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The role of renewable energy and carbon dioxide emissions on the ESG market in European Union

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Abstract

In view of global climate problems, public interest in the environment has recently evolved over decision economics. Accordingly, this study assesses the impact of carbon emission allowances (CEA), information technology (IT), renewable energy generation (REG), and carbon dioxide (CO₂) on the environmental, social, governance (ESG) in the European Union (EU) by applying quantile-based models from January 2, 2019 to February 29, 2024. The outcomes demonstrate that CEA and IT have an increasing effect on the ESG with the moderating effect of economic policy uncertainty (EPU). REG has a declining effect on the ESG, while the EPU moderates the effect and makes the effect increasing across higher quantiles.

1 | INTRODUCTION

Environmental problems and decarbonization are at the top of countries' political agendas. In particular, climate change and the increasing negative impact of this problem on humanity are prompting countries

to take new measures and examine ecological indicators. In this context, environmental governance indicators play an important role at both country and company level.

Nowadays, environmental, social, governance (ESG) is the most widely and commonly used scale to calculate the sustainable

Abbreviations: BDS, Broock, Scheinkman, Dechert, and LeBaron; BQQ, bivariate quantile-on-quantile regression; CEA, carbon emission allowances; CO₂, carbon dioxide; EPU, economic policy uncertainty; ESG, environment, social, governance; EU, European Union; GCQ, Granger causality-in-quantiles; MQQ, multivariate quantile-on-quantile regression; QR, quantile regression; REG, renewable electricity generation; IT, information technology.

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performance of companies (Martiny et al., 2024). ESG was first mentioned in 2006 in the report titled United Nations Principles for Responsible Investments to draw attention to the financial interests of investors (UNPRI, 2006). ESG reporting is more than a corporate duty; it is a mechanism that strengthens sustainable development, as it can enable companies to unleash their true potential by setting clear goals, integrating sustainability into business strategies, and increasing interaction with stakeholders, offering the opportunity for a more sustainable and equitable future for all (Chopra et al., 2024). ESG is an encouraging force for countries to improve their ability to protect the needs of future generations and use their natural resources more efficiently through the development of governance (Diaye et al., 2022). The widespread interest in ESG has encouraged companies to focus on sustainability issues (Kartal et al., 2024). ESG negatively shields companies that do not approach sustainability goals (Sahoo & Kumar, 2022). ESG awareness continues to spread in many countries, and, as a result, companies are making progress in adapting ESG-based environmental sustainability (Ng et al., 2020).

Many companies use ESG results as an important input for investment decisions and see ESG as a data input for corporate evaluation (Kao, 2023). Countries are now spending trillions of dollars on ESG investments, which enable companies to focus more on stakeholders' needs when making long-term sustainable investments (Bekaert et al., 2023). ESG performance stands for a green development approach, environmentally conscious companies and corporate policies (Lu & Cheng, 2023). ESG ratings are closely linked to the Sustainable Development Goals (SDGs). This three-part index, based on environmental, social, and governance, plays a comprehensive role in the development process, improving environmental quality and enhancing governance and many SDGs. The development and dissemination of ESG is therefore an important topic.

ESG is increasingly valued over time by companies, governments, and investors to cope with climate change (Feng et al., 2022). ESG investments increase green awareness and are therefore an important element for the SDGs (Wang, 2023). Figure 1 shows the ESG ratings of countries around the world.

In Figure 1, scores close to 0 indicate that countries are doing well in terms of ESG reporting, while scores above 30 indicate that countries are not in a good situation in terms of ESG. In this context, countries such as Brazil, Peru, Russia, and the Czech Republic do not have strong ESG standards. In contrast, Canada, the USA, and European countries have strong scores in terms of ESG. The United Nations-backed Principles for Responsible Investment Directive 2016/234 has incorporated ESG reporting into the EU legal framework (Bruno & Lagasio, 2021). Europe is well above the global average in ESG standards, and EU countries are continuing ESG development with their own governments and policy implementations as part of the EU agenda (BloombergNef, 2021). Europe is the largest market for ESG data, with EU organizations accounting for 60% of global spending on ESG data (Lofts, 2023). What is the reason that European countries are successful and some countries in the world are lagging behind in ESG? In this context, what are the factors that trigger ESG development in European countries? The study aims to find answers to these research questions.

The development of ESG is undoubtedly influenced by many factors within a country or company. The emergence of ESG stems from the needs of societies. In this context, the increase in carbon dioxide (CO₂) emissions can have an impact on ESG, as CO₂ reduction is an important target of SDG-13. Therefore, the increase in CO₂ emissions can lead to an improvement in the environmental side of ESG reporting. Similarly, renewable energy generation (REG) can have an impact on ESG, as renewable resources and technologies promote

