sustainability

MDPI

Article

The Impact of Economic Policy Uncertainty and Geopolitical Risk on Environmental Quality: An Analysis of the Environmental Kuznets Curve Hypothesis with the Novel QRPD Approach

Ibrahim Cutcu [1], Ali Altiner [2,*] and Eda Bozkurt [3]

[1] Department of Economics, Hasan Kalyoncu University, Gaziantep 27000, Türkiye; icutcu@gmail.com
[2] Department of Economics, Recep Tayyip Erdoğan University, Rize 53100, Türkiye
[3] Department of Foreign Trade, Ataturk University, Erzurum 25240, Türkiye; edabozkurt@atauni.edu.tr
* Correspondence: ali.altiner@erdogan.edu.tr

Abstract: This study aimed to determine the impact of economic policy uncertainty and geopolitical risk on environmental quality in 17 selected countries. In addition, it also aimed to test the environmental Kuznets curve hypothesis (EKC) within the scope of the determined variables and model. In this context, analyses were carried out with annual data for the period 1997–2022, based on the country group for which the economic policy uncertainty index was calculated, subject to data limitations. In this study, a Quantile Regression of Panel Data (QRPD) analysis, OLS (Ordinary Least Squares), and a panel causality test were used. As a result of the estimation with the Quantile Regression of Panel Data (QRPD), it was found that the increase in economic policy uncertainty had a positive effect on environmental quality in most of the quantiles, while geopolitical risk had significant and negative effects on environmental quality in the medium and high quantiles. The validity of the EKC hypothesis was also proved in the analysis. According to the results of the panel causality test, there was a bidirectional causality relationship between environmental quality and all the independent variables, except the square of economic growth. In order to make a comparison with the new-generation estimation method, QRPD, it was observed that the estimation results with the classical regression method, OLS, were similar. In light of these findings, it is recommended that policy makers pursue strategies that balance economic growth and environmental quality, reduce the environmental impacts of geopolitical risks, and favor a renewable energy transition. Moreover, long-term and stable environmental policies have a crucial role in the success of these strategies.

Keywords: economic policy uncertainty; geopolitical risk; environmental Kuznets curve hypothesis; panel data analysis

check for updates

Academic Editors: Bruce Morley and Alistair Hunt

Received: 29 November 2024
Revised: 26 December 2024
Accepted: 30 December 2024
Published: 2 January 2025

Citation: Cutcu, I.; Altiner, A.; Bozkurt, E. The Impact of Economic Policy Uncertainty and Geopolitical Risk on Environmental Quality: An Analysis of the Environmental Kuznets Curve Hypothesis with the Novel QRPD Approach. *Sustainability* **2025**, *17*, 269. https://doi.org/10.3390/su17010269

1. Introduction

Every country that wants to achieve sustainable development places improving environmental quality at the forefront of its goals. Today, environmental degradation has reached remarkable levels. The way to achieve a good environment is to identify the factors that cause environmental degradation [1,2]. Climate change is one of the most important environmental problems preventing sustainable economic growth at the global level [3]. The global warming dimension of climate change, which has become a crisis, is a phenomenon that is widespread worldwide, regionally, and locally and affects the lives of all living creatures and ecological systems. Global warming, which is accepted as a reflection of environmental degradation, continues to threaten all societies with its terrible effects that may continue for hundreds of thousands of years [4]. Greenhouse gas emissions (GHGs) are the most important factor that cause climate change or global warming: in short, environmental problems. Carbon dioxide (CO_2) emissions are among the leading harmful gas emissions [5,6]. Research shows that environmental degradation has steadily increased since the industrial revolution [7]. According to [8], when comparing annual global temperature differences between 1880 and 2023, the Earth's surface temperature has increased by 0.14 Fahrenheit per decade since 1880 [8]. Ref. [9] stated in its CO_2 emissions report for 2023 that global CO_2 emissions increased by 1.1% or 410 million tons in 2023, reaching a record high of 37.4 billion tons. These statistics show that environmental problems will continue to constitute a remarkable agenda for the whole world.

The activities that cause environmental degradation have always been a subject of interest for policy makers and researchers. Research indicates that human-induced activities cause environmental degradation the most. Although these activities are in economic, social, and political fields, they are mostly related to production–consumption and are economy-based [10]. In other words, the concern for economic growth is decisive in environmental performance. Energy is essential for civilizations to advance and achieve economic growth. The rising demand for energy against a limited supply and the use of mostly fossil fuels put negative pressure on environmental quality [11].

Economic growth is considered as one of the main determinants of CO_2 emissions and this relationship is analyzed through the environmental Kuznets curve (EKC) hypothesis proposed by Kuznets in 1955. This hypothesis was later developed by Grossman and Krueger in 1991 and recognized by Panayotou in 1993 [12–14]. The EKC hypothesis posits an inverted U-shaped relationship between income growth and the level of environmental degradation. In other words, while environmental degradation increases with per capita income in the initial stages of economic growth, it decreases with per capita income after a threshold level.

The threshold level is important, as the appropriate value per capita that ensures a decrease in CO_2 emissions provides information about income. It is assumed here that economic growth increases CO_2 emissions in the early stages of development. In the early stages of growth, governments prioritize increasing income and welfare at the expense of environmental degradation. Later, as income and living standards rise, countries pay more attention to the environment. A higher per capita income allows governments to implement climate change mitigation policies, implement a renewable energy transition, and improve environmental conditions [15,16]. In other words, while economic growth may initially disrupt the ecological balance, it can eventually help a country restore it [17]. It is possible to say that the EKC is based on three economic effects: the scale effect, composition effect, and technical effect. The scale effect represents the increase in production that requires the use of emission-producing inputs for economic growth. According to the scale effect, as the economy grows, the demand for natural resources increases. Thus, pollutants are produced in quantities that degrade the quality of the environment through the excessive use of natural resources. Environmental degradation starts with this effect. In contrast to this effect, the composition and technical effect states that as income increases, production and consumption are carried out by taking environmental concerns into account. Thus, CO_2 emissions start to decrease. In the composition effect, with the structural transition from agriculture to energy-intensive industrialization, the rate of resource consumption exceeds the rate of resource renewal and emissions and environmental degradation increase. However, as the economy develops and shifts to a low-polluting service sector, the rate of environmental degradation slows down. After the turning point is reached, environmental quality starts to improve. The technical effect is the replacement of polluting technology with cleaner technology through economic growth and technological progress. Thus, environmental degradation is reduced, and environmental quality is improved [18,19]. Figure 1 summarizes the relationship between economic growth and the environment, according to the EKC hypothesis.

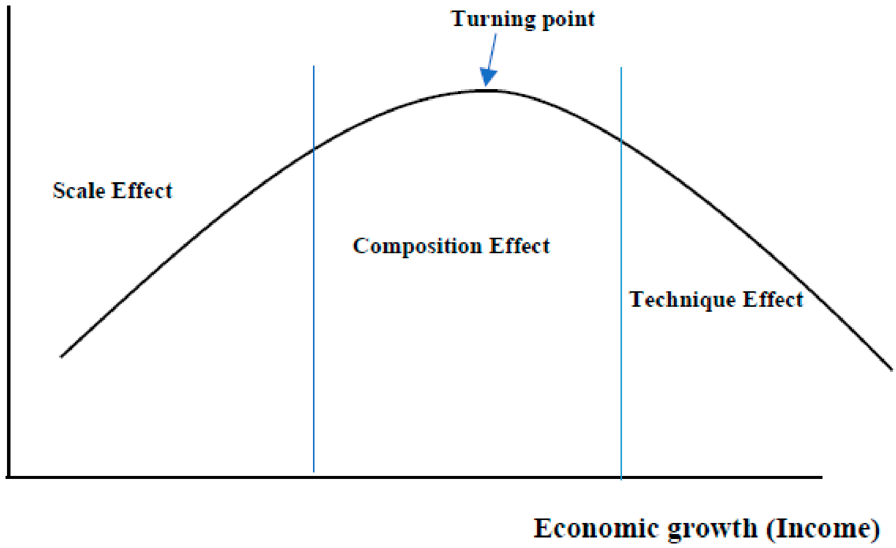

Figure 1. Environmental Kuznets curve.

Environmental Degradation

There have been many studies testing the EKC hypothesis, such as [20–31]. However, empirical analyses have always identified the existence of inconclusive results regarding the EKC hypothesis, including U-shaped or inverted U-shaped relationships. The acceptance or rejection of the EKC hypothesis can be influenced by many factors, ranging from econometric techniques to countries' environmental policies [32]. At this point, extending EKC models is seen as a way to obtain more realistic results. In this study, the model is extended by adding EPU (economic policy uncertainty) and GPR (geopolitical risk) variables to the EKC model. This is because while EPU and GPR affect economic growth, they may have important implications for changes in environmental quality. In addition, while testing the EKC hypothesis, the effect of EPU and GPR variables is determined through the environmental performance index (EPI) variable. In the literature, CO_2 and ecological footprint variables are frequently used when modeling the EKC hypothesis. However, the use of the EPI variable in this study has created a significant difference from the existing studies addressing the EKC hypothesis.

While much work has focused on the drivers of CO_2 emissions, the linkage of macro factors such as EPU or GPR to the environment is of more recent interest. For example, the COVID-19 pandemic has created great economic uncertainty and made the importance of EPU increasingly apparent. EPU, both at the macro and micro level, can be considered as the lack of definition of future government policies and regulatory frameworks. GPR is the deterioration of the peaceful course of international relations in general. GPR can disrupt the atmosphere of cooperation at the international level. Both uncertainties can lead to a global recession with many possibilities, ranging from firms hiring new workers to abandoning their decisions to invest and enter the market. Changes in production and investment decisions have environmental consequences. As a result, uncertainty reshapes the environment in which economic entities operate [6,33]. EPU and GPR can prevent environmental degradation by reducing economic growth and, hence, energy use. However, they may increase environmental degradation by preventing the preference for clean energy use based on innovation. As detailed in Sections 2 and 3, it is known that previous studies do not provide consistent results on the environmental impacts of EPU and GPR. This lack of clarity is seen as an opportunity for this study to contribute to the existing literature. This study is motivated to answer several important research questions. These can be listed as follows:

- How does EPU affect the environmental quality of countries?
- How does GPR affect the environmental quality of countries?
- Is the EKC hypothesis valid in the presence of EPU AND GPR?
- Does the energy variable change environmental quality with EPU and GPR?

The aim of this study is to make a contribution to the literature by addressing the above-mentioned problems through three main motivations. First, the relationship between economic policy uncertainty (EPU) and geopolitical risk (GPR) and their impact on the environment is explored in this study. In this respect, by analyzing in depth popular findings in the existing literature, it aims to provide a new and complementary perspective. Secondly, the environmental performance index (EPI) is used in this study as an indicator of the quality of the environment. The EPI has a multi-dimensional structure that covers various parameters related to the environment, going beyond the limited and one-dimensional indicators commonly used to measure environmental quality, such as CO_2 emissions. In this way, the quality of the environment is represented by a more comprehensive and integrated indicator. EPIs are rarely employed in the literature, which increases the originality of this study and allows it to present original findings. Furthermore, this variable evaluates the environmental Kuznets curve (EKC) hypothesis from a broader perspective than existing studies. Thirdly, the study's methodological contribution is based on panel quantile regression models, incorporating Powell's (2022) [34] Quantile Regression for Panel Data (QRPD), which provides an innovative approach. This method has some important advantages over existing estimation methods, which are explained in detail in the fourth section of this paper. In this context, this study is more powerful and novel in terms of its empirical analysis because it is the first time in the literature that this method has been applied to this issue. In addition, all countries for which the EPI index is calculated are included in the empirical analysis; only a small number of countries with missing data are excluded from the analysis. On the basis of the EKC hypothesis, the environmental impacts of the EPU and the GPR have been estimated using the QRPD method for the period 1977–2022 for 17 of the 23 countries for which the EPI index has been calculated. This comprehensive analysis increases the power of the findings, making a significant contribution to the literature.

