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RESEARCH ARTICLE

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A new look at the finance–environment nexus: How yield spread affects environmental quality in the United States

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Abstract

Enhancing environmental quality is currently a key focus for policymakers. Furthermore, researchers are also prioritizing the investigation of novel variables that can influence environmental quality. The yield spread is commonly used as a leading indicator for business cycles in the macro-finance literature, providing information about future expectations regarding business cycles. The yield spread also presents information about the borrowing costs of firms. None of the existing studies in the environmental economics literature has tested the impact of the yield spread on environmental quality, implying the level of the yield spread has not been considered a variable that can influence environmental quality. This study aims to fill this gap by providing evidence on the effect of yield spread (between 2- and 10-year government bonds) on environmental quality in the United States from June 1976 to September 2023. The results indicate that an increase in the yield spread leads to a rise in environmental destruction. These results suggest two considerable consequences. First, optimistic expectations today lead to the overuse of resources and environmental destruction. Second, firms' higher borrowing costs may be forcing them to use less environmentally friendly production methods to offset more expensive financing costs and increase their profits. This study asserts that companies should enhance their environmental sensitivity, and policymakers should adopt a more proactive stance, based on the results of this study and other research that demonstrates the detrimental impacts of environmental regulation violations and poor environmental performances on companies' stock prices and financial performances.

KEYWORDS
environmental deterioration, renewable energy, sustainable growth, threshold regression analysis, yield spread

1 | INTRODUCTION

Scientists' awareness of environmental problems began especially after the report of Meadows et al. (1972). According to them, the world's demographic pressure reached an extreme point when the demand of people was satisfied at the expense of overusing the environment. Furthermore, they argued that policymakers should act immediately to accomplish economic and ecological stability goals.

Abbreviations: ARDL, autoregressive distributed lag; CO_2, carbon dioxide; COP, Conference of the Parties; EKCH, environmental Kuznets curve hypothesis; KPSS, Kwiatkowski–Phillips–Schmidt–Shin; NH, null hypothesis; PP, Phillips & Perron; ZA, Zivot & Andrews.

Since then, many additional reports and meetings have been prepared to combat environmental problems. Among these meetings, the Conference of the Parties (COP) meetings that are organized every year stand out. At the last COP meeting in the United Arab Emirates in 2023, it was emphasized that progress in tackling climate change has been too slow and that the transition from fossil fuels to renewable sources must accelerate (United Nations Climate Change, 2024) despite the global endeavors to achieve a carbon-neutral economy through the substitution of fossil fuels with renewable energy sources (Collados-Rodríguez et al., 2023; Jones & Olsson, 2017; Pata et al., 2023; Roduner & Rohwer, 2024). The most compelling evidence supporting this perspective is the temperature data recorded in 2023. Accordingly, 2023 was the warmest year on record for the planet (National Oceanic and Atmospheric Administration, 2024). Global warming, which is evidenced by a statistically significant variation in climate elements such as temperature over various periods, is a major worry for humanity (Gao, Li, & Hao, 2024a). Hence, nations must expeditiously decrease their emissions of greenhouse gases in order to attain the carbon neutrality target (Gao et al., 2023; Gao, Zhao, et al., 2024). Moreover, identifying the determinants of environmental degradation and taking measures to improve environmental quality rapidly are crucial issues of concern to all nations.

Like scientists from different fields, economists work on the causes and solutions to environmental problems. Due to severe global environmental deterioration, the factors contributing to environmental degradation have been thoroughly examined in the relevant literature (Işik et al., 2017). Stated differently, a significant portion of the environmental economics research agenda focuses on the causes of environmental problems (Bulut, 2021). Furthermore, certain economists have also conducted research on the quality of economic growth by considering environmental issues along with some other factors (Gao, Li, & Hao, 2024c; Gao, Zhang, et al., 2024). Within this scope, the literature reveals that scholars have proposed numerous models and theories about the relationship between income, energy, and the environment. The environmental Kuznets curve hypothesis (EKCH), proposed by Grossman and Krueger (1991, 1995), is the most extensively studied model among the various models and hypotheses. The EKCH posits a curvilinear relationship between income and environmental degradation, characterized by an inverted U-shaped pattern. Thus, according to Stern (2004), there is an inverse relationship between income and environmental quality, where an initial fall is followed by a rise. The EKCH posits that the initial stages of economic growth are characterized by the predominant use of fossil energy sources, so accounting for this correlation. As the economy grows, renewable energy sources, which are newer and cleaner than fossil fuels, replace them. This transition is driving the demand for better environmental quality (Khezri et al., 2024; Sarkodie & Strezov, 2019).

Several papers in the relevant literature have explored the determinants of environmental deterioration within the EKCH. In recent years, these papers have examined whether environmental quality is associated with different types of energy (Zhu et al., 2024), internet use (Awan et al., 2022), natural resource rents (Pata & Isik, 2021), environmental patents (Liu et al., 2023), trade openness (Ashraf et al., 2023), foreign direct investments (Ghorbal et al., 2024), income inequality (Kusumawardani & Dewi, 2020), and financial development (Dong et al., 2024; Zhao & Yang, 2020). Based on the findings in the previous literature, the finance–environment nexus has been investigated through financial development, and the possible impact of other financial variables have been ignored in the literature. As Mishkin (2004) addresses, the financial sector is critical in directing funds to support increased economic efficiency. Indeed, one of the main ingredients of strong economic growth is well-functioning financial markets. The cyclical performance of the economy, individual wealth, and the actions of economic actors are all impacted by financial market activity. Hence, the finance–environment nexus can materialize through other channels.