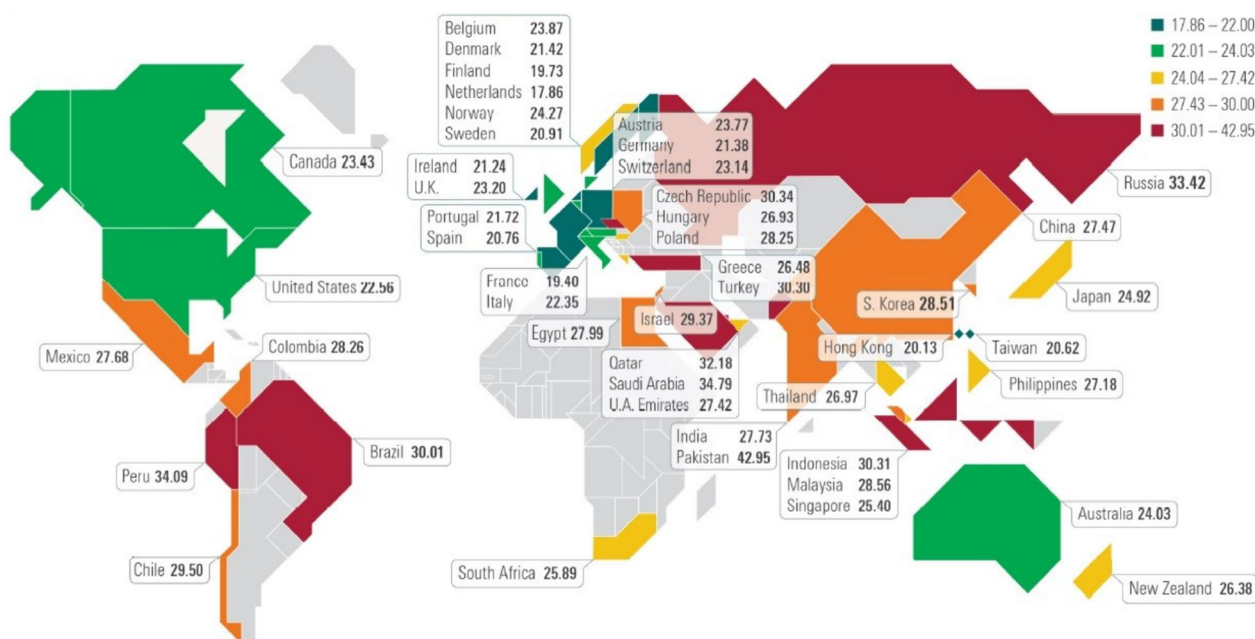


FIGURE 1 ESR ranking of the countries in 2021. Source: Morningstar (2021).

sustainable growth (Sun et al., 2024) by supporting higher environmental and social standards (Erdogan et al., 2023). Another factor that can influence ESG is the state of technology. The development and spread of information technologies (IT) can influence ESG reporting standards. Advances in IT can enable the development of ESG reporting standards and accelerate the diffusion of ESG in the financial sector.

Taking into account the effects of the abovementioned factors on ESG, this study examines the impact of carbon emission allowances (CEA), MSCI Europe IT, EU total renewable REG, and EU total CO₂ emissions on the MSCI Europe ESG leaders index. For this purpose, the study uses novel bivariate quantile-on-quantile regression (BQQ), multivariate quantile-on-quantile regression (MQQ), and Granger causality-in-quantiles (GCQ) approaches. The study contributes to existing knowledge by analyzing for the first time the impact of REG, CO₂ emissions, and MSCI Europe IT Index on ESG for EU countries. Furthermore, the study analyzes the determinants of ESG using quantile-based approaches such as BQQ, MQQ, and GCQ and discusses whether the effects of the determinants of ESG vary on a quantile basis. In doing so, the study aims to provide EU countries with more comprehensive policy recommendations for ESG development.

The study consists of five sections. Section 2 discusses various empirical studies on the determinants of ESG. Section 3 presents the methods, and Section 4 reports the outputs. Section 5 concludes the study, proposes solutions for European countries with regard to ESG development, and highlights the limitations of the study.

2 | LITERATURE REVIEW

ESG is an indicator that has close links to finance, environment, economics, accounting, and many other areas. The environmental analysis of ESG has become the subject of empirical studies, especially since 2020. In other words, the determinants of ESG have been widely discussed by researchers recently. Seow (2024) and Martiny et al. (2024) have presented a comprehensive literature review on this topic.

Various researchers have discussed the impact of factors, such as climate risk, GDP, low-carbon development, technology, financial progress, and carbon allowances on ESG. Rustam et al. (2019) employed sequential mixed method approach from 2006 to 2018 for Pakistan and concluded that higher financial leverage hinders ESG disclosure of companies. Ng et al. (2020) employed various panel estimators and noted that financial progress stimulates the ESG development in 42 countries. Vural-Yavas (2021) employed regression analysis from 2004 to 2017 and showed that economic policy uncertainty (EPU) leads a rise in ESG performance of 15 developed European countries. Asl et al. (2022) performed frequency domain causality test from October 1, 2010 to June 24, 2021 and noted that carbon allowances have a negative link with ESG in the USA. In their study, which they conducted for 29 OECD countries in the period 1996–2014 using a pooled mean group, Diaye et al. (2022) emphasized that there is a positive relationship between ESG and economic progress in the long term but not in the short term.

Alandejani and Al-Shaer (2023) applied a regression modeling from 2013 to 2020 in the USA, the UK, and China. They reported that economic uncertainties lead to an augment in ESG, while political and cultural uncertainties hinder the ESG development. El Khoury et al. (2023) employed panel regression from 2011 to 2019 for 38 banks in MENA region and concluded that firm size supports ESG, while improving firm performance hinders ESG information. Kong et al. (2023) utilized the GMM from 2009 to 2022 and noted that technological innovation improves ESG performance in 78 pharmaceutical companies. Li et al. (2023) utilized baseline regression model and

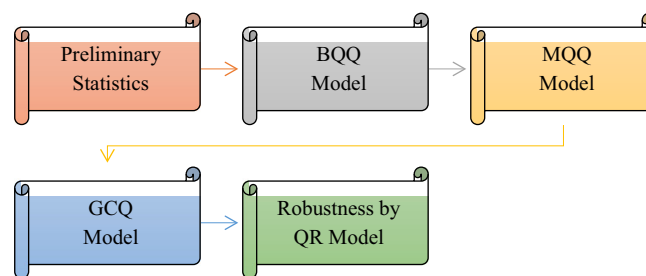


FIGURE 2 Empirical methodology.

TABLE 1 Variables.

Symbol	Variable	Unit	Source
ESG	MSCI Europe ESG leaders index*	Index	Bloomberg (2024)
CEA	S&P carbon emission allowances index	Index	Bloomberg (2024)
IT	MSCI Europe IT index	Index	Bloomberg (2024)
REG	EU total renewable energy generation (including hydro, solar, wind)	GWh/day	Carbonmonitor (2024)
CO ₂	EU total CO ₂ emissions	MtCO ₂ /day	Carbonmonitor (2024)
EPU	Equity market-related economic uncertainty index	Index	FRED (2024)

Note: * shows the dependent variable.

