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AWARENESS OF UNPREDICTABILITY IN ECONOMIC POLICY, FISCAL DECENTRALISATION, AND INNOVATIVE APPROACHES FOR THE PRESERVATION OF THE ENVIRONMENT IN SOUTH AFRICA

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Abstract:
The paper aimed to examine the awareness of unpredictability in economic policy, fiscal decentralization, and innovative approaches to preserve the environment in South Africa using annual recurrence data from 1961 to 2021 in South Africa. Dynamic ordinary least squares, completely adjusted ordinary least squares, and canonical cointegration regression are used in this study. The Maki cointegration test shows how the factors maintain an equilibrium relationship throughout the period under consideration. Data from empirical results support the environmental Kuznets curve paradigm. These findings show that the environment must be compromised during the early phases of economic growth to achieve economic success (scale phase). Long-term exponential growing economies decrease pollutants by 0.162%, but a 1% increase in economic expansion raises pollutants by 0.791%, according to the environmental Kuznets curve hypothesis. Similarly, in South Africa, long-term economic globalization, as well as unpredictability in economic policy, reduce the sustainability of the environment. In contrast, long-term fiscal decentralization and sustainable development increase it. These findings have far-reaching environmental implications. The current analysis encouraged environmental penalties and funding for projects transitioning from an energy electrical utility basis to renewables.

Keywords: Economic Policy, Fiscal Decentralisation, Innovative Approaches, Preservation Of The Environment, South Africa

INTRODUCTION

The ecological system is under pressure due to increased human demand for renewable resources, resulting in significant environmental problems (Udeagha & Breitenbach, 2023a). Some examples include severe weather, soil degradation, ocean contamination, industrial pollution, wildlife extinction, and rising sea levels. Governments have substantially invested in decarbonizing power systems and promoting sustainable development and reconstruction (Shan et al., 2021). This includes establishing rigorous environmental laws, implementing high ecological fees, offering tax reductions for renewable energy production and consumption, supporting research on environmentally friendly innovations, and launching initiatives to improve overall environmental conditions (Ji et al., 2021). Countries have also collaborated to implement various programs to prevent further degradation, such as the Montreal Protocol in 1989 to eliminate ozone-depleting chemicals, the Kyoto Protocol in 1998 to reduce carbon dioxide pollution, and the Paris Agreement signed in 2016 to limit global temperature increase (The Phan et al., 2021). Despite these efforts, the environmental condition has deteriorated significantly. According to Lingyan et al. (2022), greenhouse gas pollution rates have increased by 1.5% annually over the past decade. Carbon pollution accounted for much of the exceedingly large 55.3 Gt CO_2^e produced in 2018. In 2016, the average ecological impact per person was 2.75 global hectares, while the average biological resources

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available per person were only 1.63 global hectares (Khan et al., 2021). In simple terms, humans consume 69% of the world's biological resources. Considering the global financial crisis 2008 and the European Union's debt crisis in 2009, government officials, commentators, and researchers have placed great importance on economic decision-making unpredictability (EDMU). To gain a comprehensive understanding of the ecological impacts of EDMU, it is necessary to evaluate the present consequences in South Africa.

This part has been separated into four sections. The first section discusses the EDMU and overall environmental sustainability. The second part is the link between carbon dioxide pollution and unpredictability in economic policy. The third part examines the relationship between fiscal decentralization and CO_2 pollution. The final section delves into the relationship between sustainable development and CO_2.

EDMU significantly affects the business environment and economic growth in the government sector. Various studies have been conducted on the detrimental effects of EDMU on the manufacturing industry, innovation processes, the stock market, and the electricity market (Udeagha & Ngepah, 2022). Due to the close link between revenue generation and environmental performance, several studies have examined the potential benefits of EDMU on environmental preservation. According to Wang et al. (2023), EDMU can affect CO_2 pollution through three mechanisms. Firstly, increased EDMU diverts government attention from environmental issues, making it challenging to enforce environmental laws. Secondly, companies perform worse financially during unstable economic conditions, resulting in reduced use of renewable resources and energy consumption. Interestingly, increased pollution is expected if companies opt for cheaper but dirtier energy sources in response to an uncertain economic situation. Thirdly, if the government relaxes environmental regulations due to high EDMU, companies may lessen their commitment to reducing carbon dioxide pollution.

