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Regional Response of Low Carbon Investments to the COVID-19 Pandemic: The Case of Stock Markets in Seeking Carbon Neutrality Goals

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Low carbon investments are significant in climate change and sustainable economic growth. The research considers the impact of the COVID-19 pandemic on low carbon investments using environmental, social, and governance (ESG) factors in different regions to find the correlation between various markets and the impact of the pandemic. Our research employs the method of covariance/correlation analysis to investigate the relationship between low carbon investments in different regions. We also check the main parameters of descriptive statistics. We use the method of bivariate regression analysis to assess the impact of the COVID-19 pandemic on the performance of ESG stock indices in Emerging, European, and Global markets. The main findings reveal that the global prevalence and mortality risk of COVID-19 infection have a significant adverse effect on the performance of Emerging, European, and Global ESG stock markets. In contrast, the effect of COVID-19 cases reported deaths caused by COVID-19 infection to appear to be mixed. Our research shows that the correlation between the European ESG stock market and other ESG markets is exceptionally low or negative in the 1-year horizon. In contrast, tendencies in other markets are similar. So it means that the European ESG stock market is a good tool for diversification and risk mitigation during critical moments. Our results can be used in practice for portfolio management purposes. Institutional and other investors can use these results for low carbon portfolio management and risk mitigation.

Keywords: ESG, stock market, climate change, COVID-19, sustainable and responsible investments (SRI)

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INTRODUCTION

The COVID-19 pandemic can be named a black swan event that stifled the global economy. Unexpectedly emerged, COVID-19 resulted in complete social isolation within different countries and negatively influenced everyday life and business (resulting in employment and industry-wide shutdowns), causing many more adverse economic effects. The coronavirus pandemic and quarantine measures dramatically shocked the global economy with the deepest production slump since World War II. All scenarios of Covid's impact, which is modeled by experts, on the economy are pessimistic. The pandemic claimed many human and economic sacrifices, in the total sense of the word: a high number of deaths lost jobs and employees, closed businesses, and collapsing

economies. Macrofinancial measures designed to support a sustainable economy, applied too late or inappropriately, can increase social inequality and income imbalances. In some countries, exceptionally high public dissatisfaction is caused by the tightening of the second wave of COVID-19: There is more than just social discontent and racial unrest (Harris and Missy, 2020).

The current pandemic is a real test for the world economy and institutions of regulation of the global economy. Lots of researchers (e.g., McKibbin and Fernando, 2020; Bouey, 2020; Levine, 2020; Bakas and Triantafyllou, 2020; De Grauwe, 2020; Beck, 2020; Zandi, 2020; Abiad et al., 2020, Ramelli and Wagner, 2020; Lee, 2020) analyze and find the impact of the COVID-19 pandemic on the economy and other spheres. For example, some authors (Jordà et al., 2020) compare the COVID-19 pandemic issues with other crises. Studies that analyze the possible economic consequences of COVID-19 for world trade, economies of individual countries (Bouey, 2020), and separate sectors of the economy have appeared in a brief time (Levine, 2020).

Increased financial markets' volatility reflected difficulties in estimating the extent of the economic damage and predicting the situation's development, and the downturn's consequences could be felt over many years. COVID-19 shock could be compared to the 2007–2008 Great Financial Crisis. Despite its impact caused to financial markets, no doubt being evident and significant. This recent phenomenon should be researched in more detail.

Despite high volatility in stock markets and a big economic shock due to the COVID-19 pandemic, the importance of climate change and sustainable economic growth cannot be forgotten. Climate change now is a topic that must be discussed a lot because it significantly affects people's broad economy, community, and lives. Every day we can hear lots of announcements about natural disasters leading to losses. About half of the losses are insured. However, most of the losses are taken by others. Climate change is a significant risk that must be managed. The growing trend of catastrophic events forces us to be involved in this process and lowers the negative effect of climate change. Climate change plays a crucial role in our lives and strongly impacts economics. Climate change becomes a source of financial risk, and exposure to this type increases every day as the number of catastrophic events grows every minute. Financial institutions must take active action in risk management by adding value to the activities that lower climate risk. Central banks play an especially crucial role in the financial system; therefore, these institutions should take responsibility for climate risk mitigation. All the mentioned financial institutions.

Some authors analyze sustainability and environmental, social, and corporate governance (ESG) factors issues related with a business level and focus on the effects to company value and financial results (Egorova et al., 2022; Saygili et al., 2022; Engelhardt et al., 2021; Abdi et al., 2020; Badía et al., 2020; Bhaskaran et al., 2020; Buallay, 2020; Cordazzo et al., 2020; Drempetic et al., 2020; Garcia and Orsato, 2020; Hoang et al., 2020; Jamprasert et al., 2020; Li and Wu, 2020; Modugu, 2020; Oehmke and Opp, 2020; Oprean-Stan et al., 2020; Peng and Isa, 2020; Rajesh and Rajendran, 2020; Sabatini, 2020; Sadiq et al., 2020; Schumacher et al., 2020; Sharma et al., 2020; Sichigea et al., 2020; Tampakoudis and Anagnostopoulou, 2020; Tommaso and Thornton, 2020; Veenstra and Ellemers, 2020; Widyawati, 2020; Larcker and Watts, 2020; Mukanjari and Sterner, 2020; Palma-Ruiz et al., 2020; Pasquini, 2020), while others try to investigate the risks, benefits, and challenges related with investments in financial instruments, especially stock and bond markets (Aw et al., 2020; Amanjot, 2020; Andrew, 2020; Ardia et al., 2020; Cunha et al., 2020; Dorfleitner et al., 2020; Engle et al., 2020; Fiskerstrand et al., 2020; Garefalakis and Dimitras, 2020; Glossner et al., 2020; Gougler and Utz, 2020; Hübel and Scholz, 2020; Jens, 2020; Kaiser, 2020; Kocmanová et al., 2020; Krueger et al., 2020; Meher et al., 2020; Mercereau et al., 2020; Mercedes, 2020; Mirchandani and Rossetti, 2020; Ng and Rezaee, 2020; Rehman and Vo, 2020; Rui et al., 2020; Siri and Zhu, 2020; Vostrikova and Meshkova, 2020; Yongjun and Yupu, 2020; Zaghum et al., 2020; Ziolo et al., 2020; Khajenouri and Schmidt, 2021; Adams and Abhayawansa, 2022). Our research contributes to those scientific works related to investments, but we add more value to COVID-19 pandemic analysis and find regional stock market responses. We think that this study will help to take investment decisions having in mind regional aspects as we try to show the correlation between different markets in the COVID-19 pandemic.

Empirical studies are more focused on the country level. Studies related to China and US financial markets are oriented to investigate movements in the Shanghai Stock Exchange and New York Stock Exchange. These results make it possible to conclude the existing positive and robust relationship between fluctuations in analyzed financial markets and the number of confirmed COVID-19 cases (Sansa, 2020).

This study fills the gap in the research on the regional level. It gives a broad view of ESG investments, including Emerging Markets, Europe, and Global markets, as it is essential for institutional investors in COVID-19. Our research problem is whether low-carbon investments' performance varies among different regions? Lately, lots of low carbon investment options have been launched, and these investments demonstrate excellent performance compared to traditional investments. Financial institutions and retail investors can use different funds to achieve their maximum goals of seeking carbon neutrality.

This research will help institutional investors such as pension funds, central banks, and other financial institutions mitigate market risk using regional factors. Institutional investors usually do not take a company-level risk and implement investment strategies using more diversified instruments. So focusing on low or negative correlation markets, institutional investors will be able to manage market risk in a sustainable and responsible stock market.

The relevance and popularity of sustainable and responsible investments get more popular every day. Everyone must add value to lower climate risk because human emissions of carbon dioxide and other greenhouse gases can be considered the key driver of climate change. Numbers show that global temperatures have risen sharply over the last few decades, and the main concern is how to solve the problem not to increase climate

risk in the future. The relevance of this topic increased a lot during the pandemic period. Lots of financial institutions started to add value to climate risk management. Central banks started to work on this issue more actively, implementing socially responsible investments into their strategies. Still, at the same time, financial institutions faced significant issues in managing market risk and portfolio diversification challenges and how to implement new investments into the existing investment portfolio.

Financial institutions must take an active role in stopping climate change. Sustainable and responsible investments play a crucial role in adding value for taking efforts to decrease climate risk worldwide. Lots of financial intermediaries take part in risk management.