Abbreviations: CEA, carbon emission allowances; CO₂, carbon dioxide; EPU, economic policy uncertainty; ESG, environmental, social, governance; IT, information technology; REG, renewable energy generation.

TABLE 2 Descriptive statistics.

Parameter	ESG	CEA	IT	REG	CO ₂	EPU
Mean	89.41	243.30	146.76	2551.08	9.05	104.14
Median	88.97	246.49	148.62	2545.02	8.92	72.75
Maximum	108.38	448.95	214.80	3364.85	12.63	939.58
Minimum	58.58	68.46	86.02	1751.58	5.14	6.30
Std. dev.	10.19	120.73	27.11	307.73	1.39	102.97
Skewness	−0.14	0.07	0.17	0.00	0.16	2.82
Kurtosis	2.25	1.35	2.29	2.50	2.38	16.31
Jarque-Bera	36.12	153.96	34.60	14.08	26.96	11,732.48
Jarque-Bera probability	0.0000	0.0000	0.0000	0.0009	0.0000	0.0000
Observations	1347	1347	1347	1347	1347	1347

Abbreviations: CEA, carbon emission allowances; CO₂, carbon dioxide; EPU, economic policy uncertainty; ESG, environmental, social, governance; REG, renewable energy generation.

TABLE 3 Pearson bivariate correlations.

	ESG	CEA	IT	REG	CO ₂	EPU
ESG	1.00					
CEA	0.28	1.00				
IT	0.81	0.24	1.00			
REG	−0.04	−0.01	−0.02	1.00		
CO ₂	0.03	−0.01	0.03	−0.10	1.00	
EPU	−0.01	0.00	−0.02	−0.01	−0.05	1.00

Note: Numbers show correlation coefficients.

Abbreviations: CEA, carbon emission allowances; CO₂, carbon dioxide; EPU, economic policy uncertainty; ESG, environmental, social, governance; IT, information technology; REG, renewable energy generation.

reported that Chinese inclusion in the MSCI improves the ESG performance. Lu and Cheng (2023) applied a regression analysis from 2011 to 2018 and noted that environmental regulation policies have a positive impact on ESG performance in China. Tang et al. (2024) used Chinese Stock Exchange data from 2010 to 2020 and reported that directors' and officers' liability insurance stimulates Chinese ESG performance. Tuna et al. (2023) utilized asymmetric causality test from July 31, 2020 to May 28, 2021 and found that positive shocks in CO₂ emissions cause the positive shocks of ESG trade volume in the USA. Wang et al. (2023) employed fixed effect from 2007 to 2020 and noted that low-carbon city pilot policies improve ESG disclosures in China. Zheng et al. (2023) utilized dynamic least squares for 770 Chinese firms and concluded that green patents applications stimulate the development of the ESG.

More recently, Baskaraagac (2024) used the ARDL approach and stated that economic development increased ESG in the period 1996–2020. Bildirici et al. (2024) employed quantile causality approach from 2003 to 2022 and reported that high levels of CEO narcissism hinder ESG development in 55 energy firms in the USA. Chen et al. (2024) performed regression analysis from 2010 to 2019

and revealed that climate risk hinders ESG performance of Chinese firms. Iqbal et al. (2024) used nonlinear ARDL from February 10, 2015 to December 30, 2022 and noted that climate policy uncertainty increases ESG index in China.

Studies in the literature have generally focused on the determinants of ESG specifically in China and the USA. In this context, researchers have often analyzed the impact of GDP, company risk, and climate risk on ESG. The studies most recently considered the year 2022 as the time period. Furthermore, researchers have generally conducted empirical analyzes using mean-based approaches. Overall, there are various research gaps in the literature in terms of methodology, period, and variables taken into account.

There is no study in the literature that has simultaneously analyzed the impact of technology, CEA, CO₂ emissions, and REG on ESG in European countries. Furthermore, no previous studies have examined the determinants of ESG using novel quantile-based approaches. Quantile-based approaches can help to analyze the impact of ESG determinants on the basis of different quantiles. In this context, the study aims to fill the gaps in the literature examining the determinants of ESG for European countries with novel quantile-based methods to current data up to 2023.

3 | METHODS

3.1 | Data

To uncover the impact of CEA, IT, REG, and CO₂ emissions as well as considering the moderating role of EPU, the study focuses on the EU ESG market and uses high-frequency daily data. In this context, the data for ESG, CEA, and IT are collected from Bloomberg (2024). The data for REG and CO₂ are obtained from Carbonmonitor (2024). The data for the EPU index are gathered from FRED (2024). The study takes into account the daily data from January 2, 2019 to February 29, 2024, the most recent available data set when considering the intersection of all variables. Table 1 contains the details of the variables.

Variable	K2	K3	K4	K5	K6	Decision
ESG	0.0000	0.0000	0.0000	0.0000	0.0000	NL
CEA	0.0080	0.0001	0.0000	0.0000	0.0000	NL
IT	0.0001	0.0000	0.0000	0.0000	0.0000	NL
REG	0.0000	0.0000	0.0000	0.0010	0.0000	NL
CO ₂	0.0000	0.0000	0.0000	0.0000	0.0000	NL
EPU	0.0000	0.0000	0.0000	0.0000	0.0000	NL

Note: Numbers demonstrate *p*-values. K and NL denote dimensions and nonlinear, in order.
Abbreviations: CEA, carbon emission allowances; CO₂, carbon dioxide; EPU, economic policy uncertainty; ESG, environmental, social, governance; IT, information technology; REG, renewable energy generation.

TABLE 4 Nonlinearity test outcomes.