The content of this study is planned as follows: Section 2 presents the theoretical background and hypotheses, Section 3 presents the literature review, Section 4 presents the variables, dataset, and econometric methodology, and Section 5 presents the results of the empirical analysis. The Sections 6 and 7 concludes the study by presenting the conclusion and discussion, the limitations of the research, and the future work plan.

2. Theoretical Framework

Environmental degradation is now recognized as a major challenge for all countries. Governments are focusing on the factors that lead to the deterioration of environmental quality. Global EPU and GPR are considered to be among the phenomena causing environmental degradation in recent years. Different views explain the mechanisms through which both types of uncertainty affect the environment. In order to understand the relationship between EPU and GPR with environmental dynamics, it will be useful to explain these variables conceptually in the first step.

EPU, which is often based on the divergence of governments' economic policy forecasts [35], first became theoretically recognized when [36] conceptualized policy uncertainty [37,38]. Ref. [36] developed an EPU index for the United States (US) and examined how it had changed since 1985. They analyzed the frequency of words containing terms such as economic, uncertain, Congress, Federal Reserve, deficit, legislation, White House, and regulation in 10 leading US newspapers and 12,000 articles. The index in the US was found to rise during struggles over fiscal policy, such as the presidential elections, Gulf Wars, September 11 attacks, Lehman Brothers' bankruptcy, and economic crises [36]. While the EPU index measures the risk of undefined government policies for the near future, it also shows that uncertainty has negative effects on economic activity [39]. It has been shown that EPU can be used both at the macro level, such as for economic growth, and at the micro level, such as in corporate investment [40]; capital investment or resource structuring [41–43]; the stock market; market volatility and financial stability [44–46]; innovation and patenting [47,48]; and demand, consumption, and investment decisions [49,50]. In addition to all these, although researchers focus on the possible effects of EPU at the macroeconomic and microeconomic level, they recognize that it has an environmental reshaping role.

According to some researchers, the link between EPU and the environment is explained by the consumption effect and the investment effect. Open economies often involve energy investments and energy-intensive products. Higher uncertainties may reduce the consumption of energy-intensive products. A reduction in production based on fossil fuels can lead to a reduction in environmentally harmful factors, such as CO_2 emissions. This effect is recognized as a consumption effect. On the other hand, renewable energy investments and projects may suffer under high uncertainty. This can, again, lead to an increase in CO_2 emissions. Thus, environmental quality may suffer. This effect is the investment (substitution) effect. The magnitude of the consumption and investment effect is decisive in the potential for uncertainties to lead to environmental degradation. If consumption and investment effects are similar, then the EPU has no environmental impact [51,52].

It is also possible to explain the EPU effect on the environment by naming it as a direct policy change effect and an indirect economic demand effect [38,53].

An increase in EPU negatively affects the economy and reduces the demand for energy consumption. Environmental protection will become less important as policy makers turn their attention to how to sustain economic activities in the face of increasing EPU. This means less effort is made to protect the environment. On the other hand, firms prefer more protectionist policies as EPU increases. In other words, the speed of decision making on investment and employment slows down for firms. Firms also turn to cheaper, but polluting, fossil fuels. High EPU implies a reduction in innovation, research, and development (R&D) and renewable energy consumption. In addition, firms may consider that governments may relax environmental regulations. Firms may, thus, reduce their efforts to control CO_2 emissions. As a result, EPU leads to the deterioration of environmental quality [54,55]

In micro terms, managers are more likely to wait when making a decision that they are not sure about. In other words, they are less likely to make that decision. EPU is likely to have a negative impact on both corporate behavior and performance. It is usual for firms to tend to postpone rather than bear irreversible costs under uncertainty [56]. However, from a different perspective, there is also the view that EPU will encourage businesses to capture innovation opportunities and encourage technological innovation. That is, uncertainty can lead to high profit expectations in some technology-intensive industries. Uncertainty and risk can lead to future returns, competitive advantage, and investment expansion for businesses. Policy uncertainty may have an activity-enhancing effect on innovation, leading to environmental degradation [57].

For the relationship between EPU and the environment, the theoretical background of which is summarized above, it is possible to say that one school of thought adopts the idea that EPU increases environmental degradation and another school of thought adopts the idea that it decreases it. In addition, there is also a small number of opinions suggesting that EPU has little impact on the environment. The fact that previous studies have not yielded a generalizable result proves that the environmental link of EPU is still worthy of attention [58].

Apart from EPU, GPR is seen as one of the most common uncertainties on a global scale. GPR is defined as the risks associated with terrorist acts, wars, and tensions between states when power struggles over territory cannot be resolved peacefully and democratically. GPR covers not only the risk of these events occurring, but also new risks based on the escalation of existing events. GPR encompasses different events with various causes and consequences, ranging from the global financial crisis to Brexit and from terrorist attacks to climate change [59,60].

In order for GPR to become an indicator, Ref. [60] constructed an index based on a count of newspaper articles since 1985. While constructing the index, the articles were searched for words such as war, war threats, military, crisis, uncertainty, fear, and threat. It was observed that the GPR index increased after the Gulf War, the September 11 attacks, the invasion of Iraq, the Russia–Ukraine crisis, and the Paris terrorist attacks. If the index is extended back to 1900, it is determined that the risk increased during the first and second world wars [60]. Conflicts over land and sea borders or access to critical resources, shifts in government policies, changes in political leadership, cyber-attacks, and evolving political ideologies can lead to GPR. At the same time, events such as hurricanes, earthquakes, pandemics, rising sea levels, climate change, resource scarcity, competition for resources, and the displacement of populations can increase GPR. There is a wide range of factors that can cause GPR and the risks are no longer regional but global, incorporating political, environmental, and security-related elements [61].

GPR affects the environment through two channels. The first channel is dominated by the fact that GPR reduces economic growth and, thus, energy consumption, thus preventing environmental degradation. An environment of security and stability is a prerequisite for access to energy resources. GPR can create disruptions in energy supplies. This view is known as the mitigating effect. The second channel is the escalating effect, which argues that when GPR increases, innovation, R&D, and renewable energy investments and utilization decrease, non-renewable resources are preferred, and, thus, environmental degradation increases. In addition, as GPR increases, governments shift their attention from environmental issues to risks, and the deterioration of environmental quality is exacerbated. Based on this, GPR can either increase or decrease environmental degradation. In other words, there is no clear impact on the environmental effects of GPR [13,59]. The theoretical background shows that the environmental impacts of EPU and GPR are open to research. For this purpose, the study tests the hypothesis that "EPU and GPR variables have an impact on environmental quality within the framework of the EKC hypothesis" for the years 1997–2022 for 17 countries for which the EPI index is available, using the QRPD method.

3. Literature Review

Following our analysis of the environmental economics literature, we observed that that the impact of different variables on the environment had been analyzed within the scope of different models in recent years. However, the impact of EPU and GPR on the environment and their evaluation within the scope of the EKC hypothesis have not been sufficiently studied. First, we observed that there are studies that deal with EPU and

GPR together or individually. Second, different indicators were used in the literature to represent the environmental variable included in the analysis as the dependent variable. For example, Refs. [1,62–65] used CO_2 emissions to represent the environment, while Ref. [13] used ecological footprint, Ref. [66] used green growth, Ref. [54] used the score of environmental performance, and Ref. [67] used greenhouse gas emissions to represent the environment. This diversity causes the related literature to become quite disorganized. In the Literature Review Section, studies on EPU and GPR from an environmental perspective are reviewed, and, in order to systematize the literature, (i) studies with CO_2 emissions as the independent variable are grouped together, and (ii) studies using independent variables other than CO_2 are grouped together.

3.1. EPU, GPR, and CO_2 Emissions

Studies investigating the relationship between EPU and GPR with CO_2 emissions, which are considered to be the main cause of global warming, climate change, and environmental degradation, have shown that these variables can cause environmental degradation. For example, Refs. [37,56,68,69] argue that EPU, Refs. [3,70] argue that GPR, and Ref. [2] argues that both EPU and GPR increase CO_2 emissions. However, there are also some studies in the literature that present different results. For example, Refs. [64,71] found that EPU reduces CO_2 emissions. Ref. [72] determined that while GPR reduces CO_2 in the short term, it increases it in the long term. In another study, Ref. [7] stated that GPR will prevent CO_2 emissions in the short term while increasing CO_2 in the long term. Ref. [73] claimed that EPU intensifies CO_2 emissions in the short term and reduces them in the long run. In conclusion, it is seen that studies on the impact of EPU and GPR on the environment present contradictory results. The literature review on EPU, GPR, and CO_2 emissions is summarized in Table 1.

Table 1. EPU, GPR, and CO_2 studies.

Author(s)	Country	Period	Method	Findings
[62]	10 resource-rich countries	1996–2017	PMG-ARDL, Pedroni and Kao Cointegration Test, Dumitrescu and Hurlin Panel Causality	EPU and GPR increase CO_2.
[74]	UK	1985–2017	ARDL Bound Test, Granger Causality	In the short term, EPU reduces CO_2. In the long term it increases it.
[63]	32 countries	1996–2014	GMM	EPU increases CO_2.
[5]	China	1980–2016	ARDL Bound Test, STIRPAT Model, Dynamic ARDL Simulations	EPU increases CO_2.
[71]	G7 countries	1997–2015	Parks–Kmenta Model	EPU reduces CO_2.
[64]	Iran	1971–2018	NARDL	EPU reduces CO_2.
[75]	325 provinces in China	2001–2017	Two-Way Fixed Effects Model	EPU increases CO_2.
[76]	BRICST	1990–2015	Westerlund (2007) Cointegration, AMG and CCEMG, Fixed Effects and Panel Quantile Regression	EPU reduces CO_2 in low and middle quantiles and increases it in higher quantiles. GPR increases CO_2 at low quantiles. It decreases it at medium and higher quantiles.