Different authors have analyzed if sustainable and responsible investments can generate higher profitability compared to investments not having sustainability and responsibility factors. But despite the mentioned facts, sustainable investments are getting more popular day by day. Analyzing investments, we usually have a return, which can be achieved by taking a risk position. Yue et al. (2020) found no unmistakable evidence confirming that sustainable funds can generate higher returns than traditional piers or benchmark indexes. Let's consider participation in climate risk management and adding value to climate change. We cannot think only about profit factors and can just pay more attention to social factors. Lewis and Juravle (2010) pointed out that sustainable investments got popularity because of "the profitability of investments, company scandals, globalization, geophysical and environmental changes, changes in public opinion, political climate." Kurtz (2020) found that "approximately 50% of assets under management (AUM) in Europe, Canada, and Australia were managed under a responsible investment policy." The numbers increase every day. Due to reputational risk management, SRI investments attracted more attention from institutional investors. Urwin et al. (2009) pointed out that "sustainable investment can help pension funds and other financial institutions use a more effective portfolio management style."

McKibbin and Fernando's (2020) research is one of the earliest systematic studies of the potential economic cost of COVID-19. The authors explored scenarios of the impact of a pandemic on the macroeconomic and financial markets. They suggested that even a controlled short-term outbreak significantly impacts the global economy. The result of the COVID-19 pandemic is previously unknown intense mixed and negative shock of supply and demand, harming production. As it is argued by De Grauwe (2020), double-shocks will lead to multiple "domino effects." Companies with high fixed costs face bankruptcy, wherefore banks lending to these companies will also experience severe problems and difficulties, which makes a banking crisis possible. Abiad et al. (2020) show the main channels of influence of COVID-19: a temporary decline in domestic consumption and investment, shrinkage of the tourism, manufacturing, and trade sectors, supply overruns, health consequences, and changed expenditures on health care.

A direct sign of the economic impact of the pandemic is a loss of trust from consumers and investors. Rational anticipation of future COVID-19 cases and the associated impact on the economy and society are among the most reasonable arguments for this rapid and sharp market decline. Ramelli and Wagner (2020), using a sector-level decomposition of stock price moves, argue that markets initially focused on the trade impact of the pandemic, also suggesting concerns about supply chains. Having analyzed the first impact of COVID-19 sentiment on the US stock market, Lee (2020) notes that the impact of COVID-19 varies depending on the industry. Mamaysky (2020) argues that the information environment played a first-order role in markets' crisis response—the crucial influence of innumerable headlines in mass media results in adverse investors' expectations. Considering that in February and March 2020, reliable data on the real coronavirus pandemic's economic impact were not available, speculations "about future disastrous economic consequences and associated negative impacts on corporate profitability" (Mamaysky, 2020) significantly affected investors' sentiment. Recent research concerns the impact of this pandemic on the global financial sector. It claims that adverse effects of tax capacity in the financial system will not occur at once. Therefore, there is time to make justified decisions (Beck, 2020; Zandi, 2020). However, side effects in the markets are sudden. As a result, it is necessary to focus on potential financial system disruptions and combine confidence in financial markets.

As this topic is among the most discussed topics nowadays, it is exciting to analyze how sustainable and responsible investments were affected by the COVID-19 pandemic. We think that all the scientists agree that the COVID-19 pandemic strongly influences the economy, but what about the stock market when we see new highs in some regions and what about sustainable and responsible investments. There are scientific works analyzing the impact of COVID-19 on the stock market in broad (e.g., Lööf et al., 2022; Lee, 2020; Albulescu, 2020a; Albulescu, 2020b; Ashraf, 2020; Al-Awadhi et al., 2020; Bloom et al., 2005; Demers et al., 2020; Ding et al., 2020; Dottling and Kim, 2020; Kapecki et al., 2020; Zhang et al., 2020, Zaremba et al., 2020; Czech et al., 2020, and Akhtaruzzaman et al., 2022), but there is a lack of scientific discussions relating to the impact on sustainable investments in the field of the stock market in different regions. Lately, we can find some more research made on ESG investments and COVID pandemic in specific countries. Jun et al. (2022) analyzed China market, and Takahashi and Yamada (2021) focused on Japanese stock market. Korean stock market using social responsible factors was analyzed by Lee et al. (2022). Pisani and Russo (2021) made a research on ESG funds having MSCI Europe index as a benchmark.

The primary purpose of this research is to find if the COVID-19 pandemic impacted sustainable and responsible investments and if there were any differences in different regions, including Emerging Markets, Europe, and Global markets.

We add value to the scientific literature by analyzing the impact of the COVID-19 pandemic impact on sustainable and responsible investments in different regions. Our results showed lots of differences between ESG investments in Emerging, European, and Global ESG stock markets during the COVID-19 pandemic and that the best choice for the highest diversification effect is the European ESG stock market.

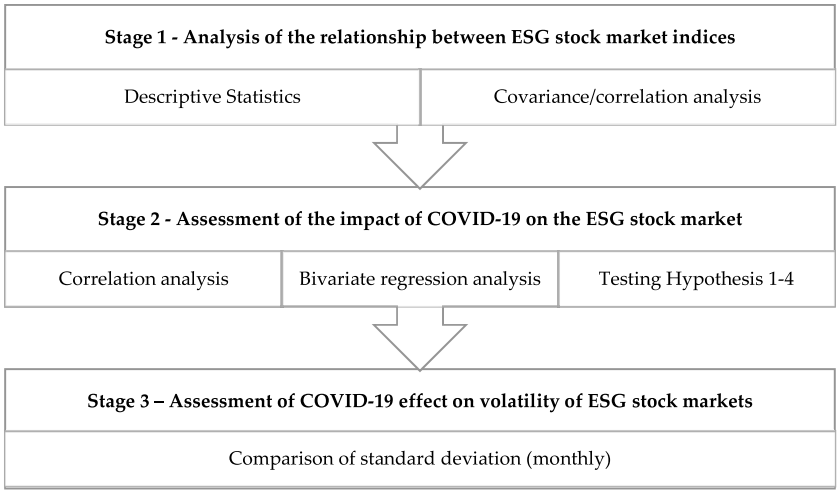

FIGURE 1 | Research design.

Hence, our research expanded the list of critical literature about sustainable and responsible investments valuing the impact of the COVID-19 pandemic and considering the factor of different regions.

This article consists of three parts. Firstly, we reviewed different scientific works to find what has been done till now. Secondly, we presented methodological issues. Our methodology calculates descriptive statistics parameters, applies covariance/correlation analysis, and uses bivariate regression analysis. Finally, we discussed our results using stock market indices in different regions. Our main results show that the European ESG stock market is a good tool for diversification and risk mitigation during critical moments. Our results can be used in practice for portfolio management purposes. Institutional and other investors can use these results for SRI portfolio management and risk mitigation.

RESEARCH FRAMEWORK

Main Variables and Development of Hypotheses

This research consists of three stages: 1) analysis of the relationship between selected ESG stock market indices, 2) analysis of the impact of COVID-19 on the ESG stock market, and 3) assessment of COVID-19 effect on the volatility of ESG stock markets, which will be discussed in detail. The research design is summarized in **Figure 1**.

For the empirical analysis, we used daily data of four stock market indices: S&P Emerging LargeMidCap E.S.G. Index, S&P Global 1200 ESG Index, S&P Europe 350 ESG Index, and S&P Global LargeMidCap E.S.G. Index. The choice of indices is because: 1) they are broad-based indices measuring the performance of securities from the underlying index that meet the sustainability criteria (S&P Dow Jones Indexes, 2020); 2) the choice of indices allows to analyze ESG investments in different regions, that is, Emerging, Europe, and Global markets. We used different periods to measure descriptive statistics parameters together with correlation and covariance between indices. We have chosen the other period to find the impact of COVID-19 on ESG stock market indices.

The sample covers the period from January 2020 to September 2020.

Data of stock market indices are retrieved from Reuters. In contrast, COVID-19-related data such as confirmed cases of infection, confirmed deaths, countries affected, case fatality rates, etc., are collected from World Health Organisation Coronavirus disease (COVID-19) situation reports (WHO, 2020) and the website of the European Centre for Disease Prevention and Control (ECDC, 2020).