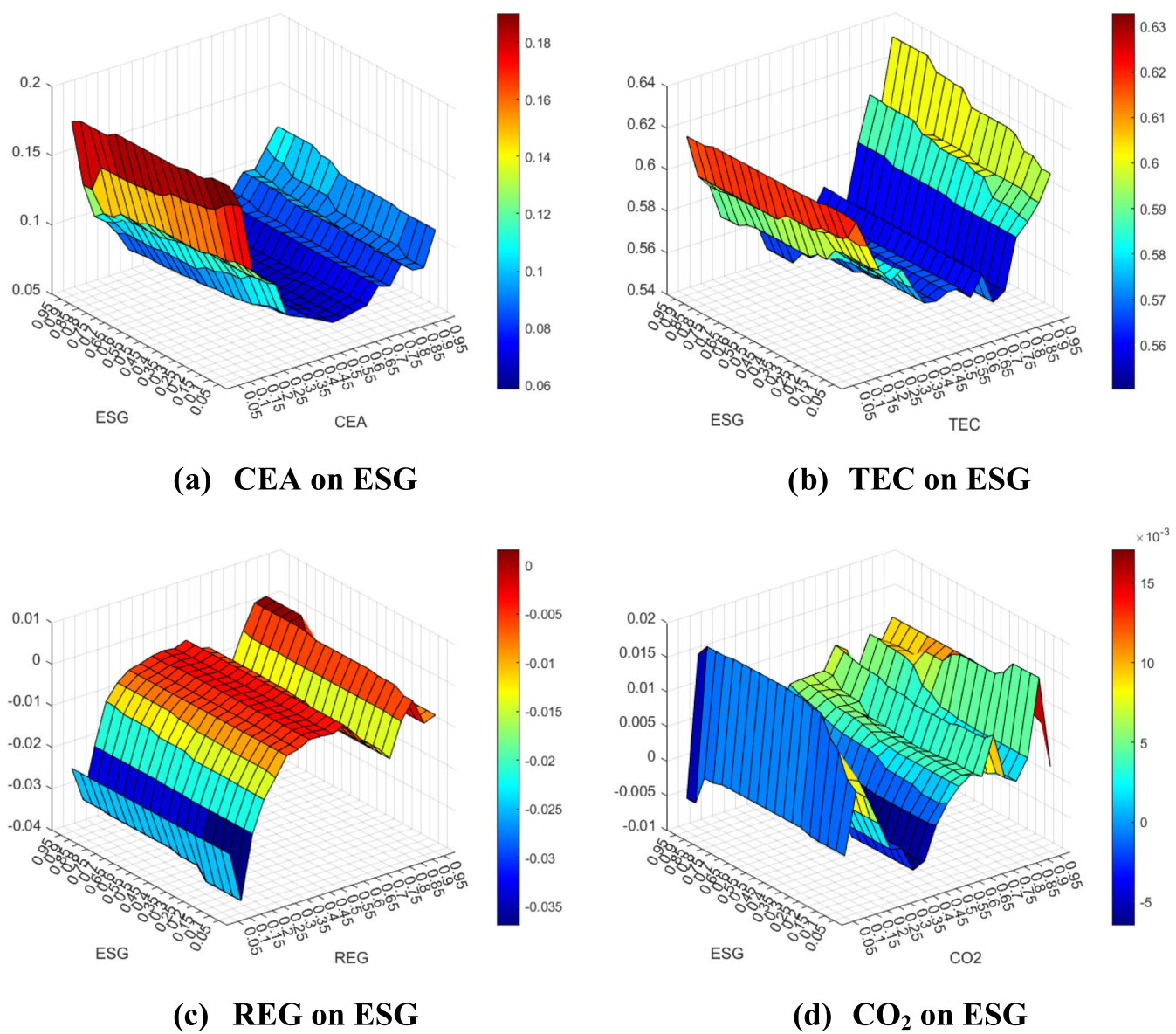


FIGURE 3 Bivariate quantile-on-quantile regression (BQQ) outcomes.