Table 1. *Cont.*

Author(s)	Country	Period	Method	Findings
[77]	India	1985Q1–2019Q4	QQR Regression	GPR increases environmental degradation in the middle quantiles and decreases it in the lower and higher quantiles.
[78]	21 developed and developing countries	2009M2–2022M8	GARCH-MIDAS, CAViaR Approach	EPU and GPR increase carbon market risk.
[79]	OECD	2003–2019	GMM, SELPDM, Westerlund Panel Cointegration, Dumitrescu and Hurlin Causality	EPU degrades environmental quality.
[1]	China and US	1995Q1–2020Q4	Lasso and Ridge Regressions, NARDL, Nonlinear Granger Causality Test	An unfavorable change in EPU reduces emissions in China but increases them in the US.
[70]	China	1995–2020	QARDL, Granger Causality	GPR increases CO_2.
[80]	US	1997M1–2022M10	WTC and TVWCT	GPR and EPU generally reduce sectoral CO_2.
[81]	GCC countries	2000M1–2021M12	Novel Quantile-Based Method	An increase in GPR increases CO_2.
[65]	G7 countries	1995–2018	Cointegration, FMOLS, DOLS, and MMQR	EPU reduces CO_2.
[2]	BRICS	1992–2021	FMOLS, DOLS, AMG, and Cross-Sectional ARDL	EPU and GPR increase CO_2.
[82]	31 countries	2000–2019	Westerlund and Edgerton (2007), Wavelet Quantile Correlation, Dumitrescu and Hurlin Panel Causality	GPR degrades environmental quality.
[83]	18 countries	1985–2021	FMOLS, CCR, Static Time-Variant Granger Causality, Hatemi-J Cointegration, Maki Cointegration	Reducing uncertainty and GPR reduces carbon intensity.
[84]	China	2005–2021	MMQR	EPU reduces carbon efficiency.

3.2. The Literature on EPU, GPR, and Different Environmental Indicators

Some other variables besides (or in addition to) CO_2 emissions have been used to empirically represent the environment in the studies. Table 2 shows the studies that use different environmental indicators to examine the relationship between EPU, GPR, and the environment. For example, Ref. [13] determined the environmental impact of EPU and GPR for five emerging countries for the period 1995–2015 using the ecological footprint variable. The findings show that EPU increases the ecological footprint, while GPR decreases it. Ref. [54] found deteriorating relationships between the score of environmental performance and EPU in 137 countries in 2001–2018. Ref. [85] found that EPU reduced environmental pollution, with a PM2.5 pollution indicator in 25 countries in the period 1976–2018. Ref. [35] determined that EPU affected green innovation to a varying extent, with green patent applications in the period 2000–2017 in 31 provinces in China. Ref. [86] determined that EPU and GPR caused environmental degradation, with environmental quality value in BRICST countries in 1990–2020. Ref. [87], in their study of the period 1997–2018 in G-20 countries, suggested that increasing environmental quality with three variables, such as carbon footprint, ecological footprint, and carbon dioxide emissions, should reduce EPU and GPR. To summarize, in the literature investigating the environmental impacts of EPU and GPR using different dependent variables other than CO_2 emissions, it is possible to say that the net effect of EPU and GPR cannot be found as in the first group of studies.

Table 2. Studies on EPU, GPR, and different environmental indicators.

Author(s)	Country	Period	Dependent	Method	Findings
[13]	Brazil, China, Colombia, Mexico, and Russia	1995–2015	Ecological footprint	Kao Cointegration, Westerlund (2007) Cointegration Test, FMOLS, DOLS, AMG, Dumitrescu and Hurlin Panel Causality Test	EPU increases ecological footprint while GPR reduces it.
[41]	China (30 administrative regions)	2000–2017	Green technology innovation	Provincial Level Regression	EPU inhibits green innovation to different degrees.
[88]	BRICS	1985–2019	CO_2 emissions, energy consumption	NARDL Model	There are country- and group-specific results.
[66]	OECD	1994–2020	Green growth	CS-ARDL Model	Positive shock in EPU is detrimental to green growth, negative shock is insignificant.
[89]	BRICS	1995–2021	Environmental degradation	Westerlund (2007) Cointegration Test, CS-ARDL, Driscoll and Kraay, FGLS, and PCSE, Dumitrescu and Hurlin Panel Causality	GPR causes environmental degradation.
[90]	G7 countries	1997–2015	Carbon dioxide emissions and ecological footprint	Fixed Effects Model	EPU reduces CO_2 emissions and ecological footprint.
[91]	China	2000M1–2017M12	Ecological footprint	TVP-VAR	EPU and GPR cause environmental degradation.
[92]	US (1026 firms)	2002–2020	Environmental innovation	Regression	EPU leads to a reduction in environmental innovation in the long run.
[52]	South Korea	1990–2019	Energy consumption, ecological footprint	ARDL, NARDL, Bayer and Hank Test Cointegration, Asymmetric Causality Test	EPU increases environmental degradation.
[54]	137 countries	2001–2018	Score of environmental performance	STIRPAT, GMM	EPU degradation environmental performance.
[85]	25 countries	1976–2018	PM2.5 pollution	2SLS Methods	EPU reduces PM2.5 pollution.
[93]	China (30 provinces)	2008–2020	Environmental pollution emission efficiency	Fixed Effects Model	The environmental impact of EPU is more profound in developed provinces.
[94]	E7 countries	1995–2018	CO_2 emissions, ecological footprint consumptions	Kao Cointegration, Pedroni Cointegration, Westerlund (2005) Cointegration, PMG-ARDL	EPU and GPR are harmful in the long term. Beneficial in the short term.

Table 2. *Cont.*

Author(s)	Country	Period	Dependent	Method	Findings
[95]	China	1995–2021	CO_2 emissions, ecological footprint	ARDL Bound Test	EPU degrades environmental quality.
[96]	19 developed and developing countries	2001–2019	GHG emission	PCSE and GLS	EPU increases GHG.
[97]	UK, Pakistan, the USA, China, and India	2000–2021	Ecological footprint	Kao Cointegration, Westerlund Cointegration Test, DOLS, AMG, FMOLS	EPU and GPR cause environmental degradation.
[12]	BRICS	2000–2021	CO_2 emissions, GHG emissions, and primary energy consumption.	Durbin–Hausman–Westerlund (2008) and Westerlund and Edgerton (2008) Cointegration, CupFM, CupBC, FMOLS, Panel Causality	GPR degrades environmental quality. EPU improves environmental quality in the long term.
[35]	China, 31 provinces	2000–2017	Green patent applications	Fixed Effects Model, GMM, and LSDVC	EPU affects green innovation to varying extents.
[98]	60 countries—2782 firms	2019	Carbon footprint	Cross-Sectional Regression Analysis	EPU is positively correlated with carbon footprint.
[99]	Brazil, Indonesia, South Africa, India, and Turkey	1996–2019	Environmental degradation index	Pedroni, Johansen Fisher Cointegration, Panel Quantile Regression	EPU increases environmental degradation.
[100]	OECD	1990–2021	Energy transition, environmental stability	Westerlund Cointegration (2007), MMQR, Dumitrescu and Hurlin Panel Causality Test	The GPU is the regulator on environmental stability.
[87]	G-20	1997–2018	Carbon footprint, ecological footprint, and carbon dioxide emissions	FMOLS, Westerlund–Durbin–Hausman Cointegration	EPU and GPR need to be reduced to improve environmental quality.
[101]	25 emerging economies	1991–2019	Green growth	Kao, Pedroni, and Westerlund Cointegration, PMG-ARDL	EPU has a negative impact on green growth.
[67]	BRICS	1993–2020	GHG emissions	CupFM, CupBC, Westerlund and Edgerton (2007) Cointegration, Panel Quantile Regression	GPR increases GHG.
[86]	BRICST	1990–2020	Environmental quality	Pedroni Cointegration, Johansen, Fisher and Kao Cointegration, FMOLS, DOLS, Panel Quantile Regression	EPU and GPR degrade environmental quality.

Considering all of the existing literature, a few conclusions for the literature review on how EPU and GPR affect the environmental status of countries can be listed as follows:

- The studies on the subject are quite new.

- Different dependent variables are preferred to represent environmental performance in the literature.
- The impact of EPU and GPR on the environment does not provide a clear result and varies from study to study.
- Studies in the literature vary in terms of country, period, and analysis methods.

In the light of the literature summary, our study fills an important gap in the literature by choosing the environmental performance index (EPI) as a proxy for environmental quality. Moreover, our model estimation is an extended version of the EKC hypothesis with EPU and GPR indicators. In addition, unlike those in the literature, our study has strong differences and contributions in the sense that we use the QRPD method for 17 countries for which the EPI index is calculated and for the period 1997–2022, as well as in the sense that we provide evidence from traditional OLS and provide a comparison of findings.

4. Variables, Data, and Methodology

4.1. Variables

In the analysis part of the study, the impact of EPU and GPR on environmental pollution was tested within the framework of the EKC hypothesis. For this purpose, 17 (selected 17 countries: Australia, Brazil, Canada, Chile, China, France, Germany, India, Italy, Japan, Korea, Mexico, Russia, Spain, Sweden, UK, and US) selected countries were considered and an empirical analysis was conducted using annual data for the period 1997–2022, depending on the availability of the data. The reason for choosing this set of countries is that the EPU data are calculated for 23 countries. However, due to the unavailability of other variables for some countries, only 17 countries could be included in the analysis. The environmental performance index (EPI) was used as the indicator of environmental pollution, or in other words, environmental quality. The main independent variables were economic policy uncertainty (EPU) and geopolitical risk (GPR). In addition, in order to test the EKC hypothesis, the real GDP per capita (GDPpc) and the square of the real GDP per capita (GDPpc2) were included in the model as independent variables, as proxies for economic growth. Finally, primary energy consumption (ENERGY), which is considered to have a significant impact on the environment, was also included in the analysis as a control variable. Explanatory information on these variables, used in the empirical analysis, is presented in Table 3.

Table 3. Variable definitions.

Variable	Explanation	Source
EPI	Environmental performance index	[102,103]
EPU	Economic policy uncertainty index	[104]
GPR	Geopolitical risk index	[105]
GDPpc	GDP per capita, calculated at constant 2015 prices (USD)	[106]
GDPpc2	Square of GDP per capita, calculated at constant 2015 prices (USD)	[106]
ENERGY	Primary Energy Consumption (Exajoules)	[107]

4.2. Data

The environmental performance index (EPI) is an index from the Yale Center for Environmental Law and Policy (YCELP) and the Center for International Earth Science Information Network (CIESIN) that provides information on environmental sustainability worldwide. In this index, 180 countries are ranked according to 40 performance criteria in 11 topics. These topics are Biodiversity and Habitat, Fisheries, Ecosystem Services, Agriculture, Acidification, and Water Resources under the Ecosystem policy objective; Sanitation and Drinking Water, Waste Management, Air Quality, and Heavy Metals under the Environmental Health policy objective; and Climate Change under the Climate Change policy objective. The EPI, which consists of the sum of the data of 3 broad policy objectives formed by 11 topics, receives a score between 0–100. The higher the score is, the higher the environmental quality is [108].

The EPU data were developed by [36]. They are an index consisting of 3 main components. The first component is the measurement of policy-related economic uncertainty based on newspaper reports. This news-based approach was adapted to all countries to construct an index of economic policy uncertainty for each country. For the US, the second type of component is measured using reports that aggregate lists of tax law provisions. The third component, also for the US, is measured using the Philadelphia Federal Reserve Bank's Survey of Professional Forecasters. While the first component constitutes the EPU index for all countries, the sum of the three components constitutes the index for the US. An increase in this index value indicates an increase in economic policy uncertainty, while a decrease indicates a decrease in economic policy uncertainty [109].

