176	14.059	4.863
Panel C: Gold	MSCI World ESG	0.599	-0.127	0.495	0.000	0.001	-0.148	0.096	4.235	3.240
	FTSE Good Global	0.612	-0.086	0.477	0.000	0.001	-0.165	0.061	4.407	2.960
	DJSI World	0.587	-0.058	0.489	0.000	0.001	-0.101	0.036	4.283	2.730
	DJ Islamic	0.615	0.012	0.451	0.000	0.001	-0.108	0.110	4.072	3.032
	S&P Green Bond	0.888	0.147	0.150	0.000	0.001	-0.234	0.073	4.083	3.453
	S&P Clean Energy	0.439	0.011	0.592	0.000	0.003	-0.135	-0.042	4.056	4.042
	Euronext Vigeo	0.513	-0.244	0.597	0.000	0.002	-0.057	-0.108	4.345	3.196
	EEX-EU CO2	0.222	0.455	0.765	0.000	0.006	0.118	0.236	4.096	6.930
	S&P Green Build	0.551	-0.047	0.505	0.000	0.002	-0.101	-0.176	3.406	4.863
Panel D: STOXX	MSCI World ESG	0.609	0.748	0.209	0.000	0.001	0.018	0.096	3.232	3.240
	FTSE Good Global	0.609	0.681	0.240	0.000	0.001	-0.006	0.061	3.237	2.960
	DJSI World	0.583	0.749	0.255	0.000	0.001	0.060	0.036	3.039	2.730
	DJ Islamic	0.617	0.528	0.266	0.000	0.001	0.041	0.110	3.220	3.032
	S&P Green Bond	0.752	-0.139	0.429	0.000	0.001	-0.129	0.073	5.442	3.453
	S&P Clean Energy	0.342	1.143	0.495	0.000	0.003	0.037	-0.042	3.400	4.042
	Euronext Vigeo	0.334	1.123	0.248	0.000	0.002	0.014	-0.108	2.948	3.196
	EEX-EU CO2	0.193	0.905	0.775	0.000	0.006	-0.098	0.236	4.785	6.930
	S&P Green Build	0.495	0.531	0.395	0.000	0.002	0.057	-0.176	3.397	4.863

(Continues)

TABLE 13 (Continued)

		Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis	
Panel E: Nikkei	MSCI World ESG	0.719	0.497	0.195	0.000	0.001	-0.028	0.096	4.748	3.240
	FTSE Good Global	0.727	0.441	0.210	0.000	0.001	-0.060	0.061	4.393	2.960
	DJSI World	0.697	0.431	0.239	0.000	0.001	-0.041	0.036	4.082	2.730
	DJ Islamic	0.707	0.416	0.234	0.000	0.001	0.009	0.110	4.806	3.032
	S&P Green Bond	0.815	-0.055	0.337	0.000	0.001	0.449	0.073	11.627	3.453
	S&P Clean Energy	0.475	0.667	0.397	0.000	0.003	0.088	-0.042	4.350	4.042
	Euronext Vigeo	0.589	0.627	0.288	0.000	0.002	0.055	-0.108	3.606	3.196
	EEX-EU CO2	0.253	-0.035	0.748	0.000	0.006	-0.052	0.236	4.338	6.930
	S&P Green Build	0.621	0.423	0.298	0.000	0.002	-0.108	-0.176	4.454	4.863
Panel F: Hang Seng	MSCI World ESG	0.707	0.369	0.238	0.000	0.001	0.147	0.096	3.464	3.240
	FTSE Good Global	0.734	0.368	0.230	0.000	0.001	0.033	0.061	3.307	2.960
	DJSI World	0.693	0.391	0.255	0.000	0.001	0.032	0.036	3.108	2.730
	DJ Islamic	0.740	0.390	0.222	0.000	0.001	0.168	0.110	3.135	3.032
	S&P Green Bond	0.837	0.018	0.295	0.000	0.001	0.247	0.073	7.410	3.453
	S&P Clean Energy	0.444	0.666	0.423	0.000	0.003	0.132	-0.042	3.064	4.042
	Euronext Vigeo	0.571	0.379	0.363	0.000	0.002	0.156	-0.108	2.954	3.196
	EEX-EU CO2	0.224	0.909	0.718	0.000	0.006	0.177	0.236	4.365	6.930
	S&P Green Build	0.606	0.359	0.321	0.000	0.002	0.070	-0.176	3.589	4.863
Panel G: US to EUR	MSCI World ESG	0.395	-0.190	0.662	0.000	0.001	0.016	0.096	3.887	3.240
	FTSE Good Global	0.409	0.185	0.599	0.000	0.001	0.013	0.061	3.757	2.960
	DJSI World	0.379	0.176	0.625	0.000	0.001	0.060	0.036	3.735	2.730
	DJ Islamic	0.403	0.148	0.606	0.000	0.001	0.110	0.110	3.872	3.032
	S&P Green Bond	0.812	0.618	0.088	0.000	0.001	0.086	0.073	3.399	3.453
	S&P Clean Energy	0.251	0.350	0.733	0.000	0.003	-0.201	-0.042	6.510	4.042
	Euronext Vigeo	0.316	-0.582	0.761	0.000	0.002	-0.045	-0.108	3.602	3.196
	EEX-EU CO2	0.100	1.159	0.889	0.000	0.006	-0.027	0.236	3.575	6.930
	S&P Green Build	0.321	0.284	0.652	0.000	0.002	0.010	-0.176	3.761	4.863

Note: See notes Table 6.