To find the impact of COVID-19 on ESG stock market indices, four dependent and twenty independent (COVID-19 related) variables are collected (**Table 1**), the choice of which is based on the analysis of scientific literature and criteria of data availability.

In addition, for a more detailed assessment of ESG stock markets' reaction to the spread of COVID-19 infection, all the above variables (except the number of countries affected) are analyzed from four geographical perspectives: 1) China, 2) Europe, 3) the rest of the world excluding China, and 4) global perspective.

First, this research intends to investigate whether the geographical spread of COVID-19 infection affects ESG stock markets. As a significant number of researches showed negative (at least primary) response of the financial markets to the spread of the COVID-19 pandemic [e.g., Ashraf (2020); Al-Awadhi et al. (2020); Zhang et al. (2020); Czech et al. (2020); Albulescu (2020a); Zaremba et al. (2020) and others], our research intended to check in the direction of the reaction of ESG stock markets was the same (null and alternative hypotheses are described in **Supplementary Appendix SA3**). Based on the results of the literature analysis, the first hypothesis of this research is formulated as follows:

TABLE 1 | Variables of a regression model, abbreviations, and description.

Variable		Description
Abbreviation	**Full name**	
Dependent variables	—	—
SPELMUPt	S&P Emerging LargeMidCap ESG Index USD	SPELMUPt is a composite index of S&P Europe Emerging, Latin-America Emerging, Mid-East, and Africa Emerging, Asia Pacific Emerging LargeMidCap E.S.G. subindices for a period t
SPEESUPt	S&P Europe 350 ESG Index USD	SPEESUPt is an index consisting of 350 leading ESG companies from developed European markets for a period t
SPGESUPt	S&P Global 1200 ESG Index USD	SPGESUPt is an index consisting of 1222 ESG companies from 7 distinct regions and 30 countries for a period t
SPLESGUPt	S&P Global LargeMidCap ESG Index USD	SPLESGUPt is a composite index of S&P Europe Developed, Mid-East and Africa Developed, Asia Pacific Developed, Europe Emerging, Latin America Emerging, Mid-East, and Africa Emerging, Asia Pacific Emerging LargeMidCap E.S.G. subindices for a period t
Independent variables	—	—
CAt	Countries affected	CAt is measured by several countries that have confirmed coronavirus cases for a period t
NCwt	New cases world	NCwt is measured by the number of new cases of coronavirus reported in a world since the previous day for a period t (a number of cases per day)
TCwt	Total cases world	TCwt is measured by the number of total cases of coronavirus reported in a world for a period t (a cumulative number of cases)
NDwt	New deaths world	NDwt is measured by the number of new deaths caused by coronavirus reported in a world since the previous day for a period t (a number of deaths per day)
TDwt	Total deaths world	TDwt is measured by the number of total deaths caused by coronavirus reported in a world for a period t (a cumulative number of deaths)
FRwt	Case fatality rate world	FRwt is measured by a ratio between confirmed deaths and confirmed cases in a world for a period t (percent)
NCct	New cases China	NCct is measured by the number of new cases of coronavirus reported in China since the previous day for a period t (a number of cases per day)
TCct	Total cases China	TCct is measured by the number of total cases of coronavirus reported in China for a period t (a cumulative number of cases)
NDct	New deaths China	TDct is measured by the number of total deaths caused by coronavirus reported in China for a period t (a cumulative number of deaths)
TDct	Total deaths China	TDct is measured by the number of total deaths caused by coronavirus reported in China for a period t (a cumulative number of deaths)
FRct	Case fatality rate China	FRct is measured by a ratio between confirmed deaths and confirmed cases in China for a period t (percent)
NCect	New cases excl. China	NCect is measured by a number of new cases of coronavirus reported in a world excluding China since the previous day for a period t (a number of cases per day)
TCect	Total cases excl. China	TCect is measured by the number of total cases of coronavirus reported in a world excluding China for a period t (a cumulative number of cases)
NDect	New deaths excl. China	TDect is measured by the number of total deaths caused by coronavirus reported in a world excluding China for a period t (a cumulative number of deaths)
TDect	Total deaths excl. China	TDect is measured by the number of total deaths caused by coronavirus reported in a world excluding China for a period t (a cumulative number of deaths)
NCet	New cases Europe	NCet is measured by the number of new cases of coronavirus reported in Europe since the previous day for a period t (a number of cases per day)
TCet	Total cases Europe	TCet is measured by the number of total cases of coronavirus reported in Europe for a period t (a cumulative number of cases)
NDet	New deaths Europe	TDet is measured by the number of total deaths caused by coronavirus reported in Europe for a period t (a cumulative number of deaths)
TDet	Total deaths Europe	TDet is measured by the number of total deaths caused by coronavirus reported in Europe for a period t (a cumulative number of deaths)
FRet	Case fatality rate Europe	FRet is measured by a ratio between confirmed deaths and confirmed cases in Europe for a period t (percent)

Source: Compiled by the authors.

Hypothesis 1: The global prevalence of COVID-19 infection has a significant negative effect on the performance of the ESG stock market indices.

To assess the geographical spread of COVID-19 infection, some researchers (e.g., Albulescu, 2020a) use the number of countries affected by COVID-19, that is, the number of countries that have reported at least one case on a given day. Therefore, to evaluate the global prevalence of COVID-19 infection, the number of countries with confirmed infection cases (CAt) is used.

Secondly, in our research, we sought to determine whether and how the ESG stock markets are responding to the increase in the number of confirmed COVID-19 cases and deaths.

Thus, the second and third hypotheses are formulated as follows:

Hypothesis 2: The number of cases of COVID-19 confirmed has a significant adverse effect on the performance of the ESG stock market indices.
Hypothesis 3: The number of deaths caused by COVID-19 reported has a significant adverse effect on the performance of the ESG stock market indices.

It is important to note that researchers select different measures to estimate the growth of COVID-19 infections and deaths. For instance, Ashraf (2020), Al-Awadhi et al. (2020), Zhang et al. (2020), and Czech et al. (2020) have used the number of total cases and total deaths, while Albulescu (2020a) and Zaremba et al. (2020) have used the measure of new cases and new deaths reported. We are given in mind that the market can react differently to the change of daily numbers and cumulative numbers; in our research, we decided to use both approaches.

Therefore, in this research, the measures of the number of new cases of COVID-19 reported per day, and the total number of COVID-19 cases confirmed in China, Europe, the rest of the world excluding China, and globally (NCc_t, NCe_t, $NCec_t$, NCw_t; *and* TCc_t, TCe_t $TCec_t$, TCw_t, respectively); and the measures of the number of new deaths caused by COVID-19 reported per day, and the total number of deaths caused by COVID-19 reported in China, Europe, the rest of the world excluding China, and globally (NDc_t, NDe_t, $NDec_t$, NDw_t; *and* TDc_t, TDe_t $TDec_t$, TDw_t, respectively) are used.

Finally, it was essential to find whether the changes in COVID-19 mortality risk affect the performance of ESG stock markets, which is why the fourth hypothesis of our research is formulated as follows:

Hypothesis 4: Mortality risk of COVID-19 infection has a significant negative effect on the performance of the ESG stock market indices.

To estimate the actual mortality rate, we need to know the number of actual (not reported) closed cases and the number of related deaths. As these estimates are unknown due to the asymptomatic manifestation of COVID-19 and many unclosed cases, we decided to analyze the current data, that is, reported cases and deaths, as suggested by researchers (Albulescu, 2020a; Ritchie and Roser, 2020). Taking this into account, to evaluate the mortality risk, the measure of COVID-19 case fatality rate is used in this research and measured as a ratio between confirmed deaths and confirmed cases in China (FRc_t), in Europe (FRe_t), and globally (FRw_t).

These variables are further analyzed using the methods of descriptive statistics, correlation, and regression analysis. To support or reject research hypotheses, the method of bivariate regression analysis and the estimates of t statistics and *p*-values of the created models were used. For this purpose, the significance level (α) is set to 0.05 (5%).

Descriptive Statistics

In our research, we tried to find the volatility of different indices. For volatility calculation, we used standard deviation. The formula of standard deviation is shown below:

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(r_i - \bar{r})^2}, \tag{1}$$

In **Eq. (1)** r_i denotes returns in every period, and n denotes the total number of periods in a year.