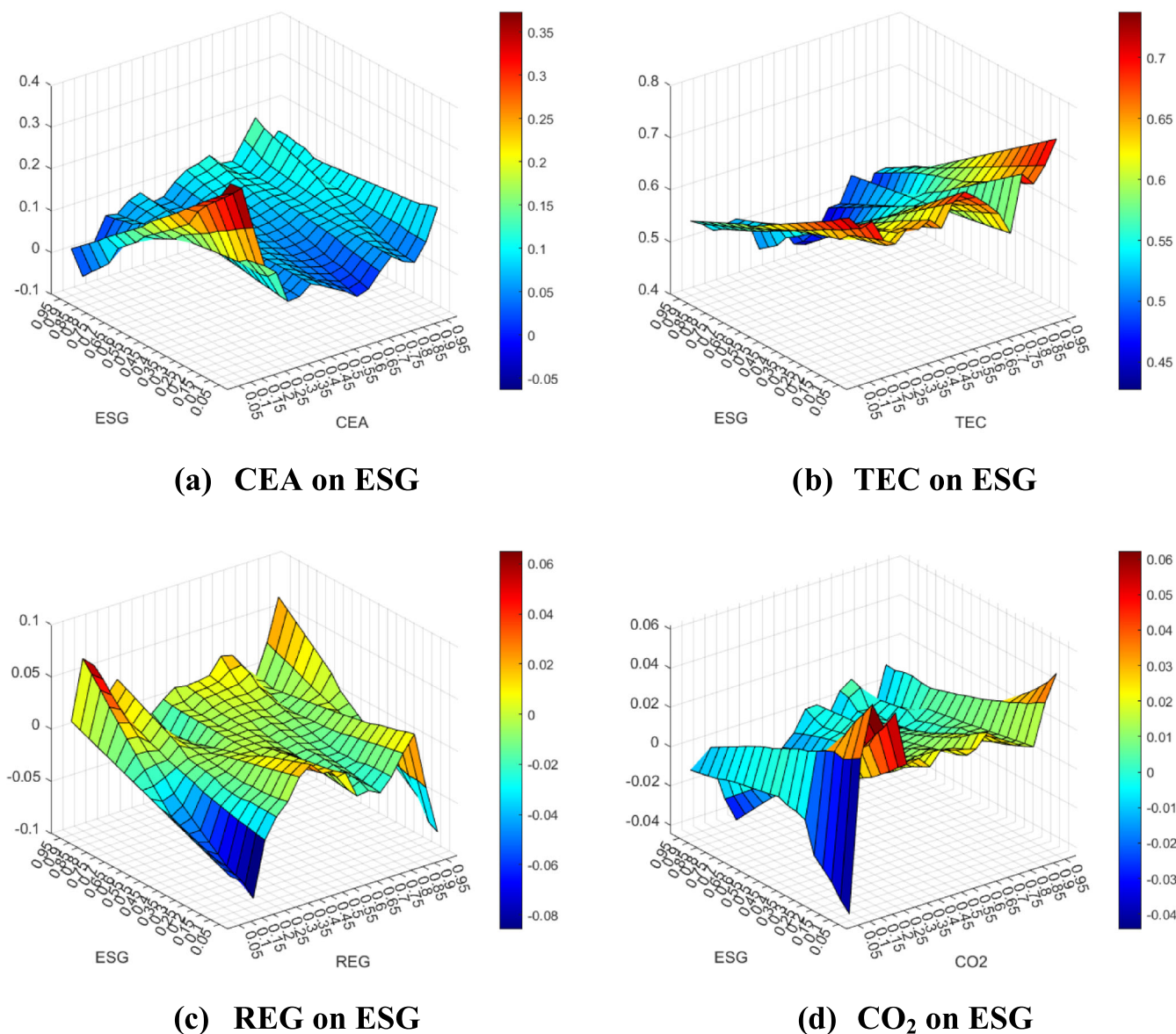


FIGURE 4 Multivariate quantile-on-quantile regression (MQQ) outcomes under economic policy uncertainty (EPU) effect.

After data collection, the study converts the raw data into return series in order to collect comparable outcomes.

3.2 | Empirical methodology

Figure 2 presents the empirical methodology applied in this empirical investigation.

First, the preliminary statistics of the variables are examined. In this context, the descriptive statistics and the correlation matrix are examined. In addition, the nonlinearities of the variables are examined using the Brook, Scheinkman, Dechert, and LeBaron (BDS) test (Brook et al., 1996). In the second step, the BQQ model (Sim & Zhou, 2015) is applied to investigate the bivariate nexus across the quantiles. In the third step, the MQQ model (Sinha et al., 2023) is

used to investigate the multivariate nexus across quantiles by considering the effect of EPU. In the fourth step, the GQ model (Troster, 2018) is used to uncover the causal effect across the quantiles. Finally, the quantile regression (QR) model (Koenker & Bassett, 1978) is used to check the robustness of both the BQQ and MQQ outcomes.

In the empirical investigation, this research uses novel quantile-based models that fit the data characteristics of the variables, which are completely non-normal and nonlinear. In such a case, performing nonlinear models is much more appropriate than running linear models. Moreover, applying nonlinear models (i.e., BQQ, MQQ, GCQ, and QR) can better capture the underlying nexus between the variables by considering the data characteristics of the variables. In addition, the usage of nonlinear quantile-based models is highly appropriate in cases, where high-frequency daily data are used, as

TABLE 5 GQ outcomes.

Path	CEA⇒ESG	IT⇒ESG	REG⇒ESG	CO ₂ ⇒ESG	EPU⇒ESG
0.05	0.11	0.11	0.11	0.11	0.35
0.10	0.00	0.00	0.00	0.00	0.00
0.15	0.00	0.00	0.00	0.00	0.00
0.20	0.00	0.00	0.00	0.00	0.00
0.25	0.00	0.00	0.00	0.00	0.00
0.30	0.00	0.00	0.00	0.00	0.00
0.35	0.00	0.00	0.00	0.00	0.00
0.40	0.00	0.00	0.00	0.00	0.00
0.45	0.00	0.00	0.00	0.00	0.00
0.50	0.11	0.11	0.11	0.11	0.13
0.55	0.32	0.32	0.33	0.33	0.73
0.60	0.00	0.00	0.00	0.00	0.00
0.65	0.00	0.00	0.00	0.00	0.00
0.70	0.00	0.00	0.00	0.00	0.00
0.75	0.00	0.00	0.00	0.00	0.00
0.80	0.00	0.00	0.00	0.00	0.00
0.85	0.00	0.00	0.00	0.00	0.00
0.90	0.00	0.00	0.00	0.00	0.00
0.95	0.00	0.00	0.00	0.00	0.00

Note: Values represent p -values.

Abbreviations: CEA, carbon emission allowances; CO₂, carbon dioxide; EPU, economic policy uncertainty; ESG, environmental, social, governance; IT, information technology; REG, renewable energy generation.

such a dataset can exhibit higher volatility. Moreover, the application of novel quantile-based models is in line with the contemporary literature (e.g., Kartal & Pata, 2023; Sinha et al., 2023). Considering these points, the study utilizes novel nonlinear quantile-based models (i.e., BQQ, MQQ, GCQ, and QR) for the empirical investigation.