The lower systemic risk contribution over the long-term horizon is consistent with Abu-Alkheil et al. (2017) who report “absence of cointegration” between conventional financial indices and the EESG assets over the long-term horizon. Furthermore, the lower risk contribution of EESG to commodities and currencies is consistent with Mensi et al. (2015), indicating that less of a connection between Sharia stocks, gold and U.S. treasury bills (T-bills) can present a hedging opportunity for the six GCC stock markets.

Figures 2–8 provide an overview of the dynamic development of VaR, CoVaR, and $\Delta CoVaR$ between the EESG assets and other underlying assets for the original and decomposed return series. In general, the findings from the time-varying uncertainty plots are

consistent with the summary statistics (Tables 3–8), indicating that the EESG exhibits similar characteristics to the financial indices. Furthermore, the intensity of spillover and systemic risk contributions are significantly higher for financial indices. While it displays heterogeneous characteristics with the commodities and currencies, the spillover and systemic uncertainty among these assets increases at turbulent times. For instance, all the EESG assets exhibit a significant increase in spillover and systemic risk with the declaration of the COVID-19 pandemic. These findings are consistent with the literature that describes the increase on spillover among assets during periods of turmoil (Aloui et al., 2013; Charfeddine & Benlagha, 2016; Jawadi et al., 2014; Shahzad et al., 2021; Yahya et al., 2020).

TABLE 14 Statistics of unhedged and hedged portfolios for medium-run trend

		Portfolio Hedge Hedging			Std dev		Skewness		Kurtosis	
		Weight	Ratio	Effectiveness	Hedged	Unhedged	Hedged	Unhedged	Hedged	Unhedged
Panel A: S&P500	MSCI World ESG	0.650	0.987	0.103	0.000	0.003	0.338	0.366	6.475	6.596
	FTSE Good Global	0.396	1.120	0.166	0.000	0.003	0.302	0.330	6.178	6.279
	DJSI World	0.558	1.092	0.170	0.000	0.003	0.283	0.292	6.261	6.462
	DJ Islamic	0.630	0.974	0.125	0.000	0.003	0.295	0.320	6.250	6.271
	S&P Green Bond	0.781	0.032	0.345	0.000	0.001	1.231	0.433	18.751	6.579
	S&P Clean Energy	0.410	0.701	0.406	0.000	0.005	0.471	0.616	7.608	8.018
	Euronext Vigeo	0.238	1.364	0.411	0.000	0.004	0.149	0.385	6.609	6.108
	EEX-EU CO2	0.124	1.985	0.783	0.000	0.006	0.537	-0.035	6.999	4.492
	S&P Green Build	0.475	0.826	0.364	0.000	0.005	0.570	0.439	7.587	7.817
Panel B: Crude oil	MSCI World ESG	0.890	0.195	0.123	0.000	0.003	-0.632	0.366	10.211	6.596
	FTSE Good Global	0.886	0.213	0.115	0.000	0.003	-0.757	0.330	10.800	6.279
	DJSI World	0.901	0.187	0.105	0.000	0.003	-0.443	0.292	9.498	6.462
	DJ Islamic	0.882	0.151	0.127	0.000	0.003	0.314	0.320	6.208	6.271
	S&P Green Bond	0.938	-0.028	0.228	0.000	0.001	-0.878	0.433	17.418	6.579
	S&P Clean Energy	0.853	0.086	0.163	0.000	0.005	-0.435	0.616	11.423	8.018
	Euronext Vigeo	0.803	0.263	0.160	0.000	0.004	-0.288	0.385	7.720	6.108
	EEX-EU CO2	0.527	0.345	0.452	0.000	0.006	-0.967	-0.035	18.330	4.492
	S&P Green Build	0.853	0.048	0.197	0.000	0.005	-0.637	0.439	13.976	7.817
Panel C: Gold	MSCI World ESG	0.453	-0.024	0.570	0.000	0.003	1.441	0.366	12.762	6.596
	FTSE Good Global	0.406	0.121	0.600	0.000	0.003	0.947	0.330	11.836	6.279
	DJSI World	0.428	0.145	0.568	0.000	0.003	1.393	0.292	12.621	6.462
	DJ Islamic	0.442	0.105	0.531	0.000	0.003	0.941	0.320	10.726	6.271
	S&P Green Bond	0.846	0.276	0.148	0.000	0.001	0.120	0.433	7.070	6.579
	S&P Clean Energy	0.388	0.131	0.596	0.000	0.005	-0.449	0.616	6.440	8.018
	Euronext Vigeo	0.331	-0.038	0.683	0.000	0.004	1.431	0.385	16.416	6.108
	EEX-EU CO2	0.123	0.168	0.889	0.000	0.006	-0.094	-0.035	5.466	4.492
	S&P Green Build	0.483	0.470	0.489	0.000	0.005	-1.210	0.439	9.712	7.817
Panel D: STOXX	MSCI World ESG	0.717	0.859	0.095	0.000	0.003	0.325	0.366	6.998	6.596
	FTSE Good Global	0.603	0.943	0.112	0.000	0.003	0.400	0.330	7.206	6.279
	DJSI World	0.712	0.917	0.084	0.000	0.003	0.261	0.292	7.095	6.462
	DJ Islamic	0.713	0.914	0.137	0.000	0.003	0.304	0.320	7.482	6.271
	S&P Green Bond	0.799	-0.081	0.343	0.000	0.001	1.036	0.433	18.560	6.579
	S&P Clean Energy	0.404	0.773	0.364	0.000	0.005	0.525	0.616	7.204	8.018
	Euronext Vigeo	0.155	1.180	0.308	0.000	0.004	0.437	0.385	6.624	6.108
	EEX-EU CO2	0.146	1.642	0.756	0.000	0.006	0.527	-0.035	7.484	4.492
	S&P Green Build	0.552	0.590	0.331	0.000	0.005	0.581	0.439	7.639	7.817
Panel E: Nikkei	MSCI World ESG	0.703	0.673	0.113	0.000	0.003	0.315	0.366	5.798	6.596
	FTSE Good Global	0.640	0.752	0.154	0.000	0.003	0.269	0.330	5.443	6.279
	DJSI World	0.653	0.730	0.144	0.000	0.003	0.305	0.292	5.717	6.462
	DJ Islamic	0.691	0.662	0.156	0.000	0.003	0.254	0.320	5.484	6.271
	S&P Green Bond	0.834	-0.011	0.338	0.000	0.001	0.779	0.433	14.757	6.579
	S&P Clean Energy	0.532	0.657	0.337	0.000	0.005	0.363	0.616	7.749	8.018