Different scientific works confirm that fund returns, compared with the returns of other securities, do not have normal distributions. Jondeau, E. et al. stressed that "asset returns do not behave according to the bell-shaped curve, associated with the Gaussian or normal distribution." This creates risks of "higher moments."

Further in our research, we used skewness and kurtosis measures to find tail risk. As explained in the literature, skewness can be described as the degree of distortion from the symmetrical normal distribution, while kurtosis can be found as a tool for heavy-tailed or light-tailed distribution identification.

Skewness is defined as

$$S = \frac{1}{n}\frac{\sum_{i=1}^{n}(r_i - \bar{r})^3}{\sigma^3} \tag{2}$$

Kurtosis is defined as

$$E_k = \frac{1}{n}\frac{\sum_{i=1}^{n}(r_i - \bar{r})^4}{\sigma^4} - 3 \tag{3}$$

In **Eqs (2)**, **(3)**, r_i points the return in a period i, $\bar{r}$ denotes the mean, and n denotes the number of days in a year, while σ denotes the standard deviation of returns.

To show the main characteristics of descriptive statistics and to check data distribution, we use data from 2 September 2019, till 1 October 2020. The period was selected quite short just to look at broad tendencies as the main goal of this research was to concentrate on time related to the COVID-19 pandemic.

Looking at the correlation matrix (**Table 3**), we can see a strong positive correlation between ESG investments in Emerging markets and ESG investments in Global markets (indices: S&P Emerging LargeMidCap E.S.G. Index, S&P Global 1200 ESG Index, S&P Europe 350 ESG Index, S&P Global LargeMidCap E.S.G. Index). Nevertheless, the most interesting fact in the correlation matrix is that we have a negative correlation between the European ESG investments and Emerging markets ESG investments. Also, we would like to pay attention to the fact that the correlation between the European ESG market and Global markets is positive but exceptionally low. Therefore, we can conclude that the European ESG market might be suitable for SRI portfolio management diversification purposes.

Data in **Figure 2** show that the European ESG market is a bit different in the period we are analyzing as the index standing for this market does not have outliers, and we see that the median is equal to the mean of the distribution, which shows that the data have a normal distribution shape and skewness and confirm normal distribution as its level is incredibly low (see **Table 2**).

TABLE 2 | Descriptive statistics.

	S&P emerging large MidCap ESG index	S&P Europe 350 ESG index	S&P global 1200 ESG index	S&P global large MidCap ESG index
Mean	84.41735	737,501.0	182.9283	171.2355
Median	86.74550	737,501.0	186.0699	174.5551
Maximum	95.63470	737,698.0	205.9576	192.2467
Minimum	62.79030	737,303.0	133.7536	124.8159
Std. Dev	7.190898	115.6798	14.00505	13.30299
Skewness	−0.850651	−0.014086	−1.037183	−1.057011
Kurtosis	2.960240	1.785621	3.881289	3.831042
Jarque-Bera	33.66613	17.15280	59.05109	59.98172
Probability	0.000000	0.000189	0.000000	0.000000
Sum	23,552.44	2.06E+08	51,036.98	47,774.72
Sum Sq. Dev.	14,375.11	3,720,147	54,527.29	49,197.53
Observations	279	279	279	279

TABLE 3 | Covariance and correlation.

Covariance	S&P emerging large MidCap ESG index	S&P Europe 350 ESG index	S&P global 1200 ESG index	S&P global large MidCap ESG index
S&P emerging large MidCap ESG index	51.52368	—	—	—
S&P Europe 350 ESG index	−134.7783	13,333.86	—	—
S&P global 1200 ESG index	91.75227	195.2416	195.4383	—
S&P global large MidCap ESG index	90.11551	130.6399	182.0577	176.3352
Correlation	S&P emerging large MidCap ESG index	S&P Europe 350 ESG index	S&P Global 1200 ESG index	S&P global large MidCap ESG index
S&P emerging large MidCap ESG index	1.000000	—	—	—
S&P Europe 350 ESG index	−0.162607	1.000000	—	—
S&P global 1200 ESG Index	0.914342	0.120945	1.000000	—
S&P global large MidCap ESG Index	0.945424	0.085198	0.980696	1.000000

Regression Model Specification

The second step of analysis is to assess the impact of COVD-19 on ESG stock market indices. Firstly, correlation analysis is conducted. Secondly, bivariate linear regression models (least squares), examining the changes of dependent variables (ESG stock market indices) as the functions of each independent (COVID-19 related) variable, are constructed (**Eq. (4)**).

$$I_n = \alpha + \beta IndVar_k + \varepsilon \quad (4)$$

In this model, α corresponds to constant, n = 1 to 4 and corresponds to ESG market indices, k = 1 to 20 and corresponds to independent (COVID-19 related) variables (see **Table 1**), and ε corresponds to error. Thus, for each of the four selected ESG stock market indices, 20 bivariate linear regression models are constructed.

The descriptive statistics of dependent and independent variables are provided in **Table 4**. The dynamics of those variables are depicted in **Supplementary Appendix SA1**.

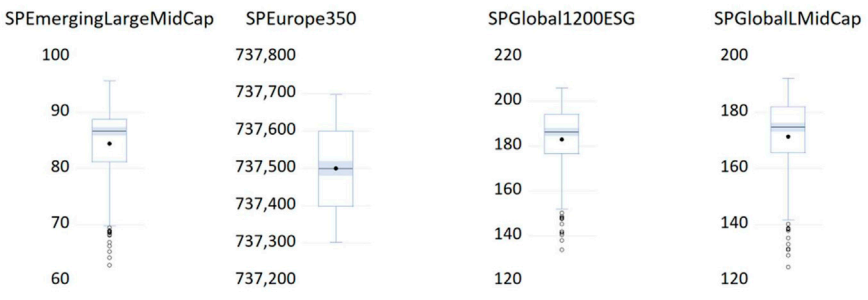

FIGURE 2 | Dynamics of ESG indices, data source Bloomberg.

TABLE 4 | Summary of descriptive statistics of model variables.

Variable	Observations	Minimum	Maximum	Mean	Median	Standard deviation
SPELMUPt	198	62.7903	95.6347	83.2953	86.1895	8.0426
SPEESUPt	195	85.2927	132.7510	115.4575	117.9002	11.8091
SPGESUPt	197	133.7536	205.9506	182.7190	187.5191	16.3329
SPLESGUPt	198	124.8159	192.2467	170.8402	175.3357	15.4752
CAt	198	1.0000	215.0000	160.6313	210.0000	82.1481
NCwt	198	0.0000	321,140.0	12,141.1	90,000.00	105,355.0
TCwt	198	27.0000	340,444,333	8,944,402	4,545,000	10,274,637
NDwt	198	0.0000	10,489.00	3679.833	4159.500	2665.414
TDwt	198	0.0000	1,015,224	354,499.8	308,248.0	335,196.1
FRwt	182	1.2500	7.300	4.4150	3.9700	1.5497
NCct	198	0.0000	15,141.00	347.5354	33.0000	1285.267
TCct	198	27.0000	90,528.000	72,332.46	84,041.50	28,807.95
NDct	198	0.0000	1290.0000	18.8333	0.0000	96.2430
TDct	198	0.0000	4739.000	3548.919	4637.500	1659.394
FRct	182	1.2800	5.5400	4.6846	5.3000	1.1179
NCect	198	0.0000	321,125.0	120,793.6	89,996.00	105,685.6
TCect	198	0.0000	33,953,905	8,872,070	4,460,959	10,260,909
NDect	198	0.0000	104,890.00	3661.000	4158.000	2670.543
TDect	198	0.0000	1,010,485	350,950.8	303,610.5	334,020.2
NCet	198	0.0000	75,797.00	18,730.80	16,284.00	16,094.05
TCet	198	0.0000	5,055,085	1,655,091	1,652,220	1,464,157
NDet	198	0.0000	5028.000	807.2525	377.5000	1101.183
TDet	198	0.0000	222,920.0	115,963.1	160,159.0	88,700.95
FRet	158	1.6700	10.3400	7.0153	7.2500	2.2269

Note: SPELMUPt, S&P Emerging LargeMidCap ESG, Index USD; SPEESUPt, S&P Europe 350 ESG, Index USD; SPGESUPt, S&P Global 1200 ESG, Index USD; SPLESGUPt, S&P Global LargeMidCap ESG, Index USD; CAt, countries affected; NCwt, new cases world; TCwt, total cases world; NDwt, new deaths world; TDwt, total deaths world; FRwt, case fatality rate world; NCct, new cases China; TCct, total cases China; NDct, new deaths China; TDct, total deaths China; FRct, case fatality rate China; NCect, new cases excl. China; TCect, total cases excl. China; NDect, new deaths excl. China; TDect, total deaths excl. China; NCet, new cases Europe; TCet, total cases Europe; NDet, new deaths Europe; TDet, total deaths Europe; FRet, case fatality rate Europe (see ***Table 1****).*

Analysis of the dynamics of COVID-19 related variables and ESG stock market indices reveals that the strongest adverse reaction of ESG stock market indices to COVID-19 is seen in March 2020–April 2020, while in the following periods investigated, such reaction is no longer clearly expressed (see **Supplementary Appendix SA1**). For this reason, a more detailed analysis is needed, the results of which are presented in the next section.