Our paper suggests a question based on the discussion above: can the finance-environment relationship be diversified with a financial variable that provides information about both firms' borrowing costs and the future level of economic activities? Economists often use yield curves to obtain information about these issues. The yield curve exhibits the relationship between long- and short-run interest rates on securities, especially government bonds (Campbell, 1995). More specifically, the yield spread is defined as the difference between long- and short-term interest rates (Parker & Schularick, 2021). The basic theory of the yield curve is the expectations hypothesis, which postulates that long-term interest rates are equal to an average of short-term interest rates expected to arise during the life of the long-term bond (Mishkin, 1990; Taylor, 1992). A yield curve is upward-sloping when short-term interest rates are expected to increase in the future and vice versa (Mishkin, 1990).

The yield spread is considered to have predictive power for business cycles (Rudebusch & Williams, 2009). Hence, the yield spread can be a leading indicator of real economic activities (Kanagasabapathy & Goyal, 2002) and an early warning sign for a possible economic crisis (Parker & Schularick, 2021). Put differently, researchers use the yield spread data to forecast the future path of an economy. In their seminal paper, Estrella and Mishkin (1996) show that the yield spread performs well in forecasting recessions in the United States. Chauvet and Potter (2005) explore the idea that the yield spread could be used to forecast recessions in the United States. Evgenidis et al. (2020) discover the ability of the yield spread in forecasting business cycles has increased over the last decades in the United States. Hasse and Lajaunie (2022) discover that the yield spreads signal recessions in 13 OECD countries, including the United States. Bluwstein et al. (2023) explore that the yield spread could have predictive power for financial crises in 17 developed countries. Hence, the papers in the extant literature present strong evidence about the predictive power of the yield spread for business cycles.

Our paper aims to test whether this leading indicator, namely, the yield spread, affects the environmental quality in the United States within an EKCH using monthly data over the period June 1976 to September 2023. The paper uses 10- and 2-year treasury yields (the difference between the yield on a 10-year government bond and the yield on a 2-year government bond) as the yield spread series. The paper's contribution to the existing literature lies in the following points.

First, this is the first paper in the literature that focuses on the possible impact of the yield spread on the environment. Stated differently, differing from the previous studies, this paper delves into the effect of the yield spread on environmental quality by considering the level of the yield spread can affect environmental quality. The influence of the yield spread on the environment can be realized through two channels. The first and second channels show the direct and indirect impacts of the yield spread on the environment, respectively. More specifically, according to the channel representing the direct effect, an increase in the spread between long- and short-term government bond yields implies an increase in long-term lending rates because there is a strong co-movement between long-term interest rates. Financing costs are among the most critical expenditures for firms, as is widely recognized. Accordingly, higher financing or borrowing costs for firms may lead them to use less environmentally friendly production methods to offset higher financing costs. In other words, firms that seek to increase their profits and market values may care less about the negative impacts of their activities on environmental quality, which in turn results in environmental degradation. This effect may become more pronounced as the level of financing costs and their proportion in the total costs increase. In other words, the impact of an increase in the yield spread on environmental damage could be exacerbated in countries where the share of financing costs in firms' cost items is high.

The indirect channel is related to the expectations hypothesis. Accordingly, future expectations for business cycles can impact real domestic absorption (the sum of private consumption, private investment, and government expenditures) in an economy, which can influence environmental quality. The examination of the impact of expectations on individual consumption and investment expenditures traces its origins to the work of Keynes. Keynes (1936) examined the impact of expectations on private consumption and investment expenditures in his renowned work, The General Theory of Employment, Interest and Money. Accordingly, private consumption expenditures are influenced by changes in expectations regarding the relationship between current and future income levels, while private investment expenditures are primarily determined by the marginal efficiency of capital, which is the expected income from a capital good. For instance, positive expectations about the future economic environment can increase domestic expenditures, meaning the over-exploitation of resources today. This could lead to increased environmental pressure. Accordingly, environmental destruction increases if the energy required for economic activities stimulated by private consumption and investment expenditures is supplied from fossil resources. Hence, the yield spread also has an indirect effect on environmental quality.

As is seen in Figure 1, the yield spread presents information about the stagnation in the United States in the early 1980s, the dot-com bubble in the 1990s that burst in the early 2000s, and the financial crisis that began in 2007. Considering the graphical analysis and the findings of the previous papers about the predictive power of the yield spread, this series can affect the environment as future expectations for business cycles can influence real domestic absorption today and borrowing costs for firms can change their sensitivities to the environment. Therefore, the distinguishing feature of this study from previous studies is that it examines the possible impact of the yield spread on the environment.

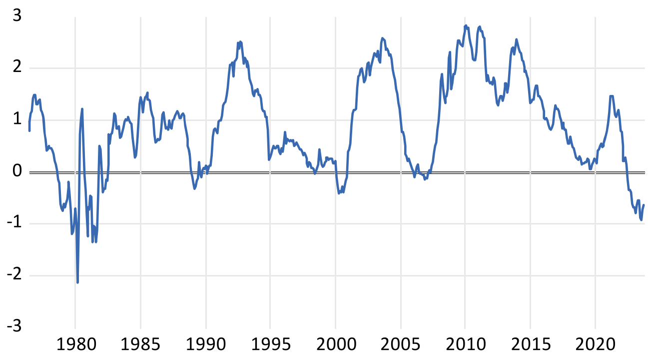

FIGURE 1 Yield spread in the United States. *Source*: Federal Reserve Bank of St. Louis (2024).

Second, many papers in the extant literature have examined whether the EKCH prevails in the United States. Roach (2013) and Işık et al. (2021) discover that the EKCH dominates in the United States. In contrast, Bilgili et al. (2016) and Ongan et al. (2022) do not present evidence in favor of the EKCH. To put it another way, the earlier studies do not show conclusive proof of the EKCH's validity in the United States. This paper also tests the EKCH in the United States to provide new empirical results.