(Continues)

TABLE 14 (Continued)

		Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis	
	Euronext Vigeo	0.469	1.003	0.254	0.000	0.004	0.155	0.385	4.962	6.108
	EEX-EU CO2	0.133	1.604	0.718	0.000	0.006	0.357	-0.035	6.414	4.492
	S&P Green Build	0.601	0.511	0.322	0.000	0.005	0.514	0.439	8.108	7.817
Panel F: Hang Seng	MSCI World ESG	0.700	0.596	0.195	0.000	0.003	0.396	0.366	6.304	6.596
	FTSE Good Global	0.685	0.655	0.185	0.000	0.003	0.239	0.330	4.790	6.279
	DJSI World	0.704	0.611	0.185	0.000	0.003	0.350	0.292	5.661	6.462
	DJ Islamic	0.709	0.655	0.194	0.000	0.003	0.372	0.320	4.994	6.271
	S&P Green Bond	0.870	0.097	0.217	0.000	0.001	0.461	0.433	10.243	6.579
	S&P Clean Energy	0.523	0.731	0.339	0.000	0.005	0.029	0.616	4.093	8.018
	Euronext Vigeo	0.552	0.808	0.276	0.000	0.004	0.062	0.385	5.820	6.108
	EEX-EU CO2	0.202	1.283	0.683	0.000	0.006	0.031	-0.035	2.476	4.492
	S&P Green Build	0.612	0.608	0.345	0.000	0.005	-0.217	0.439	5.976	7.817
Panel G: US to EUR	MSCI World ESG	0.200	-0.567	0.846	0.000	0.003	1.074	0.366	17.854	6.596
	FTSE Good Global	0.166	-0.067	0.848	0.000	0.003	0.989	0.330	16.804	6.279
	DJSI World	0.158	-0.069	0.850	0.000	0.003	1.069	0.292	16.911	6.462
	DJ Islamic	0.185	0.018	0.838	0.000	0.003	1.022	0.320	17.005	6.271
	S&P Green Bond	0.377	1.019	0.470	0.000	0.001	0.056	0.433	8.947	6.579
	S&P Clean Energy	0.135	0.288	0.840	0.000	0.005	-0.679	0.616	18.517	8.018
	Euronext Vigeo	0.136	-0.884	0.885	0.000	0.004	0.459	0.385	15.918	6.108
	EEX-EU CO2	0.036	3.934	0.971	0.000	0.006	-1.339	-0.035	12.738	4.492
	S&P Green Build	0.154	0.571	0.800	0.000	0.005	-1.288	0.439	21.250	7.817

Note: See notes Table 6.

TABLE 15 Statistics of unhedged and hedged portfolios for long-run trend for pre-COVID period

		Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis	
		Weight	Ratio	Effectiveness	Hedged	Unhedged	Hedged	Unhedged	Hedged	Unhedged
Panel A: S&P500	MSCI World ESG	0.548	0.882	0.221	0.000	0.000	0.571	0.425	3.948	3.415
	FTSE Good Global	0.428	1.015	0.416	0.000	0.000	0.549	0.538	3.906	3.768
	DJSI World	0.341	0.832	0.491	0.000	0.000	0.597	0.379	3.482	2.615
	DJ Islamic	0.345	1.109	0.465	0.000	0.000	0.296	0.192	3.438	2.724
	S&P Green Bond	0.485	0.537	0.525	0.000	0.000	0.524	0.144	4.917	2.331
	S&P Clean Energy	0.142	2.600	0.774	0.000	0.001	0.220	0.027	5.263	2.835
	Euronext Vigeo	0.189	0.980	0.681	0.000	0.001	0.865	0.147	6.036	3.197
	EEX-EU CO2	0.184	2.015	0.726	0.000	0.001	0.437	0.131	5.933	2.355
	S&P Green Build	0.292	1.194	0.657	0.000	0.001	0.673	0.487	5.239	2.873
Panel B: Crude oil	MSCI World ESG	0.952	0.046	0.085	0.000	0.000	-7.227	0.425	166.322	3.415
	FTSE Good Global	0.944	0.145	0.041	0.000	0.000	-4.835	0.538	89.633	3.768
	DJSI World	0.909	0.426	0.073	0.000	0.000	3.644	0.379	73.940	2.615
	DJ Islamic	0.904	0.548	0.087	0.000	0.000	1.348	0.192	110.744	2.724
	S&P Green Bond	0.888	0.644	0.133	0.000	0.000	3.474	0.144	51.772	2.331
	S&P Clean Energy	0.801	1.117	0.176	0.000	0.001	4.461	0.027	56.090	2.835
	Euronext Vigeo	0.853	-0.437	0.218	0.000	0.001	-1.612	0.147	39.247	3.197

TABLE 15 (Continued)

		Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis	
	EEX-EU CO2	0.778	0.925	0.223	0.000	0.001	-0.188	0.131	27.509	2.355
	S&P Green Build	0.813	0.009	0.244	0.000	0.001	-3.311	0.487	44.442	2.873
Panel C: Gold	MSCI World ESG	0.607	1.092	0.394	0.000	0.000	-0.220	0.425	3.676	3.415
	FTSE Good Global	0.594	0.898	0.327	0.000	0.000	0.000	0.538	3.291	3.768
	DJSI World	0.581	1.425	0.324	0.000	0.000	-0.153	0.379	3.167	2.615
	DJ Islamic	0.610	1.596	0.284	0.000	0.000	-0.199	0.192	2.952	2.724
	S&P Green Bond	0.675	2.078	0.228	0.000	0.000	-0.203	0.144	3.726	2.331
	S&P Clean Energy	0.299	4.664	0.570	0.000	0.001	0.464	0.027	3.820	2.835
	Euronext Vigeo	0.406	0.453	0.602	0.000	0.001	0.260	0.147	2.924	3.197
	EEX-EU CO2	0.347	-0.278	0.728	0.000	0.001	0.142	0.131	3.017	2.355
	S&P Green Build	0.432	1.822	0.513	0.000	0.001	0.324	0.487	2.767	2.873
Panel D: STOXX	MSCI World ESG	0.714	0.968	0.193	0.000	0.000	0.363	0.425	3.564	3.415
	FTSE Good Global	0.624	1.025	0.291	0.000	0.000	0.316	0.538	3.742	3.768
	DJSI World	0.551	0.924	0.395	0.000	0.000	0.129	0.379	3.435	2.615
	DJ Islamic	0.605	0.772	0.317	0.000	0.000	0.268	0.192	3.368	2.724
	S&P Green Bond	0.605	0.110	0.449	0.000	0.000	0.396	0.144	4.459	2.331
	S&P Clean Energy	0.283	1.979	0.633	0.000	0.001	0.219	0.027	3.664	2.835
	Euronext Vigeo	0.365	2.388	0.410	0.000	0.001	-0.082	0.147	2.815	3.197
	EEX-EU CO2	0.350	2.635	0.596	0.000	0.001	0.390	0.131	3.279	2.355
	S&P Green Build	0.387	0.791	0.475	0.000	0.001	0.136	0.487	2.893	2.873
Panel E: Nikkei	MSCI World ESG	0.706	0.643	0.219	0.000	0.000	0.135	0.425	3.432	3.415
	FTSE Good Global	0.617	2.233	0.326	0.000	0.000	0.195	0.538	3.115	3.768
	DJSI World	0.595	2.002	0.376	0.000	0.000	0.151	0.379	3.037	2.615
	DJ Islamic	0.599	1.418	0.406	0.000	0.000	0.157	0.192	2.985	2.724
	S&P Green Bond	0.618	0.437	0.542	0.000	0.000	0.370	0.144	4.395	2.331
	S&P Clean Energy	0.374	5.732	0.615	0.000	0.001	0.321	0.027	3.350	2.835
	Euronext Vigeo	0.443	0.635	0.455	0.000	0.001	0.105	0.147	2.544	3.197
	EEX-EU CO2	0.360	0.885	0.535	0.000	0.001	0.101	0.131	2.832	2.355
	S&P Green Build	0.404	5.818	0.482	0.000	0.001	0.264	0.487	2.875	2.873
Panel F: Hang Seng	MSCI World ESG	0.703	0.199	0.247	0.000	0.000	0.309	0.425	3.662	3.415
	FTSE Good Global	0.727	0.384	0.246	0.000	0.000	0.277	0.538	3.730	3.768
	DJSI World	0.667	0.854	0.278	0.000	0.000	0.060	0.379	3.306	2.615
	DJ Islamic	0.664	1.322	0.282	0.000	0.000	0.184	0.192	2.999	2.724
	S&P Green Bond	0.662	0.790	0.353	0.000	0.000	-0.096	0.144	3.336	2.331
	S&P Clean Energy	0.359	5.056	0.512	0.000	0.001	0.319	0.027	2.750	2.835
	Euronext Vigeo	0.522	1.186	0.473	0.000	0.001	0.436	0.147	3.371	3.197
	EEX-EU CO2	0.399	5.492	0.545	0.000	0.001	0.052	0.131	2.491	2.355
	S&P Green Build	0.551	2.899	0.381	0.000	0.001	0.427	0.487	3.283	2.873
Panel G: US to EUR	MSCI World ESG	0.484	-0.283	0.602	0.000	0.000	0.730	0.425	4.369	3.415
	FTSE Good Global	0.439	1.690	0.516	0.000	0.000	0.736	0.538	4.117	3.768
	DJSI World	0.394	1.745	0.546	0.000	0.000	0.596	0.379	2.764	2.615
	DJ Islamic	0.428	3.627	0.515	0.000	0.000	0.748	0.192	3.006	2.724
	S&P Green Bond	0.405	4.126	0.420	0.000	0.000	0.427	0.144	2.744	2.331