GPR data are an index introduced by [60]. The index measures unfavorable geopolitical events and risks, based on newspaper reports. An increase in the index value indicates a higher geopolitical risk and indicates a decline in investment and employment. The GDPpc data were taken from the World Bank's World Development Indicators database. These data are obtained by dividing the real GDP by the population in the middle of the relevant year. The GDPpc2 data were generated by squaring the GDPpc data obtained from the World Bank. The GDPpc and GDPpc2 data were used in this analysis by taking their natural logarithms. Finally, the ENERGY data were obtained from the British Petroleum Statistical Review of World Energy database and cover tradable primary fuels, including renewable energy sources used in electricity generation.

When Table 4, which includes descriptive statistics, was examined, it was determined that the EPI, GDPpc, and GDPpc2 variables are left-skewed and the EPU, GPR, and ENERGY variables follow a right-skewed distribution, according to their Skewness values. According to the kurtosis values, since the values of all the variables are greater than zero, it was observed that there is no normal distribution and there is a peaked distribution. In addition, according to the Jarque–Bera test results, applied to determine whether the variables have a normal distribution, it was observed that all the variables do not have a normal distribution since the probability values of all the variables are less than 5%. This showed that the coefficient estimates made with OLS (Ordinary Least Squares) would give inconsistent results. Therefore, it was decided that estimating the coefficients using a quantile regression would produce consistent and robust results.

Table 4. Descriptive statistics.

	EPI	EPU	GPR	GDPpc	GDPpc2	ENERGY
Mean	45.262	140.371	0.416	9.875	98.582	21.160
Median	45.992	113.261	0.182	10.356	107.252	10.596
Maximum	74.394	791.874	4.350	11.062	122.374	159.393
Minimum	16.358	27.001	0.006	6.500	42.256	1.012
Std. Dev.	13.256	99.662	0.620	1.039	19.158	29.762
Skewness	−0.268	3.042	3.249	−1.297	−1.062	2.565
Kurtosis	2.672	15.597	15.817	4.134	3.354	8.945
Jarque–Bera	7.272	3603.701	3803.159	147.681	85.468	1135.621
Probability	0.026	0.000	0.000	0.000	0.000	0.000
Observations	442	442	442	442	442	442

4.3. Methodology

In the study examining the impact of EPU and GPR on environmental quality, the model created in the specified sample and data range was constructed as follows:

$$EPI_{it} = \beta_{it} + \beta_1 EPU_{it} + \beta_2 GPR_{it} + \beta_3 GDPpc_{it} + \beta_4 GDPpc2_{it} + \beta_5 ENERGY_{it} + \varepsilon_{it} \quad (1)$$

In the model, β denotes the coefficient, i = 1, 2, 3, . . ., N denotes the horizontal cross-sectional dimension, t = 1, 2, 3, . . ., T denotes the time dimension, and ε denotes the error term. The procedure was as follows:

- ➢ Investigating the presence of cross-sectional dependence for the variables and the model with the Breusch–Pagan (1980) [110] CDlm1 test and the Pesaran (2004) [111] CDlm2 test.
- ➢ Determining whether the slope coefficients are homogeneous or heterogeneous with the Delta test developed by Powell (2022) [34].
- ➢ Applying the CIPS (cross-sectional Im, Pesaran, and Shin) unit root test developed by Pesaran 2007 [112], one of the second generation unit root tests, to examine the stationarity levels of the variables.
- ➢ Determining and comparing coefficients with the Quantile Regression of Panel Data (QRPD) and OLS estimators of [34].
- ➢ Applying the Dumitrescu and Hurlin (2012) [113] panel causality test to test the mutual causality between the EPU, GPR, and EPI variables.

4.3.1. Cross-Sectional Dependence Test (CSD)

Although cross-sectional units are assumed to be independent from each other in panel data models, relations between countries have increased rapidly. Therefore, a shock in one country may also affect other countries. Therefore, it is necessary to test for the existence of an inter-unit correlation, in other words, CSD, and to conduct other analyses accordingly. In this study, the impact of EPU and GPR on environmental quality was analyzed for 17 selected countries. Therefore, the horizontal cross-sectional dimension was N = 17. The time dimension was T = 26 since it covers the annual data for the period 1997–2022. Therefore, since T > N, the Breusch–Pagan (1980) [110] CDlm1 test and the Pesaran (2004) [111] CDlm2 test were used in the analysis.

4.3.2. Homogeneity Test

In panel data analysis methods, it is necessary to decide whether the coefficients of the variables are homogeneous in the cointegration test, coefficient estimation, and causality investigation. The homogeneity test checks whether the slope B coefficients in panel data models are different across the cross-sections. In this study, we utilized the Slope Homogeneity Test (Delta test), developed by Pesaran and Yagamata (2008) [114], to check the homogeneity. It is accepted that the Delta_tilde test is valid for large samples and the Delta_adj test is valid for small samples. In the homogeneity test, according to the null hypothesis (H_0), "Slope coefficients are homogeneous", and according to the alternative hypothesis (H_1), "Slope coefficients are heterogeneous".

4.3.3. Unit Root Test

In the third stage, we utilized a second-generation panel unit root test, CIPS (Cross-Sectional Im, Pesaran, and Shin) by Pesaran (2007) [112], which is a test that can be applied when there is CSD between the series. This test was extended with cross-sectional averages of the lag levels and the first difference values for each series. With the CADF test, a CIPS statistic for the entire panel was obtained by taking the arithmetic mean of the statistics of each cross-section. Thus, the stationarity test could be applied to the entire panel, as well as to each cross-sectional unit. If the CIPS statistics were smaller than the critical table values in the absolute value, the series was considered to have a unit root, and if they were larger, the series was considered to be stationary.

4.3.4. Coefficient Estimation

A quantile regression analysis, which was the main coefficient estimation method of this study, enables a more efficient estimation than the OLS estimator when the variables are not normally distributed. In addition, according to the OLS estimator, coefficients can only be obtained for the midpoint of the distribution, and extreme values are ignored [115]. A quantile regression analysis, on the other hand, classifies the values of the dependent variable and allows the strength of the effect of independent variables on low and high values of the dependent variable to be measured. The method was first introduced by Koenker and Basset Jr (1978) [116]. The mathematical representation of the method is as follows:

$$y_i = x_i b_{\theta i} + \mu_{\theta i}, 0 < \theta < 1 \tag{2}$$

$$Quant_{i\theta}(y_i/x_i) = x_i \beta_\theta$$

In Equation (2), x is the vector of explanatory variables, and y is the dependent variable. μ is the residual vector. A quantile is the quantile value of the specified variable, and β_θ is the θth quantile regression [117–119]. The quantile regression method is generally accepted to be useful when there is a change in conditional quantiles, and regression coefficients are determined according to the quantiles [120]. Ref. [34] developed a panel data method (QRPD) that allows for nonadditive fixed effects and provides consistent estimates when the time dimension is small. Accordingly, fixed effects were added to the average panel data estimates to identify country-specific effects. However, most panel quantile estimators include fixed effects that separate the error term and assume that variables differ by focusing on time-varying elements. In this respect, QRPD is analytically superior to other methods in terms of efficiency, robustness, reliability, and simplicity [114]. The econometric model of this method is as follows:

$$\mathrm{Y}_{\mathrm{it}}^{\mathrm{d}} = \mathrm{d}_{\mathrm{it}}' \beta \left(\mathrm{U}^{*\mathrm{d}} \right) \tag{3}$$

In the equation, $\mathrm{U}_{\mathrm{it}}^{*\mathrm{d}} \sim \mathrm{U}(0, 1)$ and $\mathrm{d}_{\mathrm{it}}' \beta(\tau)$ increase at a rate of $\beta(\tau)$. $\mathrm{U}_{\mathrm{it}}^{*\mathrm{d}}$ represents a rank variable and can be a function of error terms, some of which are constant but some of which vary over time. This method is estimated by the Markov Chain Monte Carlo (MCMC) optimization [34]. The use of the QRPD method in this study was one of the aspects that added originality to our study. This is because this method, which is a new generation method and has advantages over other panel quantile methods, was applied for the first time in the subject we are considering.

4.3.5. Causality Analysis

In this study, the causality relationship between the independent variables and the dependent variable was investigated with the test developed by Dumitrescu and Hurlin (2012) [113]. Dumitrescu and Hurlin (2012), Ref. [113], developed a causality test for heterogeneous panel data models. The statistical value of this test is based on the average individual Wald statistic of the Granger causality test between cross-sectional units and takes into account the cross-sectional dependence and heterogeneity of slope coefficients. In the case where T and N go to infinity (T, N $\to \infty$), the average statistic value with asymptotic distribution $Z_{N,T}^{Hnc}$ (Z-bar) is taken into account, but in the case where T is constant (N > T), the decision is made according to the test statistic with a semi-asymptotic distribution Z_N^{HNC} (Z-bar tilde) [121].

5. Results of Empirical Analysis

As stated in the methodology section above, we first investigated the presence of CSD in the variable and the model. The results obtained are presented in Table 5.

Table 5. CSD test results.

	EPI	EPU	GPR	GDPpc	GDPPC	ENERGY	Model
$CD_{LM\ 1}$	1891.543 [a] (0.000)	1100.840 [a] (0.000)	1133.350 [a] (0.000)	2533.740 [a] (0.000)	2522.166 [a] (0.000)	1896.687 [a] (0.000)	991.124 [a] (0.000)
$CD_{LM\ 2}$	106.445 [a] (0.000)	58.502 [a] (0.000)	60.473 [a] (0.000)	145.384 [a] (0.000)	145.046 [a] (0.000)	106.757 [a] (0.000)	51.850 [a] (0.000)

Note: a, denote cross-sectional dependence at 1%significance level, respectively.

When the results were analyzed, it was statistically determined that there is CSD in all the series, at the 1% significance level. Moreover, the econometric model also proves the existence of CSD at the 1% significance level. These findings may be important for policy makers or strategy makers. This is because they show that a decision taken or an event occurring in one unit, i.e., a country, can affect other units. The events or shocks are usually economic and political crises and natural disasters. In this context, it is of great importance to develop common national and international solutions to issues such as international politics, energy supply problems, and economic recession. Secondly, the results of the Delta test applied to investigate the heterogeneity of the model, which is important in coefficient estimation and causality tests, are presented in Table 6, below.

Table 6. Homogeneity test results.

	Statistics	Prob.
Delta_tilde	16.340 [a]	0.000
Delta_tilde_adj	19.114 [a]	0.000

Note: a, denote heterogeneity at 1%, 5%, and 10% significance level, respectively.

According to the Delta test results, which tested the homogeneity of the slope coefficients in the models, it was determined that the slope coefficients were heterogeneous at the 1% significance level. This result shows that the relationship between the dependent and independent variables of the model is different among countries. Accordingly, since the application of the same policy or strategy for all countries does not have the same effect on a variable, policies specific to each country need to be developed. Thirdly, the results of the CIPS unit root test, which is one of the second generation unit root tests that were applied since there is CSD in the series, are shown in Table 7.

Table 7. Unit root test results.

Variables	CIPS Statistics	
	Level	1. Difference
EPI	−2.839 [a]	-
EPU	−2.524 [a]	-
GPR	−2.181 [b]	-
GDP	−2.653 [a]	-
GDPpc	−2.689 [a]	-
ENERGY	−2.576 [a]	-

Note: The table critical values for the 1%, 5%, and 10% significance levels are −2.44, −2.24, and −2.13, respectively. a, and b indicate significance at 1%, and 5% significance levels, respectively.