Based on Tufail et al. (2021), EDMU can impact a company's pollution through various routes: inventiveness, the amount of petroleum and coal employed, and electricity usage. Energy consumption, renewable energy usage, carbon dioxide pollution, and ecological impacts are all significant environmental aspects of EDMU. Therefore, only a few studies have empirically examined the association between EDMU and environmental degradation at the global, national, and industrial levels. Sun et al. (2023) said fiscal decentralization (FD) has become significant in global economic trends. Decentralization is delegating more responsibility to municipal political leaders over significant fiscal and political choices to achieve financial objectives. Two ways can explain the contradictory connection between central and centralization and environmental sustainability. The first and second theories are the "Racial prejudice to the highest" and "Racial prejudice to the lowest" predictions, respectively. Fiscal decentralization, as estimated by Shan et al. (2021), is a crucial contributor to environmental deterioration.

The "Racial prejudice to the lowest" argument is responsible for fiscal decentralization's negative impact on environmental sustainability. According to Lingyan et al. (2022), the excellent relationship between fiscal decentralization and environmental sustainability results from the "racial prejudice to the highest" notion. Zhang et al. (2022) claimed that fiscal decentralization comprises the appropriate allocation of materials, expenditure capability, fees, and associated obligations from the national government to lower-division authorities (local, municipal, and provincial) to improve the supply of services to the public. When assets are dispersed, and money is created at lesser management stages, the operational efficiency of municipal governments improves. Shahbaz et al. (2022) said that in line with the general public, the municipal government responds rapidly to citizens' growing needs, allowing people with low incomes to obtain products and services while

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also making efforts to enhance sustainability at a more basic stage. Certain spots in centralized government literature adopt severe environmental laws to discourage damaging initiatives.

They use the "beggar-thy-neighbor" strategy, enabling them to transfer their destructive activities to neighboring countries. Sun et al. (2022) explained that specific locations, on the other hand, boost their environmental-related companies by enacting lenient environmental laws at the price of environmental degradation. In addition, FD is a two-edged blade that must be used with caution. Sustainable development (SD) is a different, commonly touted strategy for lowering greenhouse gas pollution. It has been shown that manufacturing processes used by multinational corporations are more protective than indigenous innovations from underdeveloped countries. Su et al. (2021) highlighted that sustainable innovation may efficiently solve environmental challenges because emerging economies rely on green technology innovation and environmentally responsible manufacturing processes.

Sustainable innovation is the most effective tool to ensure prosperity while reducing pollution and diminishing resources. Phan et al. (2021) claimed that indirect advantages involve stronger connections between regulators and customers, enhanced credibility, and wellness and security improvements. A few studies, on the other hand, revealed that, based on the conditions, the influence of sustainable innovation on pollution levels might be either beneficial or harmful. For instance, Safi et al. (2022) suggested that energy-associated innovation had no discernible impact on reducing environmental pollutants.

The above discussion results in a finding that developing successful environmental policies necessitates considering unpredictability in economic policy, fiscal decentralization, and innovations in sustainability (Xia et al., 2022). Empirical information that analyses these linkages from numerous perspectives is scarce in South Africa. Yuan et al. (2022) mentioned that the use of mining looks to be the most significant source of the nation's rising pollution levels and degradation of the environment. In South Africa, coal is the dominant energy source and an essential contributor of pollutants. Coal contributes to approximately 77% of total electricity produced, with 2% used for household generation of electricity, 12% used in the metals and steel industry, 33% used in factories, and 53% used in the use of cogeneration (Tufail et al., 2021).