RESULTS AND DISCUSSION

Correlation Between COVID-19 and the Performance of ESG Stocks

To access the effect of COVID-19 on the performance of securities meeting ESG criteria (measured by four ESG stock market indices) during the selected timeframe (01/01/2020–30/09/2020); period t = 1 . . . 198), at the first step, the correlation analysis of selected variables is conducted (see **Table 5**).

Based on the results of **Table 5** (correlation coefficients and probabilities), it can be said that:

1) Only three COVID-19-related variables [number of countries affected (*CAt*), number of new deaths confirmed per day in China (*NDct*), and number of new cases confirmed per day in Europe (*NCet*)] are not statistically related to the performance of Emerging and European ESG stock markets (S&P Emerging LargeMidCap E.S.G. and S&P Europe 350 ESG indices) (proved to be insignificant), while even 17 variables are statistically significant (99% or 95% confidence level) related to the performance of Emerging and European ESG stock markets, 14 of them directly and only 3 (fatality rate in world (*FRwt*), number of new deaths confirmed per day in Europe (*NDet*) and fatality rate in Europe (*FRet*)) inversely;
2) Only two COVID-19-related variables (number of new deaths per day and total deaths in China (*NDct* and *NCct,* respectively) are not statistically related to the performance of global ESG stock markets (S&P Global 1200 ESG and S&P Global LargeMidCap E.S.G. indices), while 18 variables are statistically significant related to global indices, 15 of them directly, while only 3 (fatality rate in world (*FRwt*), number of new deaths confirmed per day in Europe (*NDet*) and fatality rate in Europe (*FRet*)) inversely.

As we can see, the results of correlation analysis revealed an inverse relationship between the performance of Emerging, Europe, and Global ESG stock markets and: 1) the number of deaths caused by COVID-19 infection in Europe, and 2) COVID-19 mortality risk in Europe and globally.

To get a clearer view of COVID-19 effect on the performance of Emerging, European, and Global ESG stock markets, the regression analysis is further performed. To assess the impact

TABLE 5 | Correlation of selected financial market indices and COVID-19 related variables.

Variable	Correlation	Probability	Correlation	Probability	Correlation	Probability	Correlation	Probability
—	SPELMUPt		SPEESUPt		SPGESUPt		SPLESGUPt	
CA_t	0.0136	0.8652[a]	0.0044	0.9561[a]	0.1811	0.0228[b]	0.1706	0.0321[b]
NCw_t	0.7139	0.0000[c]	0.6598	0.0000[c]	0.7737	0.0000[c]	0.7734	0.0000[c]
TCw_t	0.7287	0.0000[c]	0.6695	0.0000[c]	0.7879	0.0000[c]	0.7897	0.0000[c]
NDw_t	0.1745	0.0283[b]	0.1766	0.0265[b]	0.3064	0.0001[c]	0.2969	0.0002[c]
TDw_t	0.7445	0.0000[c]	0.6978	0.0000[c]	0.8255	0.0000[c]	0.8252	0.0000[c]
FRw_t	–0.6492	0.0000[c]	–0.5722	0.0000[c]	–0.5230	0.0000[c]	–0.5361	0.0000[c]
NCc_t	0.2151	0.0066[c]	0.2465	0.0018[c]	0.0949	0.2354[a]	0.1002	0.2105[a]
TCc_t	0.5865	0.0000[c]	0.5320	0.0000[c]	0.6959	0.0000[c]	0.6928	0.0000[c]
NDc_t	–0.0555	0.4885[a]	–0.0455	0.5715[a]	–0.0556	0.4875[a]	–0.0575	0.4733[a]
TDc_t	0.3945	0.0000[c]	0.3853	0.0000[c]	0.5462	0.0000[c]	0.5375	0.0000[c]
FRc_t	0.3006	0.0001[c]	0.3070	0.0001[c]	0.4518	0.0000[c]	0.4419	0.0000[c]
$NCec_t$	0.7136	0.0000[c]	0.6594	0.0000[c]	0.7734	0.0000[c]	0.7731	0.0000[c]
$TCec_t$	0.7288	0.0000[c]	0.6695	0.0000[c]	0.7879	0.0000[c]	0.7897	0.0000[c]
$NDec_t$	0.1774	0.0283[b]	0.1789	0.0245[b]	0.3095	0.0001[c]	0.3000	0.0001[c]
$TDec_t$	0.7449	0.0000[c]	0.6581	0.0000[c]	0.8257	0.0000[c]	0.8252	0.0000[c]
NCe_t	0.1249	0.1148[a]	0.0974	0.2233[a]	0.2380	0.0026[c]	0.2369	0.0027[c]
TCe_t	0.6867	0.0000[c]	0.6475	0.0000[c]	0.7849	0.0000[c]	0.7837	0.0000[c]
NDe_t	–0.6696	0.0000[c]	–0.6271	0.0000[c]	–0.5911	0.0000[c]	–0.5991	0.0000[c]
TDe_t	0.6026	0.0000[c]	0.5913	0.0000[c]	0.7342	0.0000[c]	0.7281	0.0000[c]
FRe_t	–0.3660	0.0000[c]	–0.3071	0.0001[c]	–0.2056	0.0095[c]	–0.2205	0.0054[c]

[a]*Insignificant.*
[b]*95% c.l.*
[c]*99% c.l.,*

Note: SPELMUPt, S&P Emerging LargeMidCap ESG Index USD; SPEESUPt, S&P Europe 350 ESG Index USD; SPGESUPt, S&P Global 1200 ESG Index USD; SPLESGUPt, S&P Global LargeMidCap ESG Index USD; CAt, countries affected; NCwt, new cases world; TCwt, total cases world; NDwt, new deaths world; TDwt, total deaths world; FRwt, case fatality rate world; NCct, new cases China; TCct, total cases China; NDct, new deaths China; TDct, total deaths China; FRct, case fatality rate China; NCect, new cases excl. China; TCect, total cases excl. China; NDect, new deaths excl. China; TDect, total deaths excl. China; NCet, new cases Europe; TCet, total cases Europe; NDet, new deaths Europe; TDet, total deaths Europe; FRet, case fatality rate Europe (see ***Table 1****). Model Const. = model constant; Coef. = coefficient; p-Stat = p-Statistics; Observ. = observations.*

TABLE 6 | Bivariate regression models for COVID-19 effect on S&P Emerging LargeMidCap E.S.G. Index.