When the unit root test results were examined, it was determined that all the variables were stationary at the level values. In addition, it was observed that the other variables, except the GPR variable, were stationary at the 1% significance level, and the GPR variable was stationary at the 5% significance level. The fact that all the variables were stationary at the level values indicates that the analyzed series had a stable structure over time and did not have trend or unit root problems. Since all the variables were stationary at the level values, it was seen that no spurious regression problem would be encountered. Therefore, the relationships were analyzed directly at the level values without the need to apply procedures such as difference or transformation. Accordingly, the QRPD test, which allows long-term estimates to be made, was applied, and the results obtained are given in Table 8.

Table 8. Coefficient estimation results.

Variables	**Quantiles**					**OLS**
	0.10	**0.25**	**0.50**	**0.75**	**0.90**	
EPU	0.009 [a] (0.000)	0.005 (0.164)	0.021 [a] (0.000)	0.025 [a] (0.000)	0.020 [a] (0.000)	0.023 [a] (0.000)
GPR	0.194 (0.187)	−0.065 (0.703)	−1.085 [a] (0.004)	0.581 (0.476)	−1.193 [a] (0.005)	−0.294 (0.638)
GDPpc	−9.731 [a] (0.000)	−1.962 (0.252)	−16.220 [b] (0.011)	−12.051 [a] (0.000)	−9.018 [b] (0.015)	−10.212 [b] (0.015)
GDPpc2	0.998 [a] (0.000)	0.658 [a] (0.000)	1.349 [a] (0.000)	1.248 [a] (0.000)	1.076 [a] (0.000)	1.094 [a] (0.000)
ENERGY	−0.105 [a] (0.000)	−0.162 [a] (0.000)	−0.140 [a] (0.000)	−0.217 [a] (0.00)	−1.131 [a] (0.000)	−0.150 [b] (0.045)

Note: a, and b, indicate that the coefficients are statistically significant at 1%, and 5% significance levels, respectively.

Considering the QRPD results, the effect of the economic policy uncertainty variable represented by EPU, one of the variables constituting the basis of the study, on the environmental performance index was statistically significant and positive, except for in the 0.25th quantile. In other words, the increase in economic policy uncertainty positively affects environmental quality. Although the coefficient was positive in this quantile, it was statistically insignificant. It was determined that the strength of the effect was generally low and increased as the quantile value increased, i.e., towards higher quantiles. It was observed that the effect of geopolitical risk, another basic independent variable and represented by GPR, had statistically significant effects only in the 0.50th and 0.90th quantiles, and the direction of this effect was negative. In other words, the increase in geopolitical risk negatively reduces environmental quality. The findings show that the strength of the effect increased from the 0.50th quantile to the 0.90th quantile. The effects of the GDPpc and GDPpc2 variables, which were included in the analysis to test the EKC hypothesis and represent economic growth, on the EPI were negative and positive, respectively. This supports the EKC hypothesis. It is because the increase in the economic growth rate negatively affects environmental quality up to a certain stage. This situation is explained by the fact that the effect of the GDPpc variable on the EPI was significant and negative, except for in the 0.25th quantile. The strength of the effect showed a significant change as the quantile level increased. When the increase in the economic growth rate exceeded a certain level, it positively affected environmental quality. This situation can be explained by the fact that the effect of the GDPpc2 variable on the EPI had significant and positive effects in all the quantiles. The strength of the effect increased up to the middle quantile, while it tended to decrease in the upper quantiles. Finally, the effect of primary energy consumption, which was included in the analysis as an important determinant of environmental pollution and is shown by ENERGY, on the EPI was found to be negative and significant in all the quantiles. The strength of the effect decreased as the quantile level increased. As a result of the OLS analysis, applied to make comparisons with traditional methods, it was determined that the findings obtained an overlap with the findings obtained through the QRPD method. It can be seen that the results applied by the traditional and current methods did not differ for this model and country set. However, it was also observed that the results of the QRPD were different in the country sets where the level of environmental quality was different. Therefore, these results suggest that QRPD provides more comprehensive and detailed results by taking into account the heterogeneity at the unit level. Furthermore, the different strengths of the impacts of the variables in different quantiles provides more specific and targeted recommendations to policy makers. With these features, the QRPD method can be said to have a significant advantage over traditional techniques.

The results of the causality relationship between the independent variables and the dependent variable investigated with the Dumitrescu and Hurlin (2012) [113] test are given in Table 9, below.

Table 9. Causality test results.

Null Hypothesis	W-Stat	Zbar-Stat.	Zbar_tilde-Stat	Direction
EPU→EPI	6.510	5.908 [a] (0.000)	3.813 [a] (0.000)	Bi-directional
EPI→EPU	6.923	6.604 [a] (0.000)	4.324 [a] (0.000)	
GPR→EPI	3.056	0.094 (0.925)	−0.462 (0.644)	Neutrality
EPI→GPR	3.229	0.385 (0.705)	−0.248 (0.804)	
GDPpc→EPI	6.328	5.602 [a] (0.000)	3.588 [a] (0.000)	Bi-directional
EPI→GDPpc	5.029	3.415 [a] (0.001)	1.980 [b] (0.048)	
GDPpc2→EPI	6.259	5.486 [a] (0.000)	3.502 [a] (0.001)	Bi-directional
EPI→GDPpc2	5.018	3.396 [a] (0.001)	1.966 [a] (0.049)	
ENERGY→EPI	5.806	4.724 [a] (0.000)	2.942 [a] (0.000)	Bi-directional
EPIENERGY	5.950	4.966 [a] (0.000)	3.121 [a] (0.002)	

Note: a, and b, indicate statistical significance at 1%, and 5%significance levels, respectively.

According to the causality test results, it was determined that EPU and the EPI have a bidirectional causality relationship. Accordingly, while economic policy uncertainty affects environmental quality, it was determined that environmental quality also affects economic policy uncertainty. Therefore, while the uncertainty of environmental policies can create economic uncertainty, similarly, economic uncertainty can negatively affect investments and policies made in the environment. No causality relationship was found between GPR and the EPI. The fact that geopolitical risks do not have a direct effect on the environment may suggest that there is an indirect, if not direct, relationship between these two variables in the period considered. A bidirectional relationship was observed between GDPpc and the EPI and GDPpc2 and the EPI. This result reveals a mutual relationship between economic development and environmental quality. Accordingly, while environmental quality affects economic growth, economic growth also affects environmental quality. In addition, the relationship between GDPpc2 and environmental quality supports the environmental Kuznets curve (EKC) hypothesis. This shows that economic development initially causes environmental degradation but can improve environmental quality when a threshold is exceeded. Finally, the findings obtained show that there is a bidirectional causality relationship between ENERGY and the EPI. In other words, while energy consumption affects environmental quality, it also indicates that environmental quality affects energy policies. According to this result, the following comment can be made: while the high-level consumption of fossil fuels harms the environment, environmental regulations can lead to the transformation of energy policies. Therefore, it has been concluded that there is a mutual relationship between all the variables and environmental quality, except geopolitical risk.

6. Discussion

In this study, the effects of economic policy uncertainty and geopolitical risk on environmental quality were investigated. In addition, the validity of the environmental Kuznets hypothesis was tested and the relationship between energy consumption and environmental quality was also examined. In this context, a panel data analysis was performed for 17 selected countries. As a result of the analysis performed with QRPD, one of the new generation estimation methods, it was determined that economic policy uncertainty generally positively affected environmental quality, but geopolitical risk negatively affected environmental quality in significant quantiles. It was observed that the environmental Kuznets hypothesis was valid because environmental quality decreased at the current values of economic growth and environmental quality increased at higher values of economic growth. In addition, the negative effects of primary energy consumption on environmental quality were among the findings obtained. The OLS estimation results, applied for comparison, also presented similar findings. Therefore, no significant difference was observed between the results of the modern technique and the traditional method. According to the Dumitrescu and Hurlin (2012) [113] causality test, it was determined that there was a bidirectional causality between all the variables, except geopolitical risk and environmental quality. However, no significant relationship was found between geopolitical risk and environmental quality.

The result that EPU has a positive effect on environmental quality is similar to the findings of the studies by [64,65,71,85] in the literature. In contrast to our study, Refs. [5,52,63,75,95,99,101] found that EPU negatively affects environmental quality. For example, Ref. [63] examined sub-Saharan African countries in their studies. The countries in the study of [63] show significant differences in terms of the development level from the countries in our sample. This may have caused the findings to differ from each other. Ref. [5] conducted an investigation specifically on China. China is one of the world's largest pollutants. Individual country studies may produce different results. Ref. [75] used the intensity of CO_2 emissions in cities; Ref. [52] used energy consumption and ecological footprint; and Ref. [101] used green growth as an indicator of environmental quality. It seems that the choice of the independent variable representing environmental quality may cause differences in the empirical findings.

Another result of this study is the finding that an increase in GPR increases environmental degradation in some quantiles. These results are consistent with those of [12,67,76,77,81,82,89]. Unlike our study, Refs. [13,80,100] found that GPR positively affects environmental quality. Refs. [13,80,100] differed from our study in terms of the dependent and independent variables but did not consider the modeling within the framework of the EKC hypothesis. This may cause the similarity of the findings to decrease. On the other hand, Ref. [80] made estimates with methods that took into account the dependency effects that vary depending on time and frequency. The methods used may have an effect on the analysis results.

7. Conclusions and Recommendations

The most important factor underlying the positive impact of EPU on environmental quality is the consumption effect. In increasingly globalized economies, production requires a lot of energy. In cases where EPU increases, the consumption of products with a high energy density may decrease. Uncertainty may discourage economic activities. In particular, the decrease in production made with fossil fuels increases environmental quality by reducing polluting factors. EPU can reduce environmental pollution. However, it should not be forgotten that investments in the country decrease with every entrepreneur who gives up investing and producing due to EPU. In addition, the increase in EPU condemns countries to non-renewable and pollution-emitting production.

Another result of this study is the finding that an increase in GPR increases environmental degradation in some quantiles. This result is explained by the escalating effect. When GPR increases in these country groups, innovations, R&D, and renewable energy investments and use decrease. The continued use of non-renewable resources increases environmental degradation. As GPR increases, governments shift their attention from environmental issues to risks. The deterioration of environmental quality intensifies. Another important result of the estimation findings is that primary energy consumption negatively affects environmental quality. These results show that countries need to take urgent action on renewable energy applications. Countries should not ignore environmental decisions, even when shaping their fiscal and monetary policies. While increasing production is a prerequisite for sustainable development, encouraging green energy investments and developing environmental policies should become a priority for countries. For this, it is vital to think about innovations such as energy efficiency and green energy. Incentives and subsidies for clean energy and clean production can be strengthened as a policy tool. In addition, a good and solid financial structure should be established for subsidies and incentives.

In uncertain situations, companies, businesses, and investors should establish new policies, as well as governments. Uncertainties can have deep effects on human behavior and decisions. While human behavior changes following general economic phenomena, environmental degradation can also cause similar effects. Changes in consumer behavior cause fluctuations in companies' market shares. Companies and investors should predict changes in EPU and GPR trends and make investment decisions accordingly. Each company may respond differently to uncertainties. While companies with well-managed institutional conditions are less affected by uncertainties, others may react more dramatically. In an environment of high uncertainty, companies may have to change their strategies regarding cash flow positions, etc. They may even abandon initiatives such as mergers. Even if it is not in their own country, uncertainties in the partner countries of the companies may have an effect as if it were in their own country. Investors may sometimes withdraw from the markets or increase asset diversification to distribute the risk. Capital allocation and risk management should be shaped professionally. Investors should transparently and efficiently transform the support opportunities provided by governments, such as grants and funds, into green investments. For this, they should prioritize R&D and technology-supported activities.