South Africa heavily relies on the electricity generated by industry, particularly with a significant proportion of coal-generating industrial businesses, as well as has reported coal deposits of 35,053 million metric tonnes (MMst) through 2021 (Ji et al., 2021). Second, throughout the past thirty years, South Africa has shifted from a centralized to a very decentralized stance, resulting in it being exceedingly decentralized nowadays (Safi et al., 2022). The country has been named one of the most significant eight least decentralized worldwide, having a decentralization of finance percentage more significant than the worldwide average of 58% in 2018 (Shan et al., 2021). Third, South Africa can achieve the Sustainable Development Goals (SDGs) to promote social and political issues and ecological and socioeconomic objectives (Sun et al., 2022). These characteristics allow us to examine how unpredictability in economic policies, fiscal decentralization, and innovations in sustainability all combine to impact the environmental conditions in South Africa. The present research contributes to the corpus of empirical literature in various manners. First, this research is groundbreaking in that it measures the collective impact of fiscal decentralization, unpredictability in economic policy, and sustainable innovation on South African environmental performance. In line with Lingyan et al. (2022), the research produced an overall fiscal decentralization index that considers the effects of income and expenditure. Third, unlike previous studies, we modeled and analyzed the ecological effects of unpredictable economic policies, decentralization of financial issues, and innovative sustainable practices in South Africa in the context of orientation and intensity simultaneously.

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The relationship between UEPs and CO_2 pollution. Some theoretical studies have discovered a relationship between UEP and environmental quality. For example, Udeagha and Breitenbach (2023b) found two distinct ways UEP influences environmental quality: the immediate policy modification impact and the supplementary policy request impact. The previous example demonstrates how the rise in UEP frequently postpones and moves the government's attention towards fixing ecological degradation since greater emphasis is placed on controlling unpredictability than enhancing the sustainability of the environment. In addition, environmental degradation is increasing as every resource is put into ensuring an economic turnaround because, when it involves energy use, the UEP impacts both personal and corporate economic behavior and processes for making choices (Sun and Razzaq, 2022). In addition, as Wang et al. (2023) found in a recent theoretical study, UEP possesses an influence on environmental quality throughout both purchasing and investing pathways. On the one hand, UEP strengthens environmental quality by lowering the utilization of costly to-operate consumables.

UEP, on the other hand, affects environmental quality across the expenditure route by preventing technological advancements and cutting R&D spending. UEP inhibits technological innovation, limits additional R&D expenditure, and consequently provides growing CO_2 pollution. Su et al. (2021) noticed the three routes UEP influences environmental quality: electricity consumption, the proportion of renewable power, and inventiveness. The analysis of the energy concentration route first demonstrates that UEP increases the intensity of electricity, resulting in a significant decrease in ecological sustainability. Second, especially concerning the amount of electricity generated through petroleum and coal, unpredictability in economic policy produces a rise in the percentage of sources of electricity that are not renewable, dramatically increasing CO_2 pollution.

The relationship between fiscal decentralization and CO_2 pollution. Decentralization in government and politics remains a hot topic between governments and academic groups. A large body of empirical and theoretical studies examines how fiscal decentralization impacts the accessibility of government programs such as the preservation of the environment. This section assesses the study with the intent to reach results concerning the experimental implications of decentralization on the preservation of the environment. In this literature, multiple ideas relate fiscal decentralization to increased pollutants in various regions of a nation's economy. According to Kuai et al. (2019), decentralization enhances inter-jurisdictional diversity by allowing regions to manage their greenhouse gas pollution. Utilizing information collected from 1984 to 2018, Guo et al. (2020) investigated the influence of asymmetrical fiscal decentralization on revenue growth and environmental quality in Pakistan. Their research revealed that in Pakistan, spending decentralization had immediate and long-term asymmetric effects on economic growth and CO_2 pollution. Hence, both good and bad fluctuations in expenditure decentralization affect economic growth and CO_2 pollution in Pakistan in a variety of methods.

Based on the asymmetrical ARDL outcomes, though the positive effects of income decentralization increased the economy's expansion and CO_2 pollution, the harmful effects of income decentralization lowered in the immediate and long term (Hao et al., 2020). The "environment" has become one of the most significant and disputed worldwide concerns, so governments are investigating different pollutant release estimates. As a result, numerous countries have advocated for fiscal decentralization to provide monetary autonomy for regional and sub-national governments, therefore protecting environmental integrity. Safi et al. (2022) shed light on how natural resource leasing and fiscal decentralization affect CO_2 pollution. The researchers used survey information compared to eight extensively decentralized OECD (Organisation for Economic Collaboration and Development)--accredited nations from 1990 to 2018.