Variable	Model Const.	Coef	t-stat	*p*-value	R	Observ.
CA_t	91.2446	–0.0495	–8.2016	0.0000[a]	0.2555	198
NCw_t	81.7591	1.27 e-05	2.3585	0.0193[b]	0.0276	198
TCw_t	81.2259	2.31 e-07	4.3316	0.0000[a]	0.0874	198
NDw_t	86.4701	–0.0009	–4.1773	0.0000[a]	0.0818	198
TDw_t	81.3799	5.40 e-06	3.2357	0.0014[a]	0.0507	198
FRw_t	98.5307	–3.6181	–14.3058	0.0000[a]	0.5320	182
NCc_t	82.7832	0.0015	3.3920	0.0008[a]	0.0554	198
TCc_t	93.2176	–0.0001	–7.8981	0.0000[a]	0.2414	198
NDc_t	83.2809	0.0008	0.1284	0.8980[b]	0.0001	198
TDc_t	90.3555	–0.0019	–6.3018	0.0000[a]	0.1685	198
FRc_t	90.1806	–1.6274	–3.2681	0.0013[a]	0.0560	182
$NCec_t$	81.7994	1.24 e-05	2.3092	0.0220[b]	0.0265	198
$TCec_t$	81.2276	2.33 e-07	4.3601	0.0000[a]	0.0884	198
$NDec_t$	86.4453	–0.0009	–4.1438	0.0000[a]	0.0816	198
$TDec_t$	81.3686	5.49 e-06	3.2786	0.0012[a]	0.0519	198
NCe_t	85.6060	–0.0001	–3.5665	0.0005[a]	0.0609	198
TCe_t	81.9187	8.23 e-07	2.1445	0.0332[b]	0.0229	198
NDe_t	87.5062	–0.0052	–14.2822	0.0000[a]	0.5099	198
TDe_t	83.1499	1.25 e-06	0.1936	0.8467[b]	0.0002	198
FRe_t	89.5366	–1.1946	-–4.9127	0.1339[b]	0.0000	158

[a]*99% c. l.,*
[b]*95% c. l.*
[c]*Insignificant.*

Note: SPELMUPt, S&P Emerging LargeMidCap ESG, Index USD; CAt, countries affected; NCwt, new cases world; TCwt, total cases world; NDwt, new deaths world; TDwt, total deaths world; FRwt, case fatality rate world; NCct, new cases China; TCct, total cases China; NDct, new deaths China; TDct, total deaths China; FRct, case fatality rate China; NCect, new cases excl. China; TCect, total cases excl. China; NDect, new deaths excl. China; TDect, total deaths excl. China; NCet, new cases Europe; TCet, total cases Europe; NDet, new deaths Europe; TDet, total deaths Europe; FRet, case fatality rate Europe (see ***Table 1****). Model Const., model constant; Coef., coefficient; t-Stat, t-Statistics; Observ. = observations.*

TABLE 7 | Bivariate regression models for COVID-19 effect on S&P Europe 350 ESG Index.

Variable	Model Const.	Coef.	t-stat	*p*-value	R	Observ.
CA_t	128.3832	–0.0803	–9.3058	0.0000[a]	0.3097	195
NCw_t	114.4615	8.07 e-06	1.0059	0.3157[c]	0.0052	195
TCw_t	113.4129	2.26 e-07	2.7892	0.0058[a]	0.0387	195
NDw_t	120.6616	–0.0014	–4.6748	0.0000[a]	0.1017	195
TDw_t	113.7956	4.63 e-06	1.8458	0.0665[c]	0.0173	195
FRw_t	136.7965	–5.0956	–12.9571	0.0000[a]	0.4826	182
NCc_t	114.5033	0.0027	4.3235	0.0000[a]	0.0883	195
TCc_t	131.5891	–0.0002	–8.8448	0.0000[a]	0.2884	195
NDc_t	115.3737	0.0044	0.5001	0.6176[c]	0.0013	195
TDc_t	127.5030	–0.0034	–7.4434	0.0000[a]	0.2229	195
FRc_t	129.3069	–3.2036	–4.4536	0.0000[a]	0.0993	182
$NCec_t$	114.5299	7.61 e-06	0.9519	0.3423[c]	0.0047	195
$TCec_t$	113.4085	2.28 e-07	2.8149	0.0054[a]	0.0294	195
$NDec_t$	120.6357	–0.0014	-4.6860	0.0000[a]	0.1022	195
$TDec_t$	113.7714	4.75 e-06	1.8857	0.0681[c]	0.0181	182
NCe_t	119.5136	–0.0002	–4.3005	0.0000[a]	0.0874	195
TCe_t	114.5786	5.26 e-07	0.9096	0.3642[c]	0.0043	195
NDe_t	121.3638	–0.0076	–12.8395	0.0000[a]	0.4607	195
TDe_t	116.2049	–7.24 e-06	-0.7586	0.4490[c]	0.0029	195
FRe_t	121.6335	–1.3963	–4.0304	0.0001[a]	0.0943	158

[a]*99% c. l.,*

[b]*95% c. l.*

[c]*Insignificant.*

Note: SPEESUPt, S&P Europe 350 ESG, Index USD; CAt, countries affected; NCwt, new cases world; TCwt, total cases world; NDwt, new deaths world; TDwt, total deaths world; FRwt, case fatality rate world; NCct, new cases China; TCct, total cases China; NDct, new deaths China; TDct, total deaths China; FRct, case fatality rate China; NCect, new cases excl. China; TCect, total cases excl. China; NDect, new deaths excl. China; TDect, total deaths excl. China; NCet, new cases Europe; TCet, total cases Europe; NDet, new deaths Europe; TDet, total deaths Europe; FRet, case fatality rate Europe (see ***Table 1****). Model Const. = model constant; Coef. = coefficient; t-Stat = t-Statistics; Observ., observations.*

TABLE 8 | Bivariate regression models for COVID-19 effect on S&P Global 1200 ESG Index.

Variable	Model Const	Coef.	t-stat	*p*-value	R	Observ
CA_t	192.1835	–0.0586	–4.2754	0.0000[a]	0.0857	197
NCw_t	176.0338	5.49 e-05	5.2835	0.0000[a]	0.1252	197
TCw_t	175.9874	7.49 e-07	7.4629	0.0000[a]	0.2222	197
NDw_t	184.5678	–0.0005	–1.1403	0.2556[c]	0.0066	197
TDw_t	175.2941	2.08 e-05	6.6043	0.0000[a]	0.1828	197
FRw_t	210.3695	–6.4263	–10.1788	0.0000[a]	0.3653	182
NCc_t	181.7608	0.0003	3.0951	0.0023[a]	0.0468	197
TCc_t	195.3807	–0.0002	–4.4396	0.0000[a]	0.0918	197
NDc_t	182.6925	0.0014	0.1154	0.9082[c]	0.0001	197
TDc_t	189.5525	–0.0019	–2.7445	0.0066[a]	0.0372	197
FRc_t	186.8723	–1.0406	–0.9495	0.3436[c]	0.0049	182
$NCec_t$	176.1447	5.42 e-05	5.2195	0.0000[a]	0.1226	197
$TCec_t$	176.0124	7.52 e-07	7.4927	0.0000[a]	0.2235	197
$NDec_t$	184.5578	–0.0005	–1.1422	0.2548[c]	0.0066	197
$TDec_t$	175.3008	2.10 e-05	6.6505	0.0000[a]	0.1849	197
NCe_t	183.9785	–6.69 e-05	-0.9217	0.3578[c]	0.0043	197
TCe_t	175.9469	4.07 e-06	5.4691	0.0000[a]	0.1329	197
NDe_t	190.5438	–0.0009	–11.9727	0.0000[a]	0.4237	197
TDe_t	177.3897	4.5 e-05	3.5727	0.0004[a]	0.0614	197
FRe_t	190.2500	–1.5148	–2.6242	0.0095[a]	0.0423	158

[a]*99% c. l.,*

[b]*95% c. l.*

[c]*Insignificant.*

Note: SPGESUPt, S&P Global 1200 ESG, Index USD; CAt, countries affected; NCwt, new cases world; TCwt, total cases world; NDwt, new deaths world; TDwt, total deaths world; FRwt, case fatality rate world; NCct, new cases China; TCct, total cases China; NDct, new deaths China; TDct, total deaths China; FRct, case fatality rate China; NCect, new cases excl. China; TCect, total cases excl. China; NDect, new deaths excl. China; TDect, total deaths excl. China; NCet, new cases Europe; TCet, total cases Europe; NDet, new deaths Europe; TDet, total deaths Europe; FRet, case fatality rate Europe (see ***Table 1****). Model Const., model constant; Coef., coefficient; t-Stat, t-Statistics; Observ., observations.*

TABLE 9 | Bivariate regression models for COVID-19 effect on S&P Global LargeMidCap ESG Index.