Third, the present study also inspects the effects of fossil and renewable energy sources on environmental quality in the United States. To this end, the study avoids the possible omitted variable bias through an empirical including considerable determinants of environmental degradation, such as fossil and renewable energy. Hence, in addition to examining the impact of the yield spread on environmental destruction, the study investigates whether harmony exists between some sustainable development goals (SDGs). Within this scope, the study explores the relationship between SDG 13 (climate action), SDG 7 (affordable and clean energy), SDG 8 (decent work and economic growth), and SDG 12 (responsible consumption and production).

Fourth, the paper focuses on a relatively big sample with 568 observations. The paper deals with the possible asymmetric effects of the yield spread on environmental quality due to this large sample. Hence, the paper not only estimates the coefficient of the yield spread for the whole sample but also obtains this coefficient for certain sub-samples based on the values of the yield spread. The paper performs a threshold regression (TR) model considering the impact of the yield spread on environmental quality, which can vary with different values of the yield spread. Therefore, the paper aims to reveal efficient findings about the impact of the yield spread on environmental degradation in the United States.

We believe that this study provides clear implications for research and practice. First and foremost, this investigation offers a novel viewpoint on the finance-environment relationship, which is frequently characterized by an interaction between environmental quality and financial development. It offers a comprehensive theoretical framework to elucidate this novel relationship. The results of this study will indicate whether policymakers who are striving to enhance environmental quality should take into account the yield curve and the yield spread when formulating environmental policies. Therefore, policymakers can benefit from the results of this study.

The rest of the study is as follows: environmental and energy policies in the United States are briefly provided in Section 2. Section 3 provides the model along with the data set. Next, Section 4 shows the estimation techniques, while Section 5 depicts empirical results. Finally, the paper concludes in Section 6 presenting a summary of results and policy recommendations.

2 | AN OVERVIEW OF ENVIRONMENTAL AND ENERGY POLICIES IN THE UNITED STATES

Different renewable energy policies, namely, investment tax credits, production tax credits, renewable portfolio standards, loan guarantee programs, the Energy Policy Act of 2005, and the Energy Independence and Security Act of 2007, are being implemented in the United States today. Especially, after the Energy Policy Act in 2005, the scope of these policies has started to expand, and incentives towards renewable energy have increased. Due to these policies, carbon dioxide emissions (CO_2) in the United States have tended to decrease since 2005 (Figure 2). However, although the level of CO_2 decreased as a result of these policies, it is still high considering the Kyoto Protocol, whose goal is to reduce emissions by 5% from the level in 1990. The large share of fossil fuels in energy consumption causes environmental degradation in the United States. As Figure 3 illustrates, the ratio of renewables consumption to total primary energy consumption remains very low compared to the share of fossil energy consumption. Accordingly, while it was 4.31% in 2005, it reached 8.53% in 2022. Although it almost doubled from 2005 to 2022, it remains shallow, considering approximately 83% of the overall energy consumption was attributed to the use of fossil fuels in the same year. When renewable energy consumption is examined in terms of types of renewable energy, it is seen that the composition of renewable energy consumption changed (Figure 4). Accordingly, even though biomass has had the highest share in total renewable energy consumption for years, the shares of biomass and hydro have decreased in the last years. In contrast, wind and solar energy shares have rapidly increased over the last few years. In other words, the United States has replaced biomass and hydro with wind and solar energy over the previous years. The shares of biomass, wind, hydro, solar, and geothermal were respectively 60.02%, 18.31%, 10.74%, 9.45%, and 1.46% by 2022.

This study inspects two indicators to examine the relative stringency of environmental policies in the United States: the environmental policy stringency index and environment-related tax revenues. As seen in Figure 5, for 2020, the United States ranks 18th out of 25 OECD countries in terms of the stringency of environmental policies. In other words, environmental policy in the United States is looser than those of many OECD countries. Considering that the horizontal line in the figure represents the average, it is concluded that

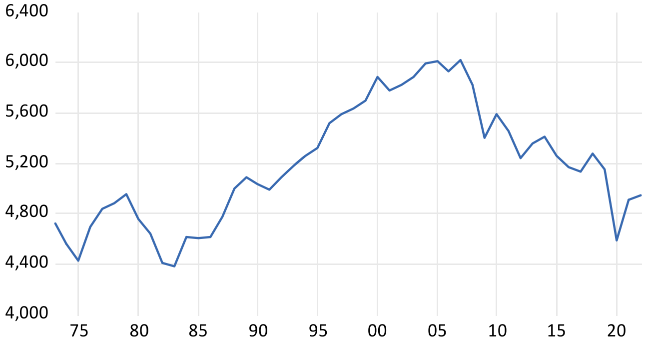

FIGURE 2 CO_2 emissions in the United States (million metric tons, 1973–2022). *Source*: US Energy Information Administration (2024).

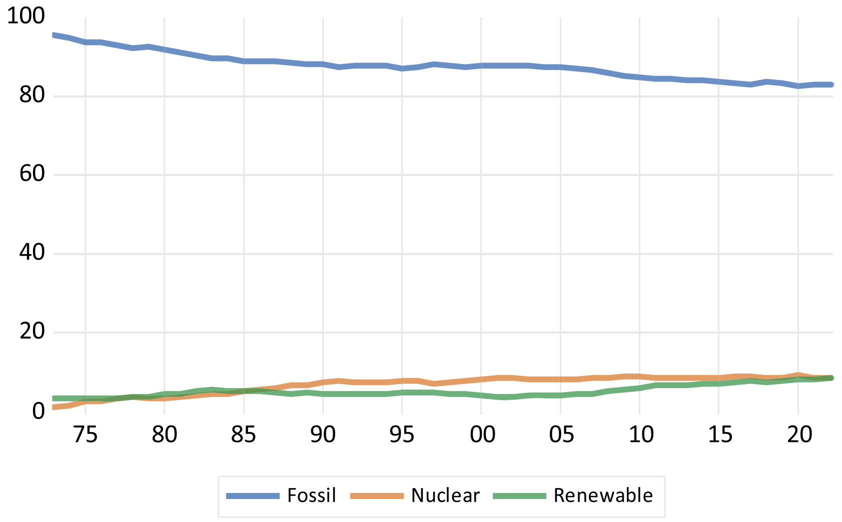

FIGURE 3 The energy mix in the United States (shares of energy sources, %, 1973–2022). *Source*: US Energy Information Administration (2024).