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Their results showed that lowering CO_2 pollution using fiscal decentralization and rental of resources is beneficial to the environment. In addition, when the institutional environment improves, CO_2 pollutions decrease, but GDP and overall environmental rental grow, and CO_2 pollution is compensated for by a decrease in institutional quality (Phan et al., 2021). Declining environmental health endangers the existence of the Planet as we understand it. Many countries have attempted to lessen their dependency on fossil fuels for energy by developing new energy-efficient methods that establish a more environmentally conscious manufacturing system. Que et al. (2018), who examined the effect of advancement in technology and fiscal decentralization on greenhouse gas (CO_2) pollution in the bigger picture of China's GDP as well as globalization from 2005 Q1 to 2018 Q4, discovered that all of these variables substantially are responsible for explaining China's CO_2 pollutions. GDP, globalization, fiscal decentralization, and technological advancements are among these causes.

Regarding policy implications, the researchers suggested that China minimize pollution by fostering an environmentally friendly infrastructure to deal with the degrading ecological stability. Outlining roles and duties at multiple tiers of government remains critical to meeting the goals of low CO_2 pollution and conservation of energy fiscal spending. Despite the lack of data, assessing whether fiscal decentralization may successfully reduce carbon dioxide (CO_2) pollution has grown more critical. Song et al. (2022) used an equitable dataset of eight OECD nations spanning 1990 and 2018 to explore the influence of fiscal decentralization on CO_2 pollution and give empirical evidence to back up the speculation statement. Their findings indicated that fiscal decentralization benefited the sustainability of the environment. Enhancements in institutional quality and human capital growth bolstered the link between fiscal decentralization and the preservation of the environment.

The relationship between SD and CO2 pollution. Various research has investigated the empirical relationship between SD and CO_2 pollution. SD technologies may decrease CO_2 pollution without negatively impacting industrial productivity by assisting enterprises in reducing their reliance on electricity. Businesses, municipalities, and educational institutions are all investing in technology to improve the effectiveness and output of financial supply (Kuai et al., 2019).

For example, using the wholly adjusted ordinary least square approach, Chen and Chang (2020) examined the relationship between SD and CO2 in the USA, spanning 1990Q1 until 2016Q4. According to their findings, the increase in SD during the expansion period led to an overall decrease in CO_2 pollution. Throughout the contraction stage, the SD's negative portion led CO_2 to increase. The usage of green electricity reduced CO_2 pollution, while the expansion of GDP increased it. Zhao et al. (2022) investigated the asymmetrical correlation between CO_2 pollution and SD in strongly decentralized countries. They discovered that the CO_2 in the middle to higher percentiles was reduced. In addition, SD had a minimal impact on percentiles with fewer pollutants and the highest impact on percentiles with more significant pollutants. Hence, the effects appeared less concentrated, with fewer pollution percentiles seeing the slightest rise and greater pollution percentiles seeing the most significant rise. This applies to demographics and growth in gross domestic product (GDP).

Similarly, a Qin (2022) analysis of the countries in the BRICS indicated that the pollution decrease benefit of SD was merely detectable at higher pollution percentiles. However, SD was positively correlated with CO_2 at fewer pollution quantities, as described. Cai et al. (2022), the top ten CO_2 polluters, assert that SD dropped as GDP boosted CO_2 pollution. Furthermore, Farzanegan and Mennel (2012) revealed that while GDP raised pollution levels, sustainable development lowered them in the G-7. The results of Guo et al. (2020) suggest that GDP climbed while SD cut CO2 pollution in countries with financially decentralized governments. The paper aimed to examine

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the awareness of unpredictability in economic policy, fiscal decentralization, and innovative approaches to preserving the environment in South Africa.