Variable	Model Const.	Coef.	t-stat	*p*-value	R	Observ
C*at*	180.2380	−0.05851	−4.5741	0.0000[a]	0.0965	198
NC*wt*	164.7979	4.99 e-05	5.0543	0.0000[a]	0.1153	198
TC*wt*	164.6310	6.94 e-07	7.2712	0.0000[a]	0.2124	198
ND*wt*	172.9748	−0.0006	−1.4058	0.1614[c]	0.0099	198
TD*wt*	164.0736	1.91 e-05	6.3570	0.0000[a]	0.1709	198
FR*wt*	197.3981	−6.1948	−10.4967	0.0000[a]	0.3797	182
NC*ct*	169.9427	0.0026	3.0745	0.0024	0.0460	198
TC*ct*	183.2605	−0.0002	−4.7229	0.0000[a]	0.1022	198
ND*ct*	170.8242	0.0009	0.0743	0.9408[c]	0.0000	198
TD*ct*	177.8576	−0.0019	−3.0375	0.0027[a]	0.0449	198
FR*ct*	175.2463	−1.1096	−1.0716	0.2853[c]	0.0006	182
NC*ect*	164.8990	4.92 e-05	4.9927	0.0000[a]	0.1128	198
TC*ect*	164.6527	6.97 e-07	7.3016	0.0000[a]	0.2138	198
ND*ect*	172.9598	−0.0006	−1.4058	0.1614[c]	0.0099	198
TD*ect*	164.0770	1.93 e-05	6.4036	0.0000[a]	0.1730	198
NC*et*	172.2279	−7.41 e-05	−1.0818	0.2806[c]	0.0059	198
TC*et*	164.7207	3.70 e-06	5.2279	0.0000[a]	0.1224	198
ND*et*	178.3244	−0.0093	−12.2871	0.0000[a]	0.4251	198
TD*et*	166.2013	3.99 e-05	3.2912	0.0012[a]	0.0534	198
Fr*et*	178.5350	−1.5336	−1.8240	0.0054[a]	0.04864	158

[a]*99% c. l.*

[b]*95% c. l.*

[c]*Insignificant.*

Note: SPLESGUPt, S&P Global LargeMidCap ESG, Index USD; CAt, countries affected; NCwt, new cases world; TCwt, total cases world; NDwt, new deaths world; TDwt, total deaths world; FRwt, case fatality rate world; NCct, new cases China; TCct, total cases China; NDct, new deaths China; TDct, total deaths China; FRct, case fatality rate China; NCect, new cases excl. China; TCect, total cases excl. China; NDect, new deaths excl. China; TDect, total deaths excl. China; NCet, new cases Europe; TCet, total cases Europe; NDet, new deaths Europe; TDet, total deaths Europe; FRet, case fatality rate Europe (see ***Table 1****). Model Const., model constant; Coef., coefficient; t-Stat, t-Statistics; Observ., observations.*

of COVID-19 on ESG stock markets, the bivariate regression models (least squares) are constructed (**Tables 6**, **7**, **8**, **9**).

Effect of COVID-19 on the Performance of Emerging ESG Markets

The results of the assessment of COVID-19 impact on the performance of Emerging ESG markets are provided in **Table 6**.

Based on the results of **Table 6** (t value and *p* statistics), it can be noticed that:

1) Three variables [number of new deaths reported per day in China (*NDct*), number of total deaths in Europe (*TDet*), and case fatality rate in Europe (*FRet*)] proved to have no statistically significant effect on the performance of Emerging ESG stock markets;
2) Eight variables (NCw_t, TCw_t, TDw_t, NCc_t, $NCec_t$, $TCec$, $TDec_t$, and TCe_t) appear to affect the performance of the Emerging ESG stock market positively, while nine variables (CA_t, NDw_t, FRw_t, TCc_t, TDc_t, FRc_t, $NDec_t$, NCe_t, and NDe_t) negatively.
3) The number of countries that reported cases of COVID-19 has s significant negative impact on the performance of emerging ESG stock markets.
4) Global and China case fatality rates had the most significant negative impact on the performance of the emerging ESG stock market.
5) The number of new deaths caused by COVID-19 appeared to have a significant negative impact on the performance of Emerging ESG stock markets in three of four geographical perspectives (Europe, rest of the world excluding China, and global).
6) An interesting result is that the market reaction to an increasing number of daily COVID-19 cases confirmed differs depending on the geographical perspective: The reaction to the increase in China, the rest of the world excluding China, and global daily cases is positive, while the reaction to increase of daily cases in Europe is significantly negative.

To conclude, it can be said that in the case of Emerging ESG stock markets, the results support Hypothesis 1 and Hypothesis 4. In contrast, in the case of the remaining hypotheses, the results are ambiguous.

Effect of COVID-19 on the Performance of European ESG Markets

The results of the assessment of COVID-19 impact on the performance of European ESG markets are provided in **Table 7**.

Based on the results of **Table 7** (t value and *p* statistics), it can be said that:

1) Seven variables (NCw_t, TDw_t, NDc_t, $NCec_t$, $TDec_t$, TCe_t, and TDe_t) proved to have no statistically significant effect on the performance of the European ESG stock market (S&P Europe 350 ESG Index).

2) 10 variables (CA_t, NDw_t, FRw_t, TCc_t, TDc_t, FRc_t, $NDec_t$, NCe_t, NDe_t, and FRe_t) appear to affect the stock market negatively, while only 3 (TCw_t, NCc_t, TCect) positively.
3) The number of countries that reported cases of COVID-19 has s significant negative impact on the performance of the European ESG stock markets.
4) Global case fatality rate as well as case fatality rates in Europe and China seemed to show the most significant adverse effect on the performance of the European ESG stock market.
5) The number of new deaths per day caused by COVID-19 appeared to have a significant negative impact on the performance of the European ESG stock markets in three of four geographical perspectives (Europe, rest of the world excluding China, and global), while the number of new deaths in China has no significant impact.
6) An interesting result is that the number of total deaths in China has a significant negative impact on the European market. In contrast, the number of deaths in other regions seemed to have no statistically significant impact.

To conclude, it can be said that, in the case of the European ESG stock markets, the results support Hypothesis 1, Hypothesis 3, and Hypothesis 4. In contrast, in the case of Hypothesis 2, the results are ambiguous.

Effect of COVID-19 on the Performance of Global ESG Markets

The results of the assessment of COVID-19 impact on the performance of Global ESG markets (measured by S&P Global 1200 ESG Index and S&P Global LargeMidCap E.S.G. Index) are provided in **Tables 8** and **9**.

It is important to notice that: 1) the results in **Table 8** and **Table 9** are remarkably similar, which suggests that the impact of COVID-19 does not depend on the capitalization size and 2) the results in **Tables 8** and **9** differ from the results in **Tables 6** and **7**, thus showing that the effect of COVID-19 on Global ESG stock markets is slightly different from that on Emerging and European ESG stock markets. The main similarities and differences are worth further discussion.

Based on the results of **Tables 8** and **9** (t value and *p* statistics), it can be said that:

1) Five variables (number of new deaths reported per day in China, Europe, and in the rest of the world excluding China (NDw_t, NDc_t, $NDec_t$), the number of daily new cases reported in Europe (NCe_t), and case fatality rate in Europe (FRe_t)), proved to have no statistically significant effect on the Global ESG stock market.
2) Nine variables affect the performance of the Global ESG stock market positively (NCw_t, TCw_t, TDw_t, NCc_t, $NCec_t$, $TCec$, $TDec_t$, TCe_t, and TDe_t), while six negatively (CA_t, FRw_t, TCc_t, TDc_t, FRc_t, and NDe_t).

To conclude, it can be said that in the case of the Global ESG stock markets, the results support Hypothesis 1 and Hypothesis 4. In contrast, in the case of the remaining hypotheses, the results are ambiguous.

Comparison of COVID-19 Effect on Emerging, European, and Global ESG Markets

The comparison of findings allows us to say that:

1) As with Emerging and European markets, the number of countries that reported cases of COVID-19 has s significant negative impact on the performance of the Global ESG stock market.
2) As well as in the case of Emerging and European ESG stock markets, the global case fatality rate proved the most significant adverse effect.
3) It is interesting that unlike cases of Emerging and European markets, the Global ESG stock markets do not prove a significant reaction to the increase of daily COVID-19 cases in Europe, while the reaction to the increase in China, the rest of the world excluding China, and global daily cases is the same, that is, positive.
4) It is also worth mentioning that the number of new deaths per day caused by COVID-19 appeared to have a significant negative impact on the performance of the Global ESG stock markets only in one of four geographical perspectives (Europe) (in comparison with three of four perspectives in earlier cases).
5) Unlike the case of European ESG stock markets, the number of total deaths caused by COVID-19 in Europe, the rest of the world, excluding China, and globally has proven to have a significant positive impact on the performance of the Global ESG stock markets. In contrast, the reaction to increasing number of total deaths in China appeared to be negative.