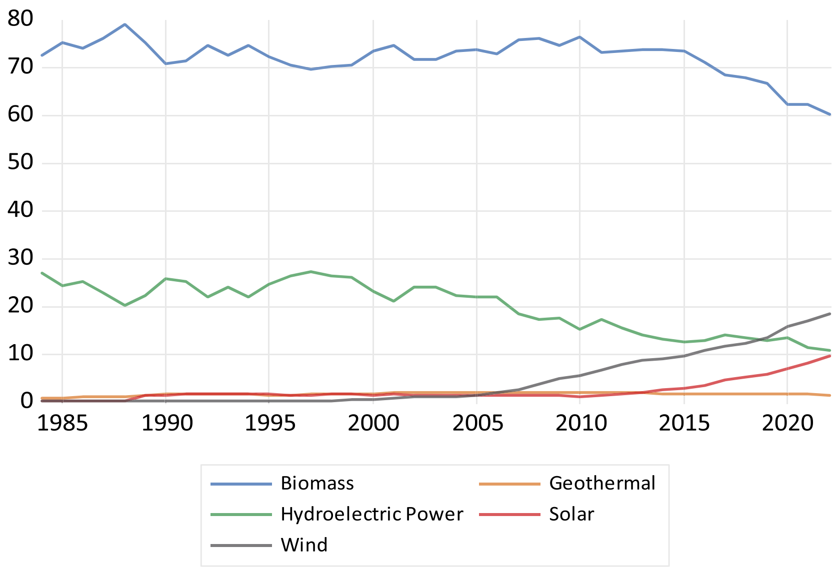

FIGURE 4 The energy mix in terms of renewable energy in the USA (shares of renewables, %, 1984–2022). Source: US Energy Information Administration (2024).

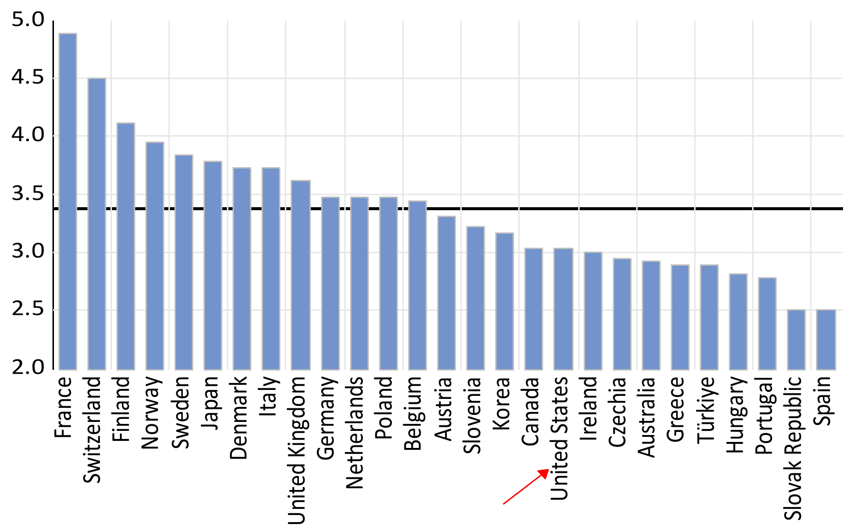

FIGURE 5 Environmental policy stringency index in OECD countries in 2020. *Source*: OECD (2024).

the stringency point of environmental policies in the United States is even below the average. Figure 6 shows the ratio of environmentally related tax revenues to total tax revenues in OECD countries for 2021. The figure shows that the United States ranks last among 33 OECD countries on this topic. Considering that the horizontal line in the illustration shows the average in this regard, it is seen that the ratio of environmentally related tax revenues to total tax revenues in the United States is well below the average value. Indeed, the primary purpose of environmentally related tax revenues is not to increase tax revenues and to improve the budget balance, but to develop mechanisms to prevent environmental damage. In this respect, the main problem for the United States is not that environmental taxes do not contribute to the budget but that low environmentally related tax revenues are evidence of loose environmental policies.

Figures 5 and 6 support each other and present evidence that the environmental policies in the United States are looser than those in many OECD countries. These data also support Figures 2 and 3 and show why CO_2 emissions in the United States have not decreased sufficiently and why renewable energy consumption has not reached the desired level.

3 | MODEL AND DATA

The paper conducts a time series analysis to delve into the possible impact of the yield spread within the framework of the EKCH. The consumption of fossil fuels and renewable energy is included in the model as control variables. Accordingly, the model is set up as follows:

$$\ln CO_{2t} = \partial_0 + \partial_1 \ln IP_t + \partial_2 (\ln IP)_t^2 + \partial_3 \ln FE_t + \partial_4 \ln RE_t + \partial_5 YS_t + \varepsilon_t \quad (1)$$

where CO_2, IP, IP2, FE, RE, YS, and ε, respectively, denote CO_2 emissions (in million metric tons), the seasonally adjusted industrial production index (2017 = 100), the square of the industrial production