METHODS

The subsequent is used to explore the mixed impact of UEP, FD, and SD on CO_2 pollution in the context of controlled variables such as economic globalization and GDP for South Africa from 1961 to 2021.

$$InCO_{2t} = \pi^1 InUEP_t + \pi^2 InFD_t + \pi^3 InSD_t + \pi^4 InGDPS_t + \pi^5 InFG_t + \pi^6 InFG_t + \varepsilon_t \quad (1)$$

When CO2 indicates carbon dioxide pollutants, UEP indicates unpredictability of economic policies, FD indicates fiscal decentralization, SD indicates sustainable development, FG indicates economic globalization, GDP indicates gross domestic product, GDPS indicates the square of GDP utilized for evaluating the existence of the EKC hypothesis, as well as ε_t is the conventional stochastic error term (Jiang et al., 2019). All variables are given as natural logs. The coefficients be calculated are π^1, π^2, π^3, π^4, π^5, and π^6, that represent varied flexibility. Because higher UEP diverts attention towards sustainability issues in government and makes environmental laws challenging to implement, it is anticipated that greater UEP will lead to a rise in CO_2 pollution. In addition, researchers believe that UEP will positively affect CO2 pollution, which means $\pi^1 > 0$. FD has been included as an essential variable in the regression, adhering to Sigman (2014). The existing research on the FD coefficient's value is inconsistent. The theoretical rationale for the negative association between FD and CO_2 pollution is that governments may effectively implement legislation to improve the sustainability of the environment while allowing lesser levels of state intervention. On the other hand, FD increases CO_2 pollution throughout domains due to the free-rider effect, i.e., the higher the fiscal capacity for expenditure supplied to reduce government units, the higher the chance of environmental deterioration (Shan et al., 2021). Furthermore, the exact character of the connection between FD and CO2 pollution is unknown, and additional study is required. As a result, we anticipate that FD will either hurt CO_2 pollution, i.e., $\pi^2 > 0$ (proof of racial prejudice to the lowest hypothesis), or have a positive effect on CO_2 pollution, i.e., $\pi^2 < 0$ (proof of racial to the highest hypothesis). Si et al. (2018) incorporate SD as an additional significant variable in our analysis.

SD promotes the broad use of green power networks, which alters how industries function and reduces CO_2 pollution. As a result, we expect that SD will have a $\pi^3 < 0$ effect on CO_2 pollution. In the literature, GDP is the primary factor influencing CO_2 pollution. More incredible economic growth necessitates greater energy use, negatively influencing the sustainability of the environment, i.e., $\pi^4 > 0$. In Formula 1, we incorporated the GDP square element to determine if the EKC hypothesis is correct. FG is a different approach crucial variable that is accounted for in this study. FG has become a measure considering FDI, commerce, and portfolio investment. Commerce worldwide and FDI are significant contributors to environmental degradation. Supporting Cubas et al. (2020), we incorporated FG as the controlling variable in formula (1). We expect FG to negatively or positively influence CO_2 pollution, i.e., $\pi^6 > 0$ or $\pi^6 < 0$. Table 1 contains the variables used in Formula 1's original information, clarifications, and assessments.

Table 1. Specifications of the Variables

Variables	Specifications	Measurements	References
CO_2	Carbon pollution	Metric Tons	WDI
UEP	The Worldwide unpredictability index is based on the proportion of	%	Xia et al. (2022).

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	publications using the word "unpredictability," as reported in EIU publications.		
FD	Subnational spending as a percentage of overall government spending	%	IMF
GDP	Gross domestic product	Permanent US Dollars, 2021	WDI
SD	Sustainable development	Percent of all innovations	WDI
FG	Financial Globalisation Index	The index is determined by foreign direct investment, commerce, and portfolio investment.	Updated KOF internationalization

Acronyms: IMF, International Money Funding, GDI, the global indicators for development.

The implementation order must be confirmed by running unit root tests until a cointegration test is executed. Transnational changes occur within our research periods, resulting in fundamental fractures. Conventional unit root tests such as EDF, DF- FGS, and KPSS do not account for fundamental fractures that can result in erroneous findings (A). We used a unit root test of two exogenous breakdowns Du and Sun (2021) presented to resolve these issues. After verifying stationarity, Kuai et al. (2019) created a cointegration test to study the integration connection among the variables under discussion. This freshly enhanced cointegration approach improves outcomes by combining multiple unique test results, especially those of Shahbaz et al. (2022). Fisher's formulas for the Bayer-Hanck technique are as follows:

$$EG - JOH = 2[In (P_{EG}) + In(P_{JOH})] \quad (2)$$

$$EG\text{-}JOH\text{-}BO\text{-}BDM = -2[In(P_{EG})+In(P_{JOH})+In(P_{BO})+ In(P_{BDM})] \quad (3)$$