As a final note, it would be appropriate to emphasize the limitations of this study and the information that future studies will be developed. First of all, due to data limitations, certain countries and a certain period were used in the empirical analysis in this study. More reliable results can be obtained with larger data sets. For example, how the results will change can be examined if the data used are selected on a monthly basis, instead of an annual basis. Again, horizontal section units can be separated according to the development level of the countries. Or instead of a country, micro results can be obtained at the regional or firm scale. Variable selection can be expanded by considering indicators such as the geographical structures and sociocultural dynamics of countries. We recommend that researchers who aim to work on this topic develop their studies in terms of individual countries. Countries may give different answers when considered one by one. We especially care about reducing the studies conducted to the sector and region scale. In addition, we suggest that it would be useful for researchers to test the effect of uncertainties on environmental quality by considering nonlinearity and asymmetric features.

Author Contributions: Conceptualization, A.A. and I.C.; methodology, A.A.; software, A.A.; validation, A.A., I.C. and E.B.; formal analysis, A.A. and I.C; investigation, E.B.; resources, E.B.; data

curation, A.A.; writing—original draft preparation, E.B.; writing—review and editing, I.C.; visualization, E.B.; supervision, I.C.; project administration, A.A, I.C. and E.B.; funding acquisition, I.C., A.A. and E.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Assamoi, G.R.; Wang, S. Asymmetric Effects of Economic Policy Uncertainty and Environmental Policy Stringency on Environmental Quality: Evidence from China and the United States. *Environ. Sci. Pollut. Res.* **2023**, *30*, 29996–30016. [CrossRef] [PubMed]
2. Cui, X.; Wang, W.; Işık, C.; Uddin, I.; Yan, J.; Gu, X.; Ahmad, M. Do Geopolitical Risk and Economic Policy Uncertainty Cause CO_2 Emissions in BRICS? The role of Institutional Quality and Energy Productivity. *Stoch. Environ. Res. Risk Assess.* **2024**, *38*, 1685–1699.427. [CrossRef]
3. Uddin, I.; Usman, M.; Saqib, N.; Makhdum, M.S.A. The Impact of Geopolitical Risk, Governance, Technological Innovations, Energy Use, and Foreign Direct Investment on CO_2 Emissions in the BRICS Region. *Environ. Sci. Pollut. Res.* **2023**, *30*, 73714–73729. [CrossRef]
4. Zribi, W.; Boufateh, T.; Lahouel, B.B.; Urom, C. Uncertainty Shocks, Investor Sentiment and Environmental Performance: Novel Evidence from a PVAR Approach. *Int. Rev. Financ. Anal.* **2024**, *93*, 103196. [CrossRef]
5. Amin, A.; Dogan, E. The Role of Economic Policy Uncertainty in the Energy-Environment Nexus for China: Evidence from the Novel Dynamic Simulations Method. *J. Environ. Manag.* **2021**, *292*, 112865. [CrossRef]
6. Liu, Y.; Zhang, Z. How does Economic Policy Uncertainty Affect CO_2 Emissions? A Regional Analysis in China. *Environ. Sci. Pollut. Res.* **2022**, *29*, 4276–4290. [CrossRef] [PubMed]
7. Ma, W.; Nasriddinov, F.; Haseeb, M.; Ray, S.; Kamal, M.; Khalid, N.; Ur Rehman, M. Revisiting the Impact of Energy Consumption, Foreign Direct Investment, and Geopolitical Risk on CO_2 Emissions: Comparing Developed and Developing Countries. *Front. Environ. Sci.* **2022**, *10*, 985384. [CrossRef]
8. National Oceanic and Atmospheric Administration-NOAA. 2024. Available online: https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature (accessed on 11 November 2024).
9. International Energy Agency-IEA. CO2 Emissions in 2023. 2024. Available online: https://www.iea.org/reports/co2-emissions-in-2023/executive-summary (accessed on 11 November 2024).
10. Zheng, X.; Faheem, M.; Fakhriddinovch Uktamov, K. Exploring the Link Between Economic Policy Uncertainty, Financial Development, Ecological Innovation and Environmental Degradation; Evidence from OECD Countries. *PLoS ONE* **2024**, *19*, e0307014. [CrossRef]
11. Li, H.; Ali, M.S.E.; Ayub, B.; Ullah, I. Analysing the Impact of Geopolitical Risk and Economic Policy Uncertainty on the Environmental Sustainability: Evidence from BRICS Countries. *Environ. Sci. Pollut. Res.* **2024**, *31*, 46148–46162. [CrossRef] [PubMed]
12. Khan, A.; Sun, C.; Xu, Z.; Liu, Y. Geopolitical Risk, Economic Uncertainty, and Militarization: Significant Agents of Energy Consumption and Environmental Quality. *Environ. Impact Assess. Rev.* **2023**, *102*, 107166. [CrossRef]
13. Anser, M.K.; Syed, Q.R.; Lean, H.H.; Alola, A.A.; Ahmad, M. Do Economic Policy Uncertainty and Geopolitical Risk Lead to Environmental Degradation? Evidence from Emerging Economies. *Sustainability* **2021**, *13*, 5866. [CrossRef]
14. Mahmood, H.; Houaneb, A. The Environmental Kuznets Curve Hypothesis in the United States: A Review. *Int. J. Energy Econ. Policy* **2023**, *13*, 397–403. [CrossRef]
15. Apergis, N.; Ozturk, I. Testing Environmental Kuznets Curve Hypothesis in Asian Countries. *Ecol. Indic.* **2015**, *52*, 16–22. [CrossRef]
16. Ayad, H.; Lefilef, A.; Ben-Salha, O.A. Revisit of the EKC Hypothesis in Top Polluted African Countries Via Combining the ARMEY Curve into the Kuznets Curve: A Fourier ARDL Approach. *Environ. Sci. Pollut. Res.* **2023**, *30*, 81151–81163. [CrossRef]
17. Luo, H.; Sun, Y. The Impact of Energy Efficiency on Ecological Footprint in the Presence of EKC: Evidence from G20 Countries. *Energy* **2024**, *304*, 132081. [CrossRef]

18. Pata, U.K.; Ahmed, Z.; Eryilmaz, S.; Zeren, F.; Gencer, Y.G. Analyzing the Environmental Kuznets Curve for Transportation Modes in European Countries. *Transp. Res. Part D Transp. Environ.* **2023**, *122*, 103893. [CrossRef]
19. Guo, X.; Shahbaz, M. The Existence of Environmental Kuznets Curve: Critical Look and Future Implications for Environmental Management. *J. Environ. Manag.* **2024**, *351*, 119648. [CrossRef] [PubMed]
20. Shahbaz, M.; Lean, H.H.; Shabbir, M.S. Environmental Kuznets Curve Hypothesis in Pakistan: Cointegration and Granger Causality. Sustain. *Energy Rev.* **2012**, *16*, 2947–2953. [CrossRef]
21. Wang, Y.; Han, R.; Kubota, J. Is there An Environmental Kuznets Curve for SO_2 Emissions? A Semi-Parametric Panel Data Analysis for China. *Sustain. Energy Rev.* **2014**, *54*, 1182–1188. [CrossRef]
22. Işık, C.; Ongan, S.; Özdemir, D. Testing the EKC Hypothesis for Ten US States: An Application of Heterogeneous Panel Estimation Method. *Environ. Sci. Pollut. Res.* **2019**, *26*, 10846–10853. [CrossRef]
23. Lau, L.S.; Choong, C.K.; Ng, C.F.; Liew, F.M.; Ching, S.L. Is nuclear energy clean? Revisit of Environmental Kuznets Curve hypothesis in OECD countries. *Econom. Model.* **2019**, *77*, 12–20. [CrossRef]
24. Suki, N.M.; Sharif, A.; Afshan, S.; Suki, N.M. Revisiting the Environmental Kuznets Curve in Malaysia: The Role of Globalization in Sustainable Environment. *J. Clean. Prod.* **2020**, *264*, 121669. [CrossRef]
25. Tenaw, D.; Beyene, A.D. Environmental Sustainability and Economic Development in Sub-Saharan Africa: A Modified EKC Hypothesis. *Renew. Sustain. Energy Rev.* **2021**, *143*, 110897. [CrossRef]
26. Magazzino, C.; Gallegati, M.; Giri, F. The Environmental Kuznets Curve in A Long-Term Perspective: Parametric Vs Semi-Parametric Models. *Environ. Impact Assess. Rev.* **2023**, *98*, 106973. [CrossRef]
27. Udeagha, M.C.; Breitenbach, M.C. Exploring the Moderating Role of Financial Development in Environmental Kuznets Curve for South Africa: Fresh Evidence from the Novel Dynamic ARDL Simulations Approach. *Financ. Innov.* **2023**, *9*, 5. [CrossRef]
28. Barak, D.; Kocoglu, M.; Jahanger, A.; Tan, M. Testing the EKC Hypothesis for Ecological and Carbon Intensity of Well-Being: The Role of Forest Extent. *Sci. Total Environ.* **2024**, *945*, 173794. [CrossRef] [PubMed]
29. Makarov, I.; Alataş, S. Production-and Consumption-Based Emissions in Carbon Exporters and Importers: A Large Panel Data Analysis for the EKC Hypothesis. *Appl. Energy* **2024**, *363*, 123063. [CrossRef]
30. Mohamed, E.F.; Abdullah, A.; Jaaffar, A.H.; Osabohien, R. Reinvestigating the EKC hypothesis: Does Renewable Energy in Power Generation Reduce Carbon Emissions and Ecological Footprint? *Energy Strat. Rev.* **2024**, *53*, 101387. [CrossRef]
31. Ximei, K.; Javaid, M.Q.; Shams, T.; Sibt-e-Ali, M. Information and Communication Technology, Economic Globalization, and Environmental Sustainability in APEC Nations: Insights from LCC and EKC Hypotheses Testing. *Sustain. Dev.* **2024**. [CrossRef]
32. Ahmed, Z.; Cary, M.; Shahbaz, M.; Vo, X.V. Asymmetric Nexus Between Economic Policy Uncertainty, Renewable Energy Technology Budgets, and Environmental Sustainability: Evidence from the United States. *J. Clean. Prod.* **2021**, *313*, 127723. [CrossRef]
33. Hoang, D.P.; Chu, L.K.; To, T.T. Geopolitical Risk, and Natural Resources Rents Affect Economic Complexity? Evidence from Advanced and Emerging Market Economies. *Resour. Policy* **2023**, *85*, 103856. [CrossRef]
34. Powell, D. Quantile Regression with Nonadditive Fixed Effects. *Empir. Econ.* **2022**, *63*, 2675–2691. [CrossRef]
35. Peng, X.Y.; Zou, X.Y.; Zhao, X.X.; Chang, C.P. How does Economic Policy Uncertainty Affect Green Innovation? *Technol. Econ. Dev. Econ.* **2023**, *29*, 114–140. [CrossRef]
36. Baker, S.R.; Bloom, N.; Davis, S.J. Measuring Economic Policy Uncertainty. *Q. J. Econ.* **2016**, *131*, 1593–1636. [CrossRef]
37. Iqbal, M.; Chand, S.; Ul Haq, Z. Economic Policy Uncertainty and CO_2 Emissions: A Comparative Analysis of Developed and Developing Nations. *Environ. Sci. Pollut. Res.* **2003**, *30*, 15034–15043. [CrossRef] [PubMed]
38. Khan, Y.; Hassan, T.; Kirikkaleli, D.; Xiuqin, Z.; Shukai, C. The Impact of Economic Policy Uncertainty on Carbon Emissions: Evaluating the Role of Foreign Capital Investment and Renewable Energy in East Asian Economies. *Environ. Sci. Pollut. Res.* **2022**, *29*, 18527–18545. [CrossRef]
39. Pirgaip, B.; Dinçergök, B. Economic Policy Uncertainty, Energy Consumption and Carbon Emissions in G7 Countries: Evidence from A Panel Granger Causality Analysis. *Environ. Sci. Pollut. Res.* **2020**, *27*, 30050–30066. [CrossRef] [PubMed]
40. Gulen, H.; Ion, M. Policy Uncertainty and Corporate Investment. *Rev. Financ. Stud.* **2016**, *29*, 523–564. [CrossRef]
41. Li, X.; Hu, Z.; Zhang, Q. Environmental Regulation, Economic Policy Uncertainty, and Green Technology Innovation. *Clean Technol. Environ. Policy* **2021**, *23*, 2975–2988. [CrossRef]
42. Kang, W.; Ratti, R.A.; Vespignani, J. Impact of Global Uncertainty on the Global Economy and Large Developed and Developing Economies. *Appl. Econ.* **2020**, *52*, 2392–2407. [CrossRef]
43. Nguyen, T.C. Economic Policy Uncertainty and Bank Stability: Does Bank Regulation and Supervision Matter in Major European Economies? *J. Int. Financ. Mark. Inst. Money* **2021**, *74*, 101387. [CrossRef]
44. Liu, L.; Zhang, T. Economic Policy Uncertainty and Stock Market Volatility. *Financ. Res. Lett.* **2015**, *15*, 99–105. [CrossRef]
45. Das, D.; Kannadhasan, M.; Bhattacharyya, M. Do the Emerging Stock Markets React to international Economic Policy Uncertainty, Geopolitical Risk and Financial Stress Alike? *N. Am. J. Econ. Financ.* **2019**, *48*, 1–19. [CrossRef]