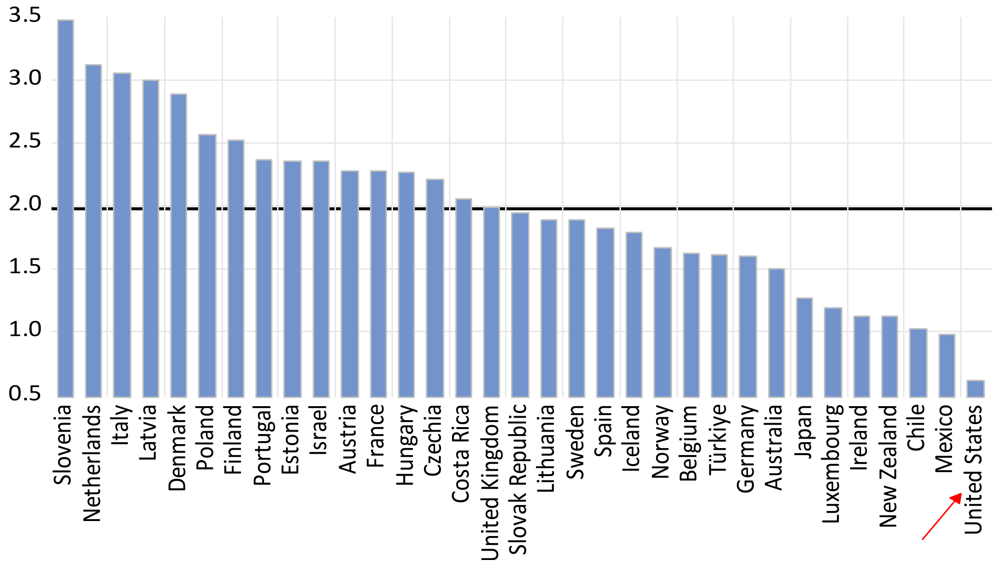

FIGURE 6 Environmentally related tax revenue in OECD countries in 2021 (%). *Source*: OECD (2024).

TABLE 1 Variables in the empirical model.

Variable	Symbol	Definition	Source
Environmental deterioration	CO_2	CO_2 emissions (million metric tons)	US Energy Information Administration (2024)
Income	IP	Seasonally adjusted industrial production index (2017 = 100)	Federal Reserve Bank of St. Louis (2024)
Fossil energy	FE	Fossil energy consumption (quadrillion Btu)	US Energy Information Administration (2024)
Renewable energy	RE	Renewable energy consumption (quadrillion Btu)	US Energy Information Administration (2024)
Yield spread	YS	10-year government bond yield minus 2-year government bond yield (%)	Federal Reserve Bank of St. Louis (2024)

index, fossil energy consumption (in quadrillion Btu), renewable energy consumption (in quadrillion Btu), the yield spread (the 10-year government bond yield minus the 2-year government bond yield, %), and the error term. The industrial production index serves as a proxy for gross domestic product. The model incorporates the industrial production index and its square to investigate the validity of the EKCH, which is the most popular hypothesis in energy and environmental economics research, in the United States. Besides, numerous articles in the literature offer compelling evidence that renewable energy can enhance environmental quality, while fossil energy can diminish it in various countries or country groups (see e.g., Bulut et al., 2024; Godil et al., 2021; Işık et al., 2024; Ozcan et al., 2020; Ozturk et al., 2023; Sadiq et al., 2022; Sharif et al., 2019, among others). Data for energy and CO_2 are extracted from the US Energy Information Administration (2024). Data on the industrial production index and the yield spread are obtained from the Federal Reserve Bank of St. Louis (2024). The data are on a monthly basis and cover the period June 1976 to September 2023. All variables except the yield spread are used in their natural logarithmic forms. The variables in the model are exhibited in Table 1.

4 | METHODOLOGY

The paper's empirical methodology commences with unit root tests, which are employed to determine whether the series being examined exhibit stationarity. This paper performs the ZA, PP, and KPSS unit root tests. The ZA, PP, and KPSS unit root tests are respectively propounded by Zivot and Andrews (1992), Phillips and Perron (1988), and Kwiatkowski et al. (1992). While ZA unit root test considers a structural break in series, PP and KPSS unit root tests do not take structural breaks into account. Because time series often exhibit non-stationary characteristics, cointegration tests are used to detect relationships between non-stationary series.

The autoregressive distributed lag (ARDL) approach to cointegration is frequently used when searching for cointegration. Thus, assuming no cointegration, the null hypothesis (NH) is initially evaluated using the bounds-testing strategy produced by Pesaran et al. (2001). Subsequently, the model suggested by Pesaran and Shin (1999) is used to estimate long-run parameters if cointegration is present. The estimation process for long-run parameters is conducted using the subsequent model:

$$y_t = \alpha + \sum_{i=1}^{p} \alpha_i x_{t-i} + \sum_{i=0}^{q} \beta_i x_{t-i} + u_t \qquad (2)$$

The error correction model calculates the short-run relation in the model once the long-run parameters have been computed. This model is described as below:

$$\Delta y_t = \theta_0 + \theta_1 EC_{t-1} + \sum_{i=1}^{p} \delta_i \Delta y_{t-i} + \sum_{i=0}^{q} \lambda_i \Delta x_{t-i} + u_t \qquad (3)$$

The negative and significant coefficient for the one-period lagged value of the error correction term (θ_1) points the short-run deviation is mended in the term. For this reason, cointegration is verified if it is negative and significant.

The paper works on a big sample with 568 observations, which lets us examine the possible asymmetric effect of the yield spread on environmental quality. Hence, the paper utilizes the nonlinearity test of Broock et al. (1996, hereafter BDS) to investigate the variables have nonlinear characteristics. Afterward, the paper employs the TR model to estimate the parameters in the model shown in Equation (1). Hansen (1999) focuses on whether the regression models are identical across observations in a sample and states that this could be addressed by way of TR methods. TR models are highly popular because they can consider nonlinearities and are easily implemented and interpreted (Gayaker et al., 2021). Accordingly, depending on the values of a variable, the sample could be divided into sub-samples, implying the coefficients of the independent variables could differ. Let us consider a simple regression model described as $y_t = \alpha_0 + \alpha_1 x_t + \varepsilon_t$. Assuming there exists one threshold, x is the threshold variable, and γ stands for the threshold value, this model can be exhibited via the TR technique as follows:

$$y_t = \alpha_0 + \alpha_1 x_t + \varepsilon_t \quad \text{if } x < \gamma \qquad (4)$$

$$y_t = \beta_0 + \beta_1 x_t + \varepsilon_t \quad \text{if } \gamma \leq x \qquad (5)$$

Equations 4 and 5 demonstrate that an augmentation in the quantity of thresholds directly corresponds to an augmentation in the quantity of regression models. The present paper uses the methodology of Bai and Perron (1998) to detect the number of thresholds.