The probability ratios in the four cointegration tests described earlier are P_{BDM}, P_{BO}, P_{JOH}, and P_{EG}. The design of Fisher statistics determines the cointegration of the underpinning variables. Shahbaz et al. (2022) cointegration test was subsequently employed to evaluate the long-running equilibrium relationship among CO_2 pollutions and their putative causes, notably UEP, GDP, FG, SD, as well as FD while accounting for different fundamental discontinuities. as stated by Song et al. (2022), the KANS cointegration test has greater size as well as strength characteristics when contrasted with similar cointegration tests that contain fundamental fractures (e.g.). In addition, confining the study to a single structure breakdown may cause incorrect outcomes when several fundamental breakdowns exist. To assess the long-term implications of UEP, GDP, FG, SD, as well as FD on CO_2 pollution in South Africa, the study employs the fully modified ordinary least squares (FMOLS), classical cointegration regression (CCR), with dynamic ordinary least squares (DOLS) tests proposed by Shahbaz et al. (2022). Qin (2022) invented the semi-parametric approach FMOLS to avoid the relationship, emphasizing that the test is asynchronously impartial and effective. CCR, an approach equivalent to FMOLS introduced by Sun et al. (2022), applies to examine cointegration vectors in an equation in which the sequence of time series variables integrating is I(1). FMOLS and CCR estimate approaches differ fundamentally in that FMOLS focuses on each data type and variable alteration, whereas CCR focuses on converting data (). The DOLS model includes follows and delays to compensate for small sample biases and simultaneous. All DOLS with FMOLS estimate approaches handle the difficulties of series correlation and endogeneity by effectively addressing their annoying characteristics (Udeagha & Ngepah, 2022). Lingyan et al. (2022) spectral BC correlation test is also utilized in the present study to identify the correlation effects of UEP, GDP,

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FG, SD, and FD on CO_2 pollution in South Africa. The spectral BC test was invented by Sun et al. (2023).

RESULT AND DISCUSSION

The stationarity test findings reveal that following the first disparity, every factor is stationary (refer to Table 2). They further demonstrate how the structural fractures in each series are reproduced. Because the variables have been incorporated in identical order, we perform the Bayer-Hanck and Maki cointegration tests (refer to Table 3). The Bayer-Hanck and Maki cointegration tests evaluate if the factors are cointegrated. A long-term link was recently shown between CO_2 pollutants and UEP, FD, SD, GDP, and FG. The Maki cointegration method yielded substantial test statistics at various scales and paradigm changes, confirming our premise of an unchanging long-term relationship between variables.

Table 2. Unit Root Analysis

Variable	Dickey-fuller FGS	Phillips-Perron	Enhanced dickey-fuller	Kwiatkowski-Phillips-Schmidt-shin	Kans () Unit root test			
	(DF-FGS)	(PP)	EDF	KPSS	Approach1		Approach 2	
Stage	Test-Statistics value				Break-Year	EDF-stat	Brak-Year	EDF-stat
$InCO_2$	-0.430	-0.214	-1.152	0.973**	1991-2003	-3.174	2004-2008	-8.151***
InUEP	-0.201	-0.141	-1.130	0.416**	2002-2008	-2.261	2005-2010	-7.161***
InFD	-0.166	-0.242	-1.136	0.331***	1985-2010	-1.504	2007-2013	-7.204***
InGDP	-0.206	-0.159	--1.308	0.874***	1981-2009	-2.904	2003-2009	-7.673***
InSD	-0.212	-0.126	-1.268	0.816***	2005-2010	-1.904	2005-2019	-6.784***
InSG	-0.142	-0.152	-1.335	1.037*	1982-2012	-3.016	2005-2010	-7.305***
The first differentiation is Vital significance (1%,5% with 10%)								
$\Delta InCO_2$	-.971***	-0.942***	-7.152***	0.713***	1961-2005	-4.801**	2005-2017	-5.874***
ΔInUEP	-0.615***	-0.617***	-6.813***	0.652***	1999-2001	-7.816***	2008-2015	-8.361***
ΔInFD	-0.731***	-0.514***	-5.841***	0.504***	1974-2003	-5.815**	2001-2008	-8.605***
ΔInGDP	-0.683***	-0.724***	-5.352***	0.551***	1998-2005	-5.831***	1999-2006	-6.862***
ΔInSD	-0.607***	-0.713***	-5.384***	0.571***	1966-2001	-8.531***	2001-2010	-5.808***
ΔInSG	-0.962***	-0.914***	-6.618	0.694***	2001-2004	-6.842**	2001-2007	-8.931***