3.3 | Estimation models

Overall, the study performs novel quantile-based (i.e., BQQ, MQQ, GCQ, and QR) models. These models are performed to uncover the effect across quantiles by considering the data structure of the variables. Equations (1) to (4) are used in the BQQ analysis:

$$ESG = \beta^\theta (CEA_t) + \sum_n \beta^\theta (x_t) + \epsilon^\theta \quad (1)$$

$$ESG = \beta^\theta (TEC_t) + \sum_n \beta^\theta (x_t) + \epsilon^\theta \quad (2)$$

$$ESG = \beta^\theta (REG_t) + \sum_n \beta^\theta (x_t) + \epsilon^\theta \quad (3)$$

$$ESG = \beta^\theta (CO_{2t}) + \sum_n \beta^\theta (x_t) + \epsilon^\theta \quad (4)$$

where ϵ denotes the error term and θ shows a particular quantile, respectively. Equations (5) to (8) are used in the MQQ analysis.

$$ESG = \beta^\theta (CEA_t) + \sum_n \beta^\theta (x_t) + \sum_n \gamma^\theta (CEA_t * EPU_t) + \epsilon^\theta \quad (5)$$

$$ESG = \beta^\theta (TEC_t) + \sum_n \beta^\theta (x_t) + \sum_n \gamma^\theta (TEC_t * EPU_t) + \epsilon^\theta \quad (6)$$

$$ESG = \beta^\theta (REG_t) + \sum_n \beta^\theta (x_t) + \sum_n \gamma^\theta (REG_t * EPU_t) + \epsilon^\theta \quad (7)$$

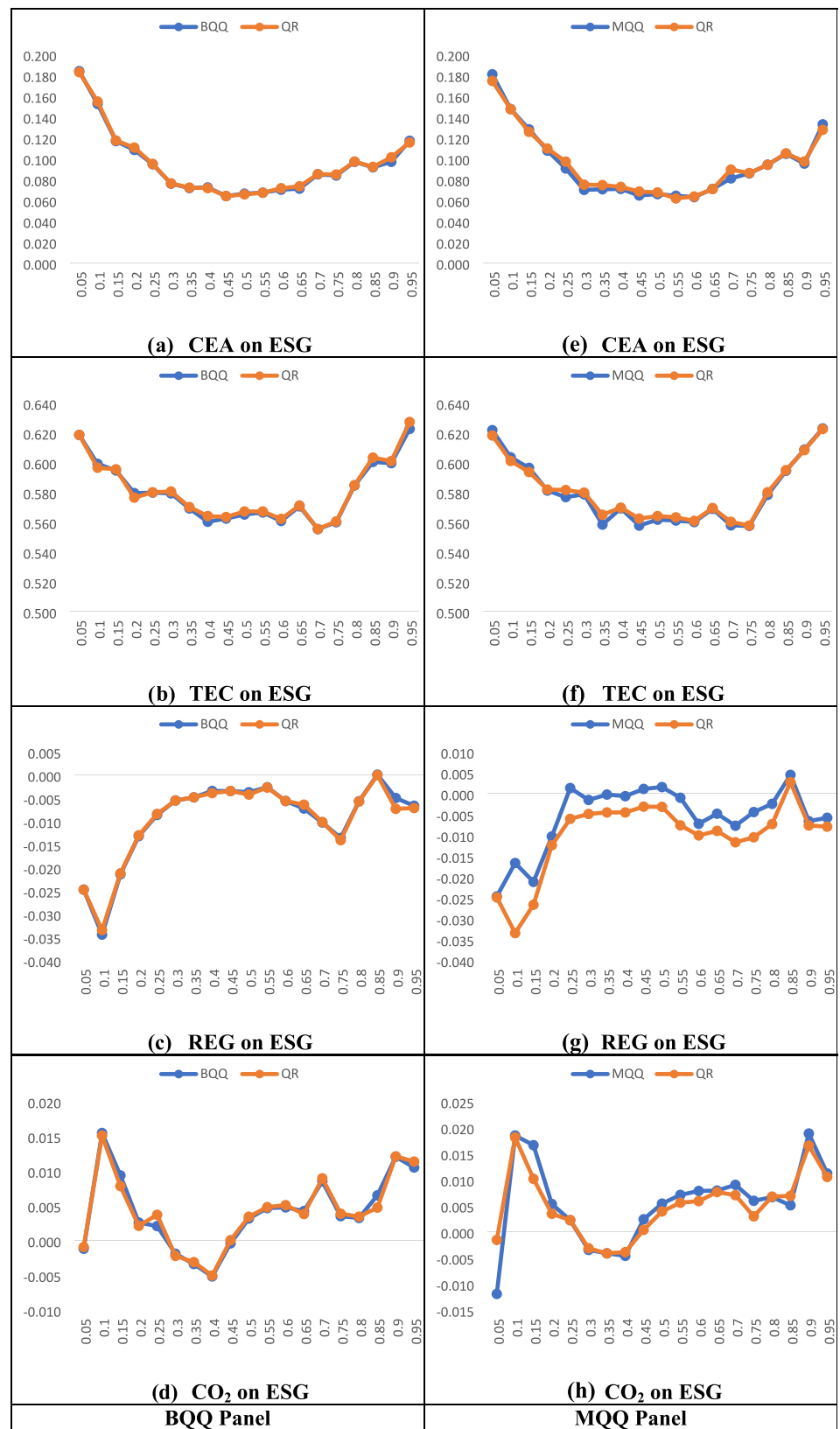
$$ESG = \beta^\theta (CO_{2t}) + \sum_n \beta^\theta (x_t) + \sum_n \gamma^\theta (CO_{2t} * EPU_t) + \epsilon^\theta \quad (8)$$

By applying the above-paced equations, the study searches for the answers to the following research questions:

- What type of effect do CAE, IT, REG, and CO₂ have on ESG?
- Does the effect of the variables on ESG differ under the EPU effect?
- Are the effects of the variables linear or do they vary across levels (i.e., quantiles)?
- Are the effects of the variables at the level of causality or do they vary across quantiles?
- Are the outcomes consistent across alternative econometric models?

Through focusing on the EU market, this study aims to test these research questions by performing quantile-based models in bivariate

FIGURE 5 Comparison of outcomes of bivariate quantile-on-quantile regression (BQQ) and multivariate quantile-on-quantile regression (MQQ) model with quantile regression (QR) model.



cases as well as multivariate cases by considering the moderating effect of EPU on the nexus between the ESG and these factors.

4 | EMPIRICAL OUTCOMES

4.1 | Preliminary statistics

The study first examines the fundamental characteristics of the variables. In this context, the main statistics are listed in Table 2.

Table 2 shows that REG has the highest mean value of all variables. REG is the leading variable among all in terms of variation. Based on the Jarque-Bera probability values, all variables are non-normally distributed. Table 3 presents the correlation coefficients among the variables.