COVID-19 Effect on the Volatility of ESG Stock Markets

In addition to the results discussed, it is worth mentioning that a substantial number of authors (e.g., Albulescu, 2020b; Zaremba et. Al., 2020; Bakas and Triantafyllou, 2020; and others) expressed the impact of COVID-19 on financial volatility rather than on market returns. Therefore, to assess the short-term effect, ESG stock market volatility expressed monthly standard deviations of the values of indices are analyzed in relation to the average number of new COVID-19 cases and deaths per month (both Global and European) (**Table 10**).

The data in **Table 10** show that the most pronounced adverse reaction (estimated by the highest volatility) of all analyzed indices was seen in March, when the number of confirmed new COVID-19 cases and deaths increased rapidly. In later periods, a decrease in volatility is seen even with the increasing incidence of COVID-19 infections.

According to the summary of research results (provided in **Supplementary Appendix SA2**), it can be concluded that the findings of this research support the following hypotheses: H1 and H4. In contrast, hypotheses H2 and H3 cannot be supported,

TABLE 10 | Monthly analysis of selected financial market indexes and COVID-19-related variables.

Variable	Month (2020)								
	M1	M2	M3	M4	M5	M6	M7	M8	M9
SPELMUPt (St.dev.)	1.8096	2.2787	7.6607	2.0497	0.9954	1.2124	1.7193	1.0663	1.5499
SPEESUPt (St.dev.)	1.3035	4.4076	11.7308	2.8958	2.7518	2.2378	2.2221	1.2829	2.5993
SPGESUPt (St.dev.)	1.6641	7.1323	15.4339	6.1979	3.6261	3.0711	2.6646	3.111	3.9835
SPLESGUPt (St.dev.)	1.6501	6.4888	14.6074	5.6299	3.3337	2.7687	2.5001	2.989	3.5887
NCwt (monthly Aver.)	370	2799	22,216	75,761	90,550	135,097	227,797	251,079	275,856
NDwt (monthly Aver.)	8	96	1115	6215	4626	4590	5330	5719	5381
NCet (monthly Aver.)	1	36	12,463	27,886	19,677	14,792	15,205	26,993	48,910
NDet (monthly Aver.)	0	1	874	3399	1280	575	329	322	509

Note: SPELMUPt, S&P Emerging LargeMidCap ESG, Index USD; SPEESUPt, S&P Europe 350 ESG, Index USD; SPGESUPt, S&P Global 1200 ESG, Index USD; SPLESGUPt, S&P Global LargeMidCap ESG, Index USD; NCwt, new cases world; NDwt, new deaths world; NCet, new cases Europe; NDet, new deaths Europe; (see ***Table 1****). St.dev., standard deviation; Aver., average; M1, January; M2 = February; M3, March; M4 = April; M5 = May; M6 = June; M7 = July; M8, August; M9, September.*

TABLE 11 | Results of the assessment of COVID-19 effect on ESG stock market indices.

Index	Hypothesis	Finding
SPELMUPt	Hypothesis 1	Supported
—	Hypothesis 2	Not supported
—	Hypothesis 3	Not supported
—	Hypothesis 4	Supported
SPEESUPt	Hypothesis 1	Supported
—	Hypothesis 2	Not supported
—	Hypothesis 3	Supported
—	Hypothesis 4	Supported
SPGESUPt	Hypothesis 1	Supported
—	Hypothesis 2	Not supported
—	Hypothesis 3	Not supported
—	Hypothesis 4	Supported
SPELMUPt	Hypothesis 1	Supported
—	Hypothesis 2	Not supported
—	Hypothesis 3	Not supported
—	Hypothesis 4	Supported

Note: SPELMUPt, S&P Emerging LargeMidCap ESG, Index USD; SPEESUPt, S&P Europe 350 ESG, Index USD; SPGESUPt, S&P Global 1200 ESG, Index USD; SPLESGUPt, S&P Global LargeMidCap ESG, Index USD (see ***Table 1****).*

while the results obtained are ambiguous and require further analysis (**Table 11**).

This research shows that the global prevalence of COVID-19 infection, expressed as the number of countries that have confirmed COVID-19 cases, has a significant negative effect on the performance of Emerging, European, and Global ESG stock markets. This research has also revealed that the mortality risk of COVID-19 infection, measured as a case fatality rate, has a significant negative effect on ESG stock markets. The effect of COVID-19 cases reported and deaths caused by COVID-19 infection appeared to be mixed.

The results of this research also revealed that: 1) all analyzed ESG stock markets (Emerging, European, and Global) are more sensitive to the growth of COVID-19 deaths in Europe than in China; and 2) China's COVID-19 case fatality rate has no statistically significant impact on the performance of Global ESG markets, while it negatively affects Emerging and European ESG stock markets. This suggests that markets tend to respond differently to the mortality of COVID-19 seen in different regions.

CONCLUSION AND FUTURE RESEARCH

Conclusion

After researching different regions and stock markets, we noticed some differences in performance and reaction to COVID 19 pandemic. The analysis of the relationship between sustainable investments in different markets revealed that ESG investments in Emerging and Global stock markets are strongly positively correlated. But the relationship between European ESG investments and Emerging markets ESG investments is inverse, so because of these results, we can say that the European ESG market can be used as a diversification measure in low carbon portfolio management.

The comparison of the regression analysis results showed specific differences between ESG investments in Emerging, European, and Global ESG stock markets. Unlike in the cases of Emerging and European ESG markets, the Global ESG stock markets do not prove a significant reaction to the increase of daily COVID-19 cases in Europe, while the reaction to the increase in China, the rest of the world, excluding China, and global daily cases is positive in all markets investigated. The other conclusions can be made that the number of new deaths per day caused by COVID-19 appeared to have a significant negative impact on the performance of the Global ESG stock markets only in one of four geographical perspectives (Europe) (in comparison with three of four perspectives in cases of Emerging and European ESG markets).

The other aspect we would like to stress from our research is that unlike in the case of the European ESG stock markets, the number of total deaths caused by COVID-19 in Europe, the rest of the world, excluding China, and globally has proven to have a significant positive impact on the performance of the Global ESG stock markets. In contrast, the reaction to the increasing number of total deaths in China appeared to be negative.

The differences in Emerging, European, and Global ESG market reactions to the COVID-19 pandemic reveal investment diversification opportunities. Private and institutional investors can achieve better portfolio market risk management results, including sustainable and responsible investments from regions with very low positive or better negative correlations. The other point that practitioners can stress is that investing in ESG investments and other values than profitability should be considered.

The summarized regression analysis results showed that an increasing number of countries that have reported COVID-19 cases have a significant adverse effect on the performance of Emerging, European, and Global ESG stock markets.

The results have also revealed that the case fatality rate of COVID-19 infection has appeared to have a significant adverse effect on ESG stock markets. In contrast, the effect of COVID-19 cases reported (new and cumulative) and deaths (new and cumulative) caused by COVID-19 infection appeared mixed.

The research also revealed that the strongest adverse reaction and volatility of ESG stock market indices to COVID-19 were seen from March 2020 to April 2020; in the later periods, such reaction is no longer dominant. Moreover, a decrease in volatility is seen even with the increasing incidence of COVID-19 infections.

Limitations and Future Research

It is particularly important to note that this research is based on limited data series. The assessment of the COVID-19 effect on ESG stock market performance (indices) using longer-term data series and assessment and comparison of the COVID-19 effect over different timeframes is a further direction for future research.

Some future research can be conducted to extend the results of our research. The longer-term data series could be used to see a more detailed picture of the analyzed issue, and the COVID-19 effect over different timeframes could be assessed and compared. It would be interesting to compare the impact of the COVID-19 pandemic on the stock market of different sectors and bond markets in future research.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material,** and further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

Conceptualization, RK, DT, GK-S, JK, and DB; methodology, DT and GS-S; software, DT and GS-S; formal analysis, DT and GS-S; investigation, DT, GS; data curation, DT, GS-S, and DB; writing-original draft preparation, DT, JK and GS-S; writing-review and editing, GS-S, DT, DB, RK, JG, GG, and XY; visualization, DT, JK, and DB; supervision, RK. All authors have read and agreed to the published version of the manuscript.

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