46. Phan, D.H.B.; Iyke, B.N.; Sharma, S.S.; Affandi, Y. Economic Policy Uncertainty and Financial Stability–Is there a Relation? *Econ. Model.* **2021**, *94*, 1018–1029. [CrossRef]
47. Chen, Z.; Kahn, M.E.; Liu, Y.; Wang, Z. The Consequences of Spatially Differentiated Water Pollution Regulation in China. *J. Environ. Econ. Manag.* **2018**, *88*, 468–485. [CrossRef]
48. He, F.; Ma, Y.; Zhang, X. How does Economic Policy Uncertainty Affect Corporate Innovation?–Evidence from China Listed Companies. *Int. Rev. Econ. Financ.* **2020**, *67*, 225–239. [CrossRef]
49. Handley, K.; Limao, N. Trade and Investment Under Policy Uncertainty: Theory and Firm Evidence. *Am. Econ. J. Econ. Policy* **2015**, *7*, 189–222. [CrossRef]
50. Levenko, N. Perceived Uncertainty as a Key Driver of Household Saving. *Int. Rev. Econ. Financ* **2020**, *65*, 126–145. [CrossRef]
51. Wang, Q.; Xiao, K.; Lu, Z. Does Economic Policy Uncertainty Affect CO_2 Emissions? Empirical Evidence from the United States. *Sustainability* **2020**, *12*, 9108. [CrossRef]
52. Oryani, B.; Moridian, A.; Rezania, S.; Vasseghian, Y.; Bagheri, M.; Shahzad, K. Asymmetric Impacts of Economic Uncertainties and Energy Consumption on the Ecological Footprint: Implications Apropos Structural Transformation in South Korea. *Fuel* **2022**, *322*, 124180. [CrossRef]
53. Shabir, M.; Ali, M.; Hashmi, S.H.; Bakhsh, S. Heterogeneous Effects of Economic Policy Uncertainty and Foreign Direct Investment on Environmental Quality: Cross-Country Evidence. *Environ. Sci. Pollut. Res.* **2022**, *29*, 2737–2752. [CrossRef] [PubMed]
54. Su, H.; Geng, Y.; Xia, X.Q.; Wang, Q.J. Economic Policy Uncertainty, Social Development, Political Regimes and Environmental Quality. *Int. J. Environ. Res. Public Health* **2022**, *19*, 2450. [CrossRef]
55. Jiang, Y.; Zhou, Z.; Liu, C. Does Economic Policy Uncertainty Matter for Carbon Emission? Evidence from US Sector Level Data. *Environ. Sci. Pollut. Res.* **2019**, *26*, 24380–24394. [CrossRef] [PubMed]
56. Atsu, F.; Adams, S. Energy Consumption, Finance, and Climate Change: Does Policy Uncertainty Matter? *Econ. Anal. Policy* **2021**, *70*, 490–501. [CrossRef]
57. Feng, G.F.; Zheng, M. Economic Policy Uncertainty and Renewable Energy Innovation: International Evidence. *Innov. Green Dev.* **2022**, *1*, 100010. [CrossRef]
58. Vitenu-Sackey, P.A.; Acheampong, T. Impact of Economic Policy Uncertainty, Energy Intensity, Technological Innovation and R&D on CO_2 Emissions: Evidence from a Panel of 18 Developed Economies. *Environ. Sci. Pollut. Res.* **2022**, *29*, 87426–87445. [CrossRef]
59. Luo, H.; Sun, Y. Effects of Geopolitical Risk on Environmental Sustainability and the Moderating Role of Environmental Policy Stringency. *Sci. Rep.* **2024**, *14*, 10747. [CrossRef]
60. Caldara, D.; Iacoviello, M. Measuring Geopolitical Risk. *Am. Econ. Rev.* **2022**, *112*, 1194–1225. [CrossRef]
61. Udeaja, E.A.; Tule, J.M.; Akadiri, S.S.; Akanni, E.O.; Offum, P.F. Do Economic Policy Uncertainty and Geopolitical Risk Impede Economic Transformation? Evidence from Resource Rich Country. *J. Econ. Financ.* **2024**. [CrossRef]
62. Adams, S.; Adedoyin, F.; Olaniran, E.; Bekun, F.V. Energy Consumption, Economic Policy Uncertainty and Carbon Emissions; Causality Evidence from Resource Rich Economies. *Econ. Anal. Policy* **2020**, *68*, 179–190. [CrossRef]
63. Adedoyin, F.F.; Ozturk, I.; Agboola, M.O.; Agboola, P.O.; Bekun, F.V. The Implications of Renewable and Non-Renewable Energy Generating in Sub-Saharan Africa: The Role of Economic Policy Uncertainties. *Energy Policy* **2021**, *150*, 112115. [CrossRef]
64. Ashena, M.; Shahpari, G. Policy Uncertainty, Economic Activity, and Carbon Emissions: A Nonlinear Autoregressive Distributed Lag Approach. *Environ. Sci. Pollut. Res.* **2022**, *29*, 52233–52247. [CrossRef] [PubMed]
65. Aslan, A.; Ilhan, O.; Usama, A.M.; Savranlar, B.; Polat, M.A.; Metawa, N.; Raboshuk, A. Effect of Economic Policy Uncertainty on CO_2 with the Discrimination of Renewable and Non Renewable Energy Consumption. *Energy* **2024**, *291*, 130382. [CrossRef]
66. Sohail, M.T.; Ullah, S.; Majeed, M.T. Effect of Policy Uncertainty on Green Growth in High-Polluting Economies. *J. Clean. Prod.* **2022**, *380*, 135043. [CrossRef]
67. Hassan, S.T.; Baloch, M.A.; Bui, Q.; Khan, N.H. The Heterogeneous Impact of Geopolitical Risk and Environment-Related Innovations on Greenhouse Gas Emissions: The Role of Nuclear and Renewable Energy in the Circular Economy. *Gondwana Res.* **2024**, *127*, 144–155. [CrossRef]
68. Ali, S.; Jiang, J.; Ahmad, M.; Usman, O.; Ahmed, Z. A Path Towards Carbon Mitigation Amidst Economic Policy Uncertainty in BRICS: An Advanced Panel Analysis. *Environ. Sci. Pollut. Res.* **2022**, *29*, 62579–62591. [CrossRef] [PubMed]
69. Sadiq, M.; Hassan, S.T.; Khan, I.; Rahman, M.M. Policy Uncertainty, Renewable Energy, Corruption and CO_2 Emissions Nexus in BRICS-1 Countries: A Panel CS-ARDL Approach. *Environ. Dev. Sustain.* **2024**, *26*, 21595–21621. [CrossRef]
70. Du, Y.; Wang, W. The Role of Green Financing, Agriculture Development, Geopolitical Risk, and Natural Resource on Environmental Pollution in China. *Resour. Policy* **2023**, *82*, 103440. [CrossRef]
71. Doğan, E.; Güler, C. How Economic Policy Uncertainty Affect Carbon Emissions: A Case of G-7 Countries. *J. Econ. Bus. Issues* **2021**, *1*, 33–38.
72. Hashmi, S.M.; Bhowmik, R.; Inglesi-Lotz, R.; Syed, Q.R. Investigating the Environmental Kuznets Curve hypothesis amidst geopolitical risk: Global evidence using bootstrap ARDL approach. *Environ. Sci. Pollut. Res.* **2022**, *29*, 24049–24062. [CrossRef]