(Continues)

TABLE 15 (Continued)

	Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis		
	S&P Clean Energy	0.187	8.532	0.754	0.000	0.001	0.870	0.027	6.355	2.835
	Euronext Vigeo	0.281	-2.436	0.764	0.000	0.001	0.385	0.147	3.780	3.197
	EEX-EU CO2	0.246	7.180	0.818	0.000	0.001	0.495	0.131	6.268	2.355
	S&P Green Build	0.281	-2.092	0.672	0.000	0.001	0.741	0.487	4.600	2.873

Note: See notes Table 6.

TABLE 16 Statistics of unhedged and hedged portfolios for long-run trend during-COVID period

	Portfolio	Weight	Hedge Ratio	Hedging Effectiveness	Std dev		Skewness		Kurtosis	
					Hedged	Unhedged	Hedged	Unhedged	Hedged	Unhedged
Panel A: S&P500	MSCI World ESG	0.419	0.836	0.140	0.000	0.000	-0.963	-0.804	2.262	2.006
	FTSE Good Global	0.234	1.433	0.507	0.000	0.000	-0.976	-0.675	2.780	2.085
	DJSI World	0.080	1.837	0.591	0.000	0.000	-1.075	-0.653	2.576	2.123
	DJ Islamic	0.117	1.866	0.703	0.000	0.001	-0.940	-0.575	3.151	2.270
	S&P Green Bond	0.112	1.781	0.585	0.000	0.000	-0.986	-0.399	2.392	2.021
	S&P Clean Energy	0.055	6.915	0.898	0.000	0.002	-2.349	-0.291	15.168	1.996
	Euronext Vigeo	0.082	2.286	0.748	0.000	0.001	-1.148	-0.390	2.774	1.686
	EEX-EU CO2	0.400	-0.243	0.513	0.000	0.000	-0.476	0.415	1.859	1.737
	S&P Green Build	0.096	2.753	0.776	0.000	0.001	-1.297	-0.183	3.603	1.586
Panel B: Crude oil	MSCI World ESG	1.000	0.051	0.000	0.000	0.000	-0.804	-0.804	2.006	2.006
	FTSE Good Global	0.991	0.068	0.004	0.000	0.000	-8.449	-0.675	86.066	2.085
	DJSI World	0.986	0.096	0.006	0.000	0.000	-2.394	-0.653	33.609	2.123
	DJ Islamic	0.964	0.109	0.033	0.000	0.001	-6.364	-0.575	53.151	2.270
	S&P Green Bond	0.956	0.092	0.056	0.000	0.000	-3.589	-0.399	42.697	2.021
	S&P Clean Energy	0.758	0.365	0.204	0.000	0.002	-2.624	-0.291	12.894	1.996
	Euronext Vigeo	0.996	0.128	0.002	0.000	0.001	-0.377	-0.390	1.772	1.686
	EEX-EU CO2	0.908	0.045	0.085	0.000	0.000	1.367	0.415	4.524	1.737
	S&P Green Build	0.976	0.175	0.011	0.000	0.001	-6.888	-0.183	71.150	1.586
Panel C: Gold	MSCI World ESG	0.842	0.146	0.153	0.000	0.000	0.123	-0.804	3.255	2.006
	FTSE Good Global	0.759	0.596	0.186	0.000	0.000	-0.139	-0.675	2.348	2.085
	DJSI World	0.834	0.525	0.118	0.000	0.000	0.062	-0.653	2.520	2.123
	DJ Islamic	0.759	0.696	0.141	0.000	0.001	-0.266	-0.575	2.321	2.270
	S&P Green Bond	0.911	0.608	0.061	0.000	0.000	0.232	-0.399	2.548	2.021
	S&P Clean Energy	0.201	2.402	0.627	0.000	0.002	-1.123	-0.291	4.347	1.996
	Euronext Vigeo	0.613	0.351	0.355	0.000	0.001	0.054	-0.390	2.134	1.686
	EEX-EU CO2	0.674	-0.506	0.475	0.000	0.000	-0.059	0.415	1.650	1.737
	S&P Green Build	0.602	0.687	0.340	0.000	0.001	-0.189	-0.183	1.895	1.586
Panel D: STOXX	MSCI World ESG	0.793	0.632	0.111	0.000	0.000	-0.761	-0.804	2.114	2.006
	FTSE Good Global	0.430	1.121	0.272	0.000	0.000	-0.450	-0.675	1.793	2.085
	DJSI World	0.485	1.495	0.384	0.000	0.000	-0.683	-0.653	2.170	2.123
	DJ Islamic	0.261	1.736	0.547	0.000	0.001	-0.345	-0.575	1.962	2.270
	S&P Green Bond	0.398	1.190	0.526	0.000	0.000	-0.490	-0.399	2.205	2.021
	S&P Clean Energy	0.061	5.028	0.865	0.000	0.002	1.575	-0.291	7.581	1.996