Note: *, ** and *** indicate statistically significant differences at 10%, 5% and 1% stages, accordingly Unilateral p-values from Song et al. (2022). SIC and AIC determine leg length. SONG-based probabilities (Si et al., 2018). The minimum and maximum values for the SONG-Popp unit root test involving two discontinuities are denoted by the symbol Su et al. (2021). All the variables have been shifted.

Table 3. Cointegration Tests

Bayer-Hanck cointegration (no fundamental fractures)

Test	Statistic	Critic value at 5%
Engle-Granger-Johansen (EGJ)	51.216***	11.810
Engle-Granger-Banerjee-Boswijk (EG-J-Ba-Bo)	55.159***	20.814

Maki cointegration (With fundamental fractures)

Approach	Test Statistics	fundamental fractures
Stage changes and trends.	-7.153*	1981-1994-2008
System changes	-12.501***	1980-1994-2028
System changes with trends	-10.160***	184-1993-2009

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Note: ***, **, as well as * indicate 1%, 5%, and 10% significance stage, accordingly

This paper empirically determines long-term coefficients through the CCR, FMOLS, and DOLS techniques (Table 4). Each of the three approaches provides identical results. The impact of UEP, FD, SD, GDP, and FG on CO_2 pollution in South Africa is clear. In the long term, the computed coefficient on the unpredictability of economic policies (In UEP) is technically significant and positive, implying that a 1% rise in UEP increases environmental damage by 0.230% in South Africa. Like nearly every other fast-rising financial benefit, South Africa is less immune to extended and acute spells of unpredictability caused by macroeconomic and political crises. According to the latest research, two significant issues attributed to the country's anticipated economic expansion in 2018: decreased trust and continuing political instability (Su et al., 2021). South African authorities and regulatory organizations have moved their focus to an increased degree of confusion regarding the aftermath of the nation's destruction through the COVID-19 epidemic along with the worldwide economic downturn of 2008, frequently referred to as the economic crisis that followed.

Thousands of South Africans lost their cash, houses, and occupations due to the worldwide financial crisis of 2008. The instability had a tremendous impact on the country's economy, leaving everybody, especially legislators and those making decisions, in a state of confusion about the prospects for the nation. As the crisis worsened, the detrimental impacts on financial markets and the government's commitment to environmental protection diminished. Therefore, an increase in UEP degrades South Africa's environmental quality. Si et al. (2018) found that UEP lowers environmental quality in Sub-Saharan Africa, which supports our empirical results. Song et al. (2022) discovered identical outcomes: UEP significantly influences CO2 pollution in China. In the long run, the projected factor on fiscal decentralization (FD) in South Africa is positive and statistically significant.

Although municipal governments operating under a decentralized structure have better availability of financial assets and increased flexibility to safeguard the environment, empirical findings imply that increased fiscal decentralization in South Africa could boost the sustainability of the environment. The municipalities are in a more advantageous position than the federal government to devote assets to improving regional sustainability because community members are more cognizant of the demands on regional ecological well-being. The data we collected revealed a "racial prejudice to the highest a position," in which regional South African governments exaggerate valuations in order to push environmental implications into additional locations.