73. Syed, Q.R.; Bouri, E. Impact of Economic Policy Uncertainty on CO_2 Emissions in the US: Evidence from Bootstrap ARDL approach. *J. Public Aff.* **2022**, *22*, e2595. [CrossRef]
74. Adedoyin, F.F.; Zakari, A. Energy Consumption, Economic Expansion, and CO_2 Emission in the UK: The Role of Economic Policy Uncertainty. *Sci. Total Environ.* **2020**, *738*, 140014. [CrossRef] [PubMed]
75. Fu, L.; Chen, Y.; Xia, Q.; Miao, J. Impact of Economic Policy Uncertainty on Carbon Emissions: Evidence at China's City Level. *Front. Energy Res.* **2022**, *10*, 866217. [CrossRef]
76. Syed, Q.R.; Bhowmik, R.; Adedoyin, F.F.; Alola, A.A.; Khalid, N. Do Economic Policy Uncertainty and Geopolitical Risk Surge CO_2 Emissions? New Insights from Panel Quantile Regression Approach. *Environ. Sci. Pollut. Res.* **2022**, *29*, 27845–27861. [CrossRef] [PubMed]
77. Adebayo, T.S.; Akadiri, S.S.; Riti, J.S.; Tony Odu, A. Interaction among Geopolitical Risk, Trade Openness, Economic Growth, Carbon Emissions and its Implication on Climate Change in India. *Energy Environ.* **2023**, *34*, 1305–1326. [CrossRef]
78. Adediran, I.A.; Swaray, R. Carbon Trading Amidst Global Uncertainty: The Role of Policy and Geopolitical Uncertainty. *Econ. Model.* **2023**, *123*, 106279. [CrossRef]
79. Ali, K.; Jianguo, D.; Kirikkaleli, D.; Oláh, J.; Altuntaş, M. Do Green Technological Innovation, Financial Development, Economic Policy Uncertainty, and Institutional Quality Matter for Environmental Sustainability? *All Earth* **2023**, *35*, 82–101. [CrossRef]
80. Pata, U.K.; Kartal, M.T.; Zafar, M.W. Environmental Reverberations of Geopolitical Risk and Economic Policy Uncertainty Resulting from the Russia-Ukraine Conflict: A Wavelet Based Approach for Sectoral CO_2 Emissions. *Environ. Res.* **2023**, *231*, 116034. [CrossRef] [PubMed]
81. Ulussever, T.; Kartal, M.T.; Kılıç Depren, S. Effect of Income, Energy Consumption, Energy Prices, Political Stability, and Geopolitical Risk on the Environment: Evidence From GCC Countries by Novel Quantile-Based Methods. *Energy Environ.* **2023**. [CrossRef]
82. Feng, Y.; Pan, Y.; Lu, S.; Shi, J. Identifying the Multiple Nexus Between Geopolitical Risk, Energy Resilience, and Carbon Emissions: Evidence from Global Data. *Technol. Forecast. Soc. Chang.* **2024**, *208*, 123661. [CrossRef]
83. Shu, Y.; Hossain, M.R.; Tillaguango, B.; Alvarado, R.; Işık, C.; Murshed, M.; Chen, Z. Geo-Political Risks, Uncertainty, Financial Development, Renewable Energy, and Carbon Intensity: Empirical Evidence from Countries at High Geo-Political Risks. *Appl. Energy* **2024**, *376*, 124321. [CrossRef]
84. Yu, Y.; Jian, X.; Wang, H.; Jahanger, A.; Balsalobre-Lorente, D. Unraveling the Nexus: China's Economic Policy Uncertainty and Carbon Emission Efficiency through Advanced Multivariate Quantile-On-Quantile Regression Analysis. *Energy Policy* **2024**, *188*, 114057. [CrossRef]
85. Xin, D.; Xin, L. The Impact of Economic Policy Uncertainty on PM2. 5 Pollution—Evidence from 25 Countries. *Environ. Sci. Pollut. Res* **2022**, *29*, 38126–38142. [CrossRef] [PubMed]
86. Khan, K.A.; Cong, P.T.; Abbas, A.; Ahmad, P.; Quynh, N.N.; Nguyen, M.Q.; Anwar, A. Navigating the Environmental Impact of Geopolitical Risk and Economic Policy Uncertainty: Evidence from Load Capacity Curve Hypothesis in BRICST Economies. In *Natural Resources Forum*; Blackwell Publishing Ltd.: Oxford, UK, 2024. [CrossRef]
87. Balsalobre-Lorente, D.; Nur, T.; Topaloglu, E.E.; Evcimen, C. The Dampening Effect of Geopolitical Risk and Economic Policy Uncertainty in the Linkage Between Economic Complexity and Environmental Degradation in the G-20. *J. Environ. Manag.* **2024**, *351*, 119679. [CrossRef] [PubMed]
88. Zhao, W.; Zhong, R.; Sohail, S.; Majeed, M.T.; Ullah, S. Geopolitical Risks, Energy Consumption, and CO_2 Emissions in BRICS: An Asymmetric Analysis. *Environ. Sci. Pollut. Res.* **2021**, *28*, 39668–39679. [CrossRef] [PubMed]
89. Bashir, M.F.; Shahbaz, M.; Malik, M.N.; Ma, B.; Wang, J. Energy Transition, Natural Resource Consumption and Environmental Degradation: The Role of Geopolitical Risk in Sustainable Development. *Resources Policy* **2023**, *85*, 103985. [CrossRef]
90. Chu, L.K.; Le, N.T.M. Environmental Quality and the Role of Economic Policy Uncertainty, Economic Complexity, Renewable Energy, and Energy Intensity: The Case of G7 Countries. *Environ. Sci. Pollut. Res.* **2022**, *29*, 2866–2882. [CrossRef]
91. Jiao, Y.; Xiao, X.; Bao, X. Economic Policy Uncertainty, Geopolitical Risks, Energy Output and Ecological Footprint–Empirical Evidence from China. *Energy Rep.* **2022**, *8*, 24–334. [CrossRef]
92. Kyaw, K. Effect of Policy Uncertainty on Environmental Innovation. *J. Clean. Prod.* **2022**, *363*, 132645. [CrossRef]
93. Yang, W.; Zhang, Y.; Hu, Y. Heterogeneous Impact of Economic Policy Uncertainty on Provincial Environmental Pollution Emissions in China. *Sustainability* **2022**, *14*, 4923. [CrossRef]
94. Chu, L.K.; Doğan, B.; Abakah, E.J.A.; Ghosh, S.; Albeni, M. Impact of Economic Policy Uncertainty, Geopolitical Risk, and Economic Complexity on Carbon Emissions and Ecological Footprint: An Investigation of the E7 Countries. *Environ. Sci. Pollut. Res.* **2023**, *30*, 34406–34434. [CrossRef]
95. Farooq, F.; Faheem, M.; Nousheen, A. Economic Policy Uncertainty, Renewable Energy Consumption and Environmental Sustainability in China. *Pak. J. Hum. Soc. Sci.* **2023**, *11*, 1926–1938. [CrossRef]
96. Huang, H.; Ali, S.; Solangi, Y.A. Analysis of the Impact of Economic Policy Uncertainty on Environmental Sustainability in Developed and Developing Economies. *Sustainability* **2023**, *15*, 5860. [CrossRef]

97. Jiatong, W.; Xu, Q.; Sibt-e-Ali, M.; Shahzad, F.; Ayub, B. How Economic Policy Uncertainty and Geopolitical Risk Affect Environmental Pollution: Does Renewable Energy Consumption Matter? *Environ. Sci. Pollut. Res.* **2023**, *30*, 101858–101872. [CrossRef]
98. Tee, C.M.; Wong, W.Y.; Hooy, C.W. Economic Policy Uncertainty and Carbon Footprint: International Evidence. *J. Multinatl. Financ. Manag.* **2023**, *67*, 100785. [CrossRef]
99. Anwar, A.; Barut, A.; Pala, F.; Kilinc-Ata, N.; Kaya, E.; Lien, D.T.Q. A Different Look at the Environmental Kuznets Curve from the Perspective of Environmental Deterioration and Economic Policy Uncertainty: Evidence from Fragile Countries. *Environ. Sci. Pollut. Res.* **2024**, *31*, 46235–46254. [CrossRef] [PubMed]
100. Bakhsh, S.; Zhang, W.; Ali, K.; Anas, M. Energy Transition and Environmental Stability Prospects for OECD Economies: The Prominence Role of Environmental Governance, and Economic Complexity: Does the Geopolitical Risk Matter? *J. Environ. Manag.* **2024**, *354*, 120358. [CrossRef]
101. Borojo, D.G.; Yushi, J.; Miao, M.; Xiao, L. The Impacts of Economic Policy Uncertainty, Energy Consumption, Sustainable Innovation, and Quality of Governance on Green Growth in Emerging Economies. *Energy Environ.* **2024**, *35*, 3647–3672. [CrossRef]
102. YCELP. Environmental Performance Index. 2024. Available online: https://epi.yale.edu/ (accessed on 10 September 2024).
103. CIESIN. Center for International Earth Science Information Network. 2024. Available online: https://www.ciesin.columbia.edu/datasets/dataset-home.html (accessed on 10 September 2024).
104. Economic Policy Uncertainty Index. 2024. Available online: https://www.policyuncertainty.com/index.html (accessed on 11 September 2024).
105. GPR. Geopolitical Risk Index. 2024. Available online: https://www.policyuncertainty.com/gpr.html (accessed on 11 September 2024).
106. World Bank. World Development Indicators. 2024. Available online: https://databank.worldbank.org/reports.aspx?source=world-development-indicators (accessed on 13 September 2024).
107. BP. Statistical Review of World Energy. 2024. Available online: https://www.energyinst.org/statistical-review (accessed on 15 September 2024).
108. Wolf, M.J.; Emerson, J.W.; Esty, D.C.; de Sherbinin, A.; Wendling, Z.A. *2022 Environmental Performance Index (EPI) Results*; Yale Center for Environmental Law & Policy: New Haven, CT, USA, 2022.
109. EPU. 2024. Available online: https://www.policyuncertainty.com/methodology.html (accessed on 16 September 2024).
110. Breusch, T.S.; Pagan, A.R. The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics. *Rev. Econ. Stud.* **1980**, *47*, 239–253. [CrossRef]
111. Pesaran, M.H. General Diagnostic Tests for Cross Section Dependence in Panels. *Camb. Work. Pap. Econ.* **2004**, *1240*, 1. [CrossRef]
112. Pesaran, M.H. A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence. *J. Appl. Econom.* **2007**, *22*, 265–312. [CrossRef]
113. Dumitrescu, E.I.; Hurlin, C. Testing for Granger Non-Causality in Heterogeneous Panels. *Econ. Model.* **2012**, *29*, 1450–1460. [CrossRef]
114. Pesaran, M.H.; Yamagata, T. Testing Slope Homogeneity in Large Panels. *J. Econom.* **2008**, *142*, 50–93. [CrossRef]
115. Aygoren, H.; Uyar, U. The Analysis of Financial Beta Behaviour Via Panel Quantile Regression Approach. *J. Econ. Financ. Account.* **2016**, *3*, 255–265. [CrossRef]
116. Koenker, R.; Bassett, G. Regression quantiles. *Econometrica* **1978**, *46*, 33–50. [CrossRef]
117. Xu, B.; Lin, B. What Cause Large Regional Differences in PM2.5 pollutions in China? Evidence from Quantile Regression Model. *J. Clean. Prod.* **2018**, *174*, 447–461. [CrossRef]
118. Salari, T.E.; Roumiani, A.; Kazemzadeh, E. Globalization, Renewable Energy Consumption, and Agricultural Production Impacts on Ecological Footprint in Emerging Countries: Using Quantile Regression Approach. *Environ. Sci. Pollut. Res.* **2021**, *28*, 49627–49641. [CrossRef] [PubMed]
119. Binder, M.; Coad, A. From Average Joe's Happiness to Miserable Jane and Cheerful John: Using Quantile Regressions to Analyze the Full Subjective Well-Being Distribution. *J. Econ. Behav. Organ.* **2011**, *79*, 275–290. [CrossRef]
120. Chen, C. An Introduction to Quantile Regression and the QUANTREG Procedure. In Proceedings of the Thirtieth Annual SAS Users Group International Conference, Philadelphia, PA, USA, 10–13 April 2005; SAS Institute Inc.: Cary, NC, USA, 2005; pp. 213–230.
121. Agbede, E.A.; Bani, Y.; Naseem, N.A.M.; Azman-Saini, W.N.W. The Impact of Democracy and Income on CO_2 Emissions in MINT Countries: Evidence from Quantile Regression Model. *Environ. Sci. Pollut. Res.* **2023**, *30*, 52762–52783. [CrossRef] [PubMed]