TABLE 16 (Continued)

		Portfolio	Hedge	Hedging	Std dev		Skewness		Kurtosis	
	Euronext Vigeo	0.294	2.621	0.496	0.000	0.001	-0.513	-0.390	1.796	1.686
	EEX-EU CO2	0.497	0.833	0.488	0.000	0.000	-0.122	0.415	1.490	1.737
	S&P Green Build	0.030	2.331	0.708	0.000	0.001	-0.722	-0.183	2.390	1.586
Panel E: Nikkei	MSCI World ESG	0.673	0.660	0.213	0.000	0.000	-0.810	-0.804	1.959	2.006
	FTSE Good Global	0.379	1.140	0.477	0.000	0.000	-0.334	-0.675	1.647	2.085
	DJSI World	0.388	1.045	0.479	0.000	0.000	-0.598	-0.653	1.794	2.123
	DJ Islamic	0.344	1.275	0.635	0.000	0.001	-0.324	-0.575	1.966	2.270
	S&P Green Bond	0.367	0.819	0.571	0.000	0.000	-0.537	-0.399	1.941	2.021
	S&P Clean Energy	0.118	4.193	0.865	0.000	0.002	0.088	-0.291	6.637	1.996
	Euronext Vigeo	0.066	2.239	0.615	0.000	0.001	-0.346	-0.390	1.611	1.686
	EEX-EU CO2	0.476	1.332	0.456	0.000	0.000	-0.097	0.415	1.623	1.737
	S&P Green Build	0.070	1.864	0.741	0.000	0.001	-0.286	-0.183	1.877	1.586
Panel F: Hang Seng	MSCI World ESG	0.815	0.653	0.122	0.000	0.000	-0.901	-0.804	2.351	2.006
	FTSE Good Global	0.619	0.993	0.233	0.000	0.000	-0.496	-0.675	1.581	2.085
	DJSI World	0.560	1.027	0.321	0.000	0.000	-0.659	-0.653	1.919	2.123
	DJ Islamic	0.485	1.156	0.411	0.000	0.001	-0.395	-0.575	1.617	2.270
	S&P Green Bond	0.530	0.571	0.425	0.000	0.000	-0.603	-0.399	2.156	2.021
	S&P Clean Energy	0.220	3.177	0.692	0.000	0.002	-0.425	-0.291	4.118	1.996
	Euronext Vigeo	0.507	1.513	0.369	0.000	0.001	-0.561	-0.390	1.818	1.686
	EEX-EU CO2	0.605	0.684	0.326	0.000	0.000	-0.044	0.415	1.532	1.737
	S&P Green Build	0.372	1.379	0.416	0.000	0.001	-0.364	-0.183	1.665	1.586
Panel G: US to EUR	MSCI World ESG	0.676	0.256	0.363	0.000	0.000	-0.791	-0.804	2.906	2.006
	FTSE Good Global	0.574	1.278	0.365	0.000	0.000	-0.974	-0.675	3.413	2.085
	DJSI World	0.509	1.159	0.322	0.000	0.000	-0.408	-0.653	1.936	2.123
	DJ Islamic	0.452	1.751	0.407	0.000	0.001	-0.558	-0.575	3.225	2.270
	S&P Green Bond	0.325	1.379	0.302	0.000	0.000	-0.087	-0.399	1.482	2.021
	S&P Clean Energy	0.107	5.558	0.798	0.000	0.002	-1.183	-0.291	11.928	1.996
	Euronext Vigeo	0.365	0.466	0.626	0.000	0.001	-0.310	-0.390	2.109	1.686
	EEX-EU CO2	0.466	-0.654	0.700	0.000	0.000	-0.308	0.415	1.992	1.737
	S&P Green Build	0.323	0.976	0.589	0.000	0.001	-0.848	-0.183	3.244	1.586

Note: See notes Table 6.