5 | FINDINGS

The unit root tests' results are displayed in Table 2. The ZA and PP unit root tests are used to test the NH of a variable having a unit root (non-stationarity). In contrast, the NH of the non-presence of a unit root (stationarity) of a variable is tested for the KPSS test. As observed, the NH for a unit root cannot be rejected at level values, but it can be rejected at first differences for ZA and PP unit root tests. Furthermore, the NH of the non-existence of a unit root is rejected at level values, yet it cannot be rejected at first differences for the KPSS test. These findings indicate that the variables in the model are not stationary in levels, but they are stationary in first differences. These results indicate that the model's cointegration link could be investigated through the ARDL cointegration test.

TABLE 2 Unit root tests.

Variables	ZA test stat.	PP test stat.	KPSS test stat.
lnCO_2	−2.420	0.155	1.267*
lnIP	−3.190	2.840	2.894*
(lnIP)^2	−3.295	2.660	2.905*
lnFE	−2.936	0.207	1.961*
lnRE	−3.954	−1.442	2.599*
YS	−3.922	−2.678	2.912*
ΔlnCO_2	−8.366*	−71.335*	0.312
ΔlnIP	−16.568*	−18.587*	0.301
Δ (lnIP)^2	−6.625*	−18.599*	0.253
ΔlnFE	−8.970*	−71.495*	0.184
ΔlnRE	−9.560*	−49.768*	0.055
ΔYS	−6.846	−16.904*	0.064

Note: Δ stands for the first difference operator. * illustrates 1% statistical significance.
Abbreviations: FE, fossil energy; IP, income; ZA, Zivot & Andrews; PP, Phillips & Perron; KPSS, Kwiatkowski–Phillips–Schmidt–Shin; RE, renewable energy; YS, yield spread.

TABLE 3 ARDL cointegration test.

Part A: The result of the cointegration test			
Test statistic	4.159*		
Part B: Long-run coefficients			
Variable	**Coefficient**	**Std. error**	***t*-statistic**
lnIP	1.595**	0.668	2.385
(lnIP)^2	−0.117**	0.078	−2.266
lnFE	0.857*	0.067	12.613
lnRE	−0.121*	0.022	−5.264
YS	0.007***	0.004	1.824

Note: The error correction model's results indicate the coefficient of the one-period lagged error correction term is statistically significant and negative.
Abbreviation: ARDL, autoregressive distributed lag.
*, **, *** show 1%, 5%, and 10% statistical significance, respectively.

The results indicated by the ARDL cointegration test are reported in Table 3. Accordingly, the results for the cointegration relationship in the model are presented in part A. As is observed, the NH indicates that the no cointegration hypothesis is rejected by the test statistic, implying that there is cointegration and the coefficients could be estimated. The long-run coefficients are illustrated in part B. Accordingly, the coefficients of lnIP, (lnIP)^2, lnFE, lnRE, and YS are 1.595, −0.117, 0.857, −0.121, and 0.007, respectively. Moreover, all coefficients are significant. These results indicate that (i) the EKCH dominates in the United States, (ii) an escalation in the utilization of fossil fuels leads to a corresponding rise in CO_2, (iii) a rise in renewables consumption

TABLE 4 BDS test.

	Dimensions				
Variable	2	3	4	5	6
$\ln CO_2$	0.039* (0.000)	0.144* (0.000)	0.166* (0.000)	0.175* (0.000)	0.179* (0.000)
lnIP	0.207* (0.000)	0.351* (0.000)	0.451* (0.000)	0.521* (0.000)	0.568* (0.000)
$(\ln IP)^2$	0.207* (0.000)	0.351* (0.000)	0.451* (0.000)	0.520* (0.000)	0.568* (0.000)
lnFE	0.095* (0.000)	0.145* (0.000)	0.168* (0.000)	0.176* (0.000)	0.176* (0.000)
lnRE	0.170* (0.000)	0.295* (0.000)	0.384* (0.000)	0.447* (0.000)	0.491* (0.000)
YS	0.174* (0.000)	0.291* (0.000)	0.368* (0.000)	0.416* (0.000)	0.447* (0.000)

Abbreviations: BDS, Broock et al. (1996); FE, fossil energy; IP, income; RE, renewable energy; YS, yield spread.
*indicates 1% statistical significance.

TABLE 5 TR model estimation.

Variable	Coefficient	Std. error	t-statistic
Panel A: YS < 0.401 (number of obs.: 183)			
lnIP	1.149*	0.298	3.850
$(\ln IP)^2$	−0.127*	0.034	−3.636
lnFE	0.960*	0.018	53.110
lnRE	−0.135*	0.007	−18.320
YS	0.015*	0.003	4.322
Panel B: 0.401 ≤ YS < 1.031 (number of obs.: 141)			
lnIP	1.583*	0.237	6.677
$(\ln IP)^2$	−0.183*	0.028	−6.554
lnFE	0.978*	0.018	52.304
lnRE	−0.097*	0.009	−10.433
YS	0.040*	0.008	5.051
Panel C: 1.031 ≤ YS < 1.481 (number of obs.: 99)			
lnIP	2.119*	0.294	7.198
$(\ln IP)^2$	−0.245*	0.034	−7.038
lnFE	1.006*	0.022	44.257
lnRE	−0.094*	0.011	−8.647
YS	0.042*	0.012	3.338
Panel D: 1.481 ≤ YS (number of obs.: 145)			
lnIP	1.184*	0.399	2.961
$(\ln IP)^2$	−0.133*	0.046	−2.876
lnFE	0.942*	0.020	47.072
lnRE	−0.046*	0.008	−5.466
YS	0.009**	0.004	2.113
$R^2 = 0.98$	$\overline{R}^2 = 0.97$	F-ist. = 978.181 (0.000)	

Abbreviations: TR, threshold regression; YS, yield spread.
* and **, respectively, illustrate statistical significance at 1% and 5%.

leads to the reduction in CO_2, and (iv) CO_2 emissions are positively related to the yield spread.