Table 3 shows that ESG has a positive correlation with CEA, IT, and CO₂, while there is a negative correlation of ESG with REG and EPU. Thus, it can be expected that some variables have an increasing effect on ESG, whereas some others have a decreasing effect. Table 4 also presents the results of the nonlinearity test.

Table 4 shows that all variables under consideration have a nonlinear structure across all dimensions. Overall, based on the preliminary statistical outcomes, all variables have a non-normal distribution and a non-normal structure. In such a case, applying nonlinear models instead of linear models can be much more correct. Considering the contemporary literature, this study continues

TABLE 6 Summary of comparison of bivariate quantile-on-quantile regression (BQQ) and multivariate quantile-on-quantile regression (MQQ) models with quantile regression (QR) model.

Variables	BQQ model	MQQ model
CEA on ESG	99.90	99.54
IT on ESG	99.61	99.59
REG on ESG	99.74	92.06
CO ₂ on ESG	99.01	92.75

Abbreviations: CEA, carbon emission allowances; CO₂, carbon dioxide; ESG, environmental, social, governance; IT, information technology; REG, renewable energy generation.

the empirical analysis by applying novel quantile-based models (i.e., BQQ, MQQ, GCQ, and QR), which have a nonlinear structure. Therefore, this study applies consistent models with the data characteristics of the variables.

4.2 | BQQ outcomes

In the second step, the study performs the BQQ model to uncover the bivariate nexus of the variables with the ESG, the outcomes of which are shown in Figure 3.

In Figure 3a, CEA has a completely increasing effect on ESG across all quantiles. While the power of the increasing effect on the ESG is much stronger in the lower quantiles, it becomes somewhat weaker at middle and higher quantiles. Nevertheless, all effects are positive across all quantiles. This outcome is consistent with the studies by Siddique et al. (2021) and Pata et al. (2024), while the outcome is not consistent with Dewaelheyns et al. (2023).

Figure 3b shows that the IT has a stimulating effect on the ESG across all quantiles. The strength of the stimulatory effect on ESG is highly stronger at both higher and lower quantiles, while the effect is relatively weaker across middle quantiles. Although the strength varies, the effect is consistently positive across all quantiles. This finding is compatible with the studies by Kraus et al. (2020), Özkan et al. (2023), and Pata et al. (2024).

Figure 3c shows that REG has a completely diminishing effect on ESG. While the declining effect is highly stronger at lower quantiles, it becomes somewhat weaker across middle quantiles. REG becomes almost inefficient at higher quantiles, which approach zero. Even though the power of the diminishing effect varies, it is below or close to zero, indicating a predominantly diminishing effect. This result is consistent with the studies of Yang et al. (2022).

Figure 3d shows that CO₂ has a mixed effect on ESG. Specifically, CO₂ decreases ESG at the lowest quantile (0.05) and in some middle quantiles (0.30–0.45), while it has an increasing effect across all other lower, middle, and higher quantiles (0.10–0.25, 0.50–0.95). This shows that CO₂ stimulates the ESG after it has crossed a critical threshold. This is compatible with the studies by Costantiello and Leogrande (2023) and Kontz (2023).

TABLE 7 Summary of the effects on environmental, social, governance (ESG).

Quantiles of ESG	Quantiles of regressors	BQQ model				MQQ model			
		CEA	IT	REG	CO ₂	CEA	IT	REG	CO ₂
L	L	↑	↑	↓	↓	↑	↑	↓	↓
M	M	↑	↑	↓	↑	↑	↑	↓	↑
H	H	↑	↑	↓	↑	↑	↑	↑	↑

Note: L, M, and H denote the lower, middle, and higher, in order.

Abbreviations: BQQ, bivariate quantile-on-quantile regression; CEA, carbon emission allowances; CO₂, carbon dioxide; IT, information technology; MQQ, multivariate quantile-on-quantile regression; REG, renewable energy generation.

Overall, IT has the strongest increasing effect on ESG, followed by CEA, while REG has a completely declining effect and CO₂ has a mixed effect, that is, either a positive or negative effect across different quantiles.

4.3 | MQQ outcomes

In the third step, the study performs the MQQ model to examine the multivariate nexus of variables with ESG under EPU effect, with the results shown in Figure 3.

In Figure 4a, CEA completely stimulates the ESG across all quantiles. The power of the stimulatory effect on ESG is much stronger at lower quantiles but gradually weakens in the middle and higher quantiles. However, the effect is consistently positive across all quantiles. The effect of CEA on ESG is not consistent with the study by Dewaelheyns et al. (2023), while it is in the same direction as Siddique et al. (2021) and Pata et al. (2024).

In Figure 4b, the IT increases the ESG completely across all quantiles. The power of the increasing effect on the ESG is stronger at higher quantiles and lower quantiles, while the effect is slightly weaker across middle quantiles. Although the power varies, the effect is consistently positive across all quantiles. This outcome is also compatible with Kraus et al. (2020) and Özkan et al. (2023).

In Figure 4c, REG lowers the ESG at the lower quantiles (0.05–0.20). However, with the moderating role of EPU, the effect becomes increasingly stronger across middle and higher quantiles (0.25–0.95). The power of the decreasing effect is quite strong for all, while the power of the increasing effect is relatively weak.

In Figure 4d, CO₂ has a mixed effect on the ESG. In particular, CO₂ decreases the ESG at the lowest quantile (0.05) and in some middle quantiles (0.30–0.40), while it increases the ESG in all other lower, middle, and higher quantiles (0.10–0.25, 0.45–0.95). In all cases, the power of the increasing effect is quite strong, while the power of the decreasing effect is relatively weak. Thus, CO₂ increases the ESG after it has exceeded a critical level. This outcome is in the same direction as that of Costantiello and Legrande (2023) and Kontz (2023).