3.5 | Wavelet-based portfolio strategies and hedge ratios

Tables 9–16 offer the summary statistics of the unhedged and hedged portfolios for the original returns and short-, medium-, and long-term horizons for the pre- and during-COVID subsamples. The time-varying portfolio weights are estimated using Equation 12. From Panel A of the original return series for the pre-COVID subsample, our findings indicate that for a \$1 portfolio, 90.7 cents should be invested in MSCI World EESG and 9.3 cents (1–0.907) should be invested in the S&P500

(conventional assets). Similarly, in terms of time-varying risk minimizing hedge ratios, our findings indicate that an investor with a \$1 long position in EESG should short \$β of conventional assets to minimize the risk of their investment. For instance, from Panel C, the hedge of 0.195 for FTSE Good Global/Gold indicate that an investor with \$1 long position in FTSE Good Global may hedge their position with a 19.5 cents short position in gold. It is important to emphasize that the hedging is rather expensive for financial indices, supporting our earlier findings on the homogeneity and integration of EESG assets with the financial indices. While the spillover and

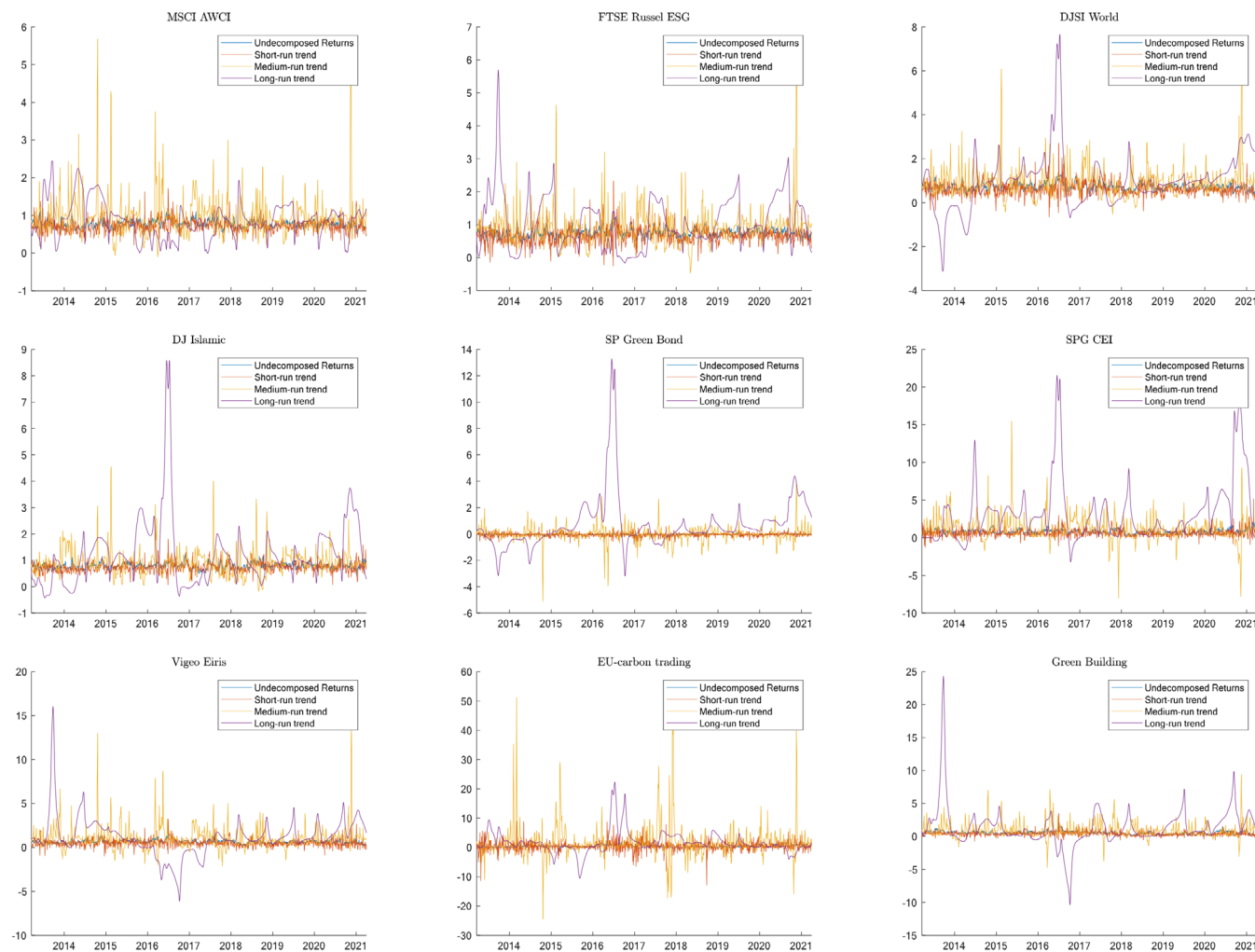


FIGURE 9 Development of hedge ratios over various frequency horizons between US and other assets [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com/doi/10.1002/jfe.2742)]

systemic risk contributions of EESG assets with US to EUR were significantly lower than other assets, the hedge between these assets was more expensive. This may be attributed to significant fluctuation in the exchange rate uncertainty which is instantaneously observed in terms of higher estimates of hedge ratios. The performance of the portfolio strategy over various frequency horizons can be observed from hedge effectiveness (HE) where the higher value indicate superior performance over individual assets. Similar to earlier findings, we observe significantly higher estimates of HE for the commodities and currencies, indicating heterogeneity and superior performance of EESG with these assets. It is important to emphasize that while the hedging is expensive for EESG and currency, the portfolios of these assets also produce superior portfolio uncertainty reduction, thereby favouring the portfolios of these assets over conventional financial indices. Furthermore, the estimates of volatility, skewness, and kurtosis are significantly lower than the

estimates of the unhedged portfolio, indicating lower risk, skewed, and leptokurtic returns.