Subsequently, the results of the BDS test are exhibited in Table 4. According to them, the NH of linearity is rejected for all variables under consideration at the 1% level. These results imply that the regressors in the model can have an asymmetric impact on CO_2 emissions, implying that the TR regression model can be employed to detect these impacts.

The parameter estimation results obtained from the TR regression model are shown in Table 5. As can be seen, four threshold values of the YS exist. Accordingly, when the value of the YS is lower than 0.401, the coefficients of lnIP, $(\ln IP)^2$, lnFE, lnRE, and YS are respectively 1.149, −0.127, 0.960, −0.135, and 0.015. Moreover, all these coefficients are statistically significant at the 1% level. When the value of the YS is between 0.401 and 1.031, the coefficients of lnIP, $(\ln IP)^2$, lnFE, lnRE, and YS, respectively, are estimated as 1.583, −0.183, 0.978, −0.097, and 0.040, while all these coefficients are significant at the 1% level. When the value of the YS is between 1.031 and 1.481, the coefficients of lnIP, $(\ln IP)^2$, lnFE, lnRE, and YS are 2.119, −0.245, 1.006, −0.094, and 0.042, respectively, with all coefficients being significant at 1%. Finally, when the value of the YS is equal to or greater than 1.481, then the estimations of the coefficients of lnIP, $(\ln IP)^2$, lnFE, lnRE, and YS are 1.184, −0.133, 0.942, −0.046, and 0.009, respectively, with the coefficient of the YS being statistically significant at 5% and the coefficients of other variables being statistically significant at 1%. Hence, the results obtained from the TR model are similar to those indicated by the ARDL cointegration test in terms of the signs of the coefficients.

For different values of the yield spread, these results clearly show that (i) the EKCH prevails in the United States, (ii) fossil energy consumption enhances CO_2, (iii) renewables consumption decreases CO_2, (iv) the yield spread enhances CO_2, and (v) the yield spread has an asymmetric impact on environmental deterioration, implying that the coefficient of the yield spread usually gets larger for higher values of the yield spread. Regarding the expectations hypothesis discussed earlier in the study, this last finding indicates that the influence of the yield spread on the environment intensifies more rapidly when short-term interest rates are expected to rise further. This finding has important implications. First, as the difference between short and long-term interest rates is higher, the environmental sensitivity of firms with higher financing costs decreases further. Second, when people have more optimistic expectations about future economic activities, higher levels of private consumption and investment expenditures occur, which in turn result in more environmental harm.

Hence, this paper discovers that there exists harmony between SDG 7, SDG 8, SDG 12, and SDG 13. Besides, the results of this paper for EKCH corroborate those of Roach (2013) and Işık et al. (2021) and contradict those of Bilgili et al. (2016) and Ongan et al. (2022). The empirical findings are compatible with those of Bilgili et al. (2016) in the sense of the impact of renewables consumption on environmental devastation. Finally, the findings indicating CO_2 emissions are positively associated with the yield spread show that firms' borrowing costs and future expectations for economic activities could influence environmental quality today.

6 | DISCUSSION AND CONCLUSION

The literature reveals that the potential impact of the yield spread on environmental quality has been disregarded by the previous papers. Nevertheless, the environment can be impacted by the yield spread through two channels. The first channel posits that an increase in the spread between long- and short-term government bond yields is indicative of an increase in long-term lending rates, as there is a significant co-movement between long-term interest rates. Consequently, firms may resort to less environmentally favorable production methods to mitigate their increased financing expenses. In other words, firms that aim to increase their profitability and market values may prioritize their operations over their environmental consequences, which ultimately leads to environmental degradation. Additionally, the second channel posits that the quality of the environment can be influenced by future expectations for business cycles, which can have an impact on real domestic expenditures in an economy. For example, the overexploitation of resources today may result from optimistic expectations regarding the future economic environment, which could result in an increase in environmental pressure. Consequently, the devastation of the environment is exacerbated if the energy necessary for economic activities that are fueled by private consumption and investment expenditures is met via fossil resources.

This paper was the first to examine the potential impact of the yield spread on environmental quality in the literature. More clearly, this paper inspected the possible influence of the yield spread on environmental deterioration in the United States within the EKCH using monthly data spanning the period 1976–2023. The model set up also incorporated fossil and renewable energy consumption. After using some unit root tests and detecting all variables became stationary at first differences, the paper performed the ARDL cointegration test and explored the presence of cointegration across the variables in the model. The study also estimated the long-run coefficients of regressors for the whole sample via the ARDL method. Then, the paper employed the TR model, considering the paper worked with 568 observations. Both the ARDL test and the TR model indicated the following results: (i) the EKCH dominated, (ii) CO_2 emissions were positively connected with fossil energy usage and negatively related to renewable energy consumption, (iii) CO_2 emissions were positively related to the yield spread, and (iv) the coefficient of the yield spread got greater for higher values of the yield spread. Based on these outputs obtained via the ARDL and TR models, this paper has certain implications and presents certain policy recommendations.