To summarize, IT is the leading driver in terms of increasing effect on the ESG, and CEA is the second most important. However, both REG and CO₂ have a mixed effect on the ESG, which can be either positive or negative across the quantiles.

4.4 | GCQ outcomes

In the fourth step, the study performs the GCQ model to examine the causal effect of the variables on ESG, and the outcomes are shown in Table 5.

All variables have a causal effect on the ESG across the quantiles. In particular, there is a causal effect from the factor to the ESG across all quantiles, with the exception of some low (0.05) and middle (0.50–

0.55) quantiles. Thus, the factors considered mainly have a causal effect on the ESG, which is compatible with the finding of Tuna et al. (2023).

4.5 | Robustness check

As the final step, the study performs the QR model to check the robustness of the BQQ and MQQ outcomes, where the outcomes are presented in Figure 5.

As can be seen from Figure 5, the outcomes between the BQQ and QR models and the MQQ and QR models are highly similar and are consistent with the outcomes of the alternative model (i.e., the QR model). A summary of Figure 5 can be found in Table 6.

Table 6 shows that the outcomes of the quantile-based models are highly consistent, that is, 99.9% across all pairs of variables. Therefore, it can be concluded that the outcomes are highly robust and a variety of policy endeavors can be argued on the basis of the outcomes of the quantile-based models. A summary of the empirical analysis can be found in Table 7.

5 | CONCLUSION, POLICY ENDEAVORS, AND FUTURE RESEARCH

5.1 | Conclusion and discussion

In the context of a highly globalized world facing a harsh and critical climate change, the importance of eco-friendly investments is increasing day by day. In this context, ESG-based products have recently become popular for making green investments on both the investor and the investee side. While investors can realize potential returns, investment recipients can simultaneously provide the necessary funds for their investments. In this way, ESG-based investments can be a strategic tool in the fight against climate-related problems.

The topic of ESG has been frequently addressed in the literature recently. A variety of research has addressed ESG from different angles, such as linking ESG performance to firm value (Aydoğmuş et al., 2022) and to the cost of financing (Agnese & Giacomini, 2023), as well as modeling ESG scores of publicly traded companies (Kartal et al., 2024). However, while these studies have been useful in developing the literature, these studies have not considered some critical factors in the examination of the ESG. Accordingly, this study analyzes the effect of selected critical factors (i.e., CEA, IT, REG, & CO₂), on the ESG markets in the EU region. For this purpose, the study uses daily high-frequency data.

By applying novel quantile-based models, the study summarizes that CEA and IT have a stimulatory effect on ESG, with and without the moderating effect of EPU, although the strength of the effect varies. REG also has a decreasing effect on ESG, while EPU moderates the effect and increases the effect at higher quantiles. In addition, there is a mixed effect of CO₂ emissions on ESG. Moreover, the trend of the effect of the above factors on ESG does not change as much,

while EPU moderates the effect. There is also a causal effect across all quantiles, except for some lower and middle quantiles. The outcomes are robust across alternative econometric models as well as in bivariate and multivariate cases. The study shows that CEA and IT have a significant stimulating effect on ESG, while REG and CO₂ mainly have a decreasing effect and their effects are moderated by EPU.

5.2 | Policy endeavors

Through considering the empirical outcomes collected from the novel empirical models, the study discusses possible policy endeavors for the EU ESG market. First, it is critical for EU policymakers to address the high-impact factors governing the ESG market. In line with the empirical outcomes, policymakers should focus primarily on IT. Accordingly, the promotion of technological progress through various incentives is of great importance to support the further progress of the performance of leading ESG companies in the EU area. In this context, policymakers can focus on further financial incentives to increase technology-based entrepreneurship in the EU area and stimulate further high-tech imports from high-tech countries. In this way, policymakers can stimulate further IT effects in the ESG market.

Second, because IT is followed by CEA as the second important factor, the next focus of policymakers should certainly be CEA. Similar to the case of IT, an increase in CEA, which implies rising prices for carbon emissions allowances, is beneficial for the progress of the ESG. Accordingly, regulators may consider increasing the CEA either a little or more, provided this does not have other negative side effects on the economy and environment of EU countries. In this way, the progress of the performance of leading ESG companies in the EU area can be further supported, and the use of further CEA by EU companies can be limited, providing two benefits at the same time.

Third, an increase in CO₂ emissions leads to an increase in the performance of the leading ESG companies in the EU area, so there is also scope for policy in this respect. With higher CO₂ emissions, companies in the EU are required to further develop their ESG practices. Due to high CO₂ emissions in the EU, policymakers can enforce new ESG reporting styles with a much more comprehensive structure and detailed style. Therefore, higher CO₂ emissions can be a lever for the ESG performance of EU companies.

Fourth, when the moderating effect of EPU is taken into account, the results, although somewhat weaker, are almost identical in the case of a smooth shift. This finding shows that policymakers should pay attention to external shocks, which can be caused by various factors, as in the case of EPU in this study. This finding calls for a continuous monitoring structure of the ESG market by policymakers rather than intermittent surveillance. With such an approach, negative effects of external shocks/factors can be recognized and prevented in time.

In line with the results, it can be concluded that EU policymakers should pay much more attention to the impact of CEA and IT in stimulating the ESG market, while REG and CO₂ have come to the fore later in this respect.

5.3 | Limitations and future research

Through applying novel quantile-based models, this research aims to comprehensively analyze the ESG market in the EU. Although this is the best attempt, it still has some limitations. New studies can consider this point as the first limitation and focus on the other areas when studying the ESG market, as the study only covers the EU ESG market.

This study considers four main indicators as explanatory factors. Therefore, new studies can consider this as a second limitation and use some other potential drivers in uncovering ESG markets.

This study conducts a quantile-based empirical analysis in bivariate and multivariate form. As a third limitation, new studies can apply other econometric techniques such as wavelet and Fourier methods to incorporate other perspectives (e.g., time, frequency, and transformational view of points) into the empirical analysis. In this way, the knowledge about ESG can be extended much further.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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