These findings indicate that the hedge is more expensive for EESG assets and financial indices. In addition, we observe significantly less improvement in HE for these assets. For commodities and exchange rate, we report that it is significantly less expensive to hedge an investment in EESG with the commodities and currencies. Furthermore, the significantly higher estimates of HE for these assets indicate the superior performance of inclusion of EESG with commodities and currencies. These findings are consistent with prior literature reporting the diminishing benefit of utilizing EESG assets with financial indices in a portfolio (Abu-Alkheil et al., 2017; Hkiri et al., 2017; Jain et al., 2019; Rizvi et al., 2015; Yilmaz et al., 2015) and higher benefit of incorporating EESG with commodities and currencies (Mensi et al., 2015). Figure 9 provides the development of time-varying hedge ratios for various investment horizons.⁷

4 | CONCLUSION

Examination of connectedness structure and systemic risk spillovers is important for asset allocation and risk management decisions. With growing digitalization and connectedness of financial assets and commodities, diversification and hedging potential has significantly declined. Furthermore, ethical business practices, climate concerns, human rights, and management structures are becoming integral to investment allocation decisions. In this regard, ethical and sustainable assets has gained significant attention from market participants as an alternative investment to conventional assets. These assets can provide financial stability and diversification benefits, and reduce uncertainty. Therefore, the objective of this study was to evaluate the time-frequency asymmetric connectedness dynamics and downside systemic risk of ethical, environmental, social, and governance assets (EESG) and conventional assets (financial indices S&P500, STOXX, Hang Seng, and Nikkei), commodities (crude oil and gold), and US to EUR exchange rate by utilizing wavelet-based copulas and CoVaR and ΔCoVaR to examine systemic risk.

We found evidence of significantly positive asymmetric connectedness and systemic risk exposure between EESG assets and financial indices, with the exception of S&P green bond. This indicate that the EESG assets exhibit homogeneous characteristics with respect to these indices. However, for the case of S&P green bond, we found weak-to-moderate negative interconnectedness with the financial indices, suggesting portfolio diversification and risk management potential for market participants. With regard to commodities and exchange rates, we found weakly negative to moderately positive connectedness with EESG assets, indicating a great opportunity to capitalize on diversification and risk management benefits. Specifically, we observed that gold can be a safe haven for market participants want to add EESG assets to their portfolios.

Furthermore, in terms of systemic risk measures, we found a significantly lower systemic risk contribution for commodities and currencies with EESG assets that tend to decline with an increase in investment horizon. Regarding optimal portfolio weights, our findings suggest a higher proportion of capital to be allocated in EESG assets compared to conventional assets to avail of diversification benefits. We observed that hedging is expensive for financial indices and EESG assets. Furthermore, we did not observe a significant improvement in hedging efficiency (HE) for the financial indices. However, for commodities and exchange rate, our findings point to significantly cheaper hedging options for market participants which have a long position in EESG and HE suggests significantly lower uncertainty for this portfolio.

These findings have the following important implications for policymakers. First, the tremendous upsurge in the VaR, CoVaR, and ΔCoVaR during the COVID-19 pandemic suggests that policymakers and regulators should systematically review the connectedness dynamics among EESG and conventional assets. Second, in light of the rapid change in the investment environment, it is advisable for policymakers to develop a dynamic roadmap to reduce the vulnerability of EESG investments to extreme shocks. Therefore, introducing more dynamic and comprehensive reforms to reduce the vulnerability of EESG assets to external shocks may enhance the confidence of market participants in EESG assets and add stability and momentum to EESG assets.

In terms of future research, one can explore the time-frequency connectedness of various US sectors with EESG assets to assess the vulnerability of EESG assets to these sectors.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from Datastream (published by Thomson Reuters). Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the authors with the permission of Thomson Reuters.

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ENDNOTES

- ¹ We present the best-suited copula framework. However, the estimates of both symmetric and asymmetric frameworks are available from the corresponding author upon request.
- ² The best GARCH model is chosen from various marginal distributional models (GARCH, EGARCH, GJR-GARCH). However, for brevity, we report only the estimates from the best-suited model. The estimates for alternative models are available upon request.
- ³ For the days of subzero futures price of crude oil, we estimate simple return as: $r_{i,t} = \frac{(P_{i,t} - P_{i,t-1})}{P_{i,t-1}}$.
- ⁴ The risk-free rate for the Sharpe ratio is the T-bill rate. The average annualized risk-free rate is 1%.
- ⁵ We select the optimal marginal distribution model from various types of GARCH (GARCH, GJR-GARCH, EGARCH) frameworks with different specifications and select the optimal marginal distribution model based on the lowest values of the Akaike

Information Criterion (AIC). Based on the AIC, the ARMA(1,0)-EGARCH(1,1) specification with Student-t distribution is the best-suited framework to capture the stylized facts embedded in the return series. For the sake of brevity, we chose not to report the estimates of marginal distribution models. However, these estimates are available from authors upon request.

⁶ We utilize both the static and the time-varying version of Student-t, Gaussian, Clayton, and SJC copula frameworks.

⁷ For the sake of brevity, we chose to report the development of hedge ratios between S&P500 and the EESG assets. However, the figures for all the assets are available from the corresponding author upon request.

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