Because long-term interest rates move in harmony, an increase in long-term bond interest rates results in a corresponding increase in long-term loan interest rates. The findings for the yield spread document that businesses might be compelled to implement less ecologically sustainable production methods due to the elevated borrowing expenses to counterbalance the additional financial expenses and bolster profits. This paper previously mentioned that if financing costs increase, the impact of the yield spread on environmental deterioration can be greater. According to a recent survey conducted by RSM (2024), the cost of financing for small and medium-sized enterprises in the United States has increased from 11% to 15.5%. Therefore, firms may be utilizing less environmentally sustainable methods to reduce their total costs as a result of the increasing cost of borrowing in the United States. However, at present, there is considerable public interest in the environmental performance of corporations (Jo & Na, 2012; Wellalage & Kumar, 2021). Policymakers and stakeholders expect firms to contribute to the preservation of the natural environment and mitigate the harm caused by their operations (Braam et al., 2016; Manrique & Marti-Ballester, 2017). A recent report prepared by Clune et al. (2022) shows that the firms in the United States have not yet reached the desired level of awareness and sensitivity about environmental sustainability. According to this report, roughly 400 prominent American corporations have committed to achieving net-zero emissions, and a significant number of these companies have established particularly ambitious targets for 2030 or earlier. These goals of firms are in line with United States targets to reduce greenhouse gas emissions by half by 2030 and to achieve net zero emissions by 2050. However, only a few of these firms have yet to implement these commitments into comprehensive strategies for adapting their business models to operate effectively in a net-zero economy, implying the priorities of firms are still to increase profits and market values. The findings of the paper also imply that optimism for future economic activities leads to the over-exploitation of resources and increasing environmental pressure. This may be because the production activities stimulated by expenditures are mostly carried out using fossil energy.

The Federal Reserve Act reveals that the targets of the Fed are related to the promotion of maximum employment, stable prices, and moderate long-term interest rates (Federal Reserve, 2024). Long-term interest rates are affected by the expected inflation rate, risk premia, and short-run interest rates. Hence, considering the components of long-run interest rates and the Federal Reserve Act, this paper does not argue that the Fed should try to decrease the yield spread. Instead, the United States government should consider the negative impact of the yield spread on the environment. Put differently, the United States government should know that an increase in lending rates may lead firms to be less environmentally sensitive in their activities and that positive expectations about the future lead to more expenditures and environmental pressures today. The paper also argues that the government should closely follow future possible sharp increases in the yield spread as it has a further negative impact on environmental quality for higher yield spread values. Combining the empirical findings about the impact of fossil fuel consumption, renewables consumption, and the yield spread on the environment and the outputs that indicate the United States has loose environmental policies compared to other countries (Figures 5 and 6), the paper also contends that environmental policies in the United States should be tightened further to encourage more renewables utilization and improve environmental quality. Accordingly, the United States government can increase firms' sensitivity to environmental quality by imposing more environmental taxes and also improve loan conditions and provide financial support packages including tax incentives and grants for firms with cleaner and more environmentally friendly activities. The European Central Bank announced in September 2020 that it would accept green bonds as collateral for Eurosystem credit operations and include them in its asset purchase schemes in order to support sustainable finance and confront the climate change menace, as emphasized by Okimoto and Takaoka (2024). The Fed could take a more active role in the fight against climate change and engage in similar activities to encourage the issuance of green bonds. Put differently, to achieve a cleaner environment at a reduced cost, policymakers should integrate their environmental and financing policies to create a cleaner environment. Within this scope, considering eco-sustainable projects are endeavors linked to investments that are ethical, environmentally friendly, and socially responsible (Richardson, 2009; Russo et al., 2021; Schueth, 2003; Sparkes & Cowton, 2004), the United States government could provide financial support for firms to pursue these projects. A recent paper by Villalba-Rios et al. (2023) reveals that boards of directors in firms can influence the environmental sustainability of firms in Spain. Accordingly, large boards, characterized by a high proportion of women and a low presence of family members, result in a high level of environmental sustainability, whereas boards lacking a dedicated sustainability committee and independence due to family presence achieve a low level of environmental sustainability. These findings should be well analyzed by the policymakers in the United States. A similar study for the US firms can provide policymakers with new information about environmental sustainability of these firms. Because achieving net zero necessitates substantial modifications for firms, encompassing alterations in capital allocation, operations, and performance management (Clune et al., 2022), we argue that the policymakers in the United States should take an active role in terms of environmental sensitivity and sustainability of firms. Moreover, some papers in the extant literature find evidence that a considerable negative impact on a company's stock price results from the disclosure of environmental regulation violations and subpar environmental performance (see e.g., Bouzzine & Lueg, 2020; Dasgupta et al., 2001, 2006; Gupta & Goldar, 2005; Lundgren & Olsson, 2010, among others). Therefore, an enhancement in environmental sensitivity and sustainability of firms may positively affect their market values. Besides, some papers in the extant literature indicate that the environmental performance of a firm improves its financial performance (Kitzmueller & Shimshack, 2012).

Beyond the financial performances of firms, the implementation of the environmental policies suggested above will also positively impact environmental health. Considering environmental health focuses on the interactions between individuals and their surroundings, enhanced environmental quality, characterized by the presence of cleaner air and drinking water, has the potential to mitigate the occurrence of diseases such as asthma, heart attacks, and cancer (American Public Health Association, 2024).

Finally, this paper invites further possible research that may examine the influence of the yield spread on environmental quality in other countries. Consequently, researchers can investigate two research questions. The initial research question is directed at researchers who utilize macro data and is as follows: is the environmental quality influenced by the yield spread between government bonds? The second research question is for researchers who have access to microdata and is as follows: is the environmental quality influenced by the corporate bond spread? Researchers can provide macroeconomic policy recommendations along with sector- or firm-specific policy recommendations considering these research questions.

ETHICS DECLARATIONS

Not applicable.

ETHICAL APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

All data generated or analyzed during this study are available from the corresponding author on a reasonable request.

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