Table 4. Long Term Estimations

Variables	$Coefficients_{CCR}$ (Standard error)	$Coefficient_{FMOLS}$ (Standard error)	$Coefficient_{Dolls}$ (Standard error)
InFD	-0.320***(0.073)	-0.371***(0.085)	-0.314***(0.031)
InUEP	0.230**(0.034)	0.216***(0.015)	0.204(0.032)
InFG	0.128***(0.021)	0.160(0.517)	0.136***(0.036)
InSD	-0.205*(0.164)	-259**(0.152)	-241**(0.160)
InGDP	0.791***(0.140)	0.795**(0.016)	0.694(0.318)
InGDPS	-0.162***(0.061)	-0.157**(0.068)	-165***(0.071)
Constant	-0.281**(0.013)	-0.263***(0.048)	-0.201**(0.031)

Note: ***, **, and * denote 1%, 5%, and 10% significance stage, accordingly. Standard errors were denoted by Song et al. (2022). Acronyms: ACR, authoritative cointegrating regression; DOLS, dynamic ordinary least squares; FMOLS, fully modified ordinary least squares.

South African regional governments prioritized environmental policies above those of the government in the past few years. The environment benefits from fiscal decentralization, which is a

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racial prejudice to the highest method. Certain cities possess severe environmental regulations and "beggar-thy-neighbor" regulations, which allow individuals to move their detrimental behaviors to neighbor regions as an aspect of the "racial prejudice to the highest." The outcome aligns with what was discovered by Song et al. (2022), who discovered that FD improves environmental quality. Shahbaz et al. (2022) found comparable findings when studying the different effects of fiscal decentralization on CO_2 pollution in strongly decentralized economies. The researchers further stated that fiscal decentralization employs a variety of organizations and approaches that help restore environmental wellness, assisting in the renewal of the ecosystem. By implementing strict pollution regulations, fiscal decentralization fosters environmentally conscious behavior and reduces pollutant concerns. Despite this, the research's results contradict Lingyan et al. (2022), who found that fiscal decentralization boosted CO_2 pollution inside and above the region. Sun et al. (2022) show that fiscal decentralization has a detrimental influence on environmental sustainability in China's financially prosperous and eastern regions. Our findings show that calculated long-term economic development (in GDP) coefficients are positive and statistically significant, implying that South Africa's flourishing economy is linked to a rise in CO_2 pollution.

Hence, the expected correlations in the square of prosperity (in GDPS) are statistically substantial and adverse in the long run, suggesting that South Africa's GDP square component leads to improved environmental quality. In South Africa, our research results give experimental corroboration of the EKC theory. CO_2 pollution is increasing in tandem with economic expansion, yet at a particular stage, sustained prosperity enhances environmental quality. A combination of various variables, such as shifts in institutions, technological improvements, and stringent enforcement of environmental legislation, South Africa exhibits a reverse U-shaped link between wealth and pollutants. Furthermore, as money grows, so does awareness of environmental issues, leading to stronger ecological regulations that require adopting environmentally friendly technologies to keep the environment from deteriorating. Our findings are consistent with the results reported by Wang et al. (2023). Our findings contradict those of Sun et al. (2022). The calculated sustainable development coefficient (in SD) is both harmful and highly significant in the near run. Based on our research, a 1% rise in sustainable development results in a 0.205% reduction in CO_2 pollution over time. Sustainable development cuts CO2 pollution dramatically in South Africa and is a sustainable technological invention. It encourages intelligent energy use and provides inexpensive energy utilization from natural sources, allowing South Africa to minimize its carbon footprint.

Implementing end-of-pipe internet, critical for decreasing carbonaceous material pollution and adopting efficiency in terms of energy manufacturing procedures and fuel mix alterations, all help to enhance South Africa's ecological standards. Technological advancements boost energy conservation throughout these routes, significantly increasing the country's ecological sustainability. Government institutions ' use of environmentally friendly technologies has substantially enhanced South Africa's environmental condition, owing primarily to the nation's massive expenditures on research and development and technical advancements. South Africa further implemented various steps to produce significant technological advances to lower pollution compared to the production processes and other industries that generate revenue connected with significant pollution. This is an element of the overall approach to minimizing the growing amount of greenhouse gases released into the atmosphere. According to Xia et al. (2022), technological developments enable lower consumption of energy, greater energy effectiveness, and significantly lower greenhouse gas pollution. Qin (2022) confirms this empirical data by discovering that environmentally friendly innovations benefited the preservation of the environment in South Africa. Our findings confirm the findings reached by Sun et al. (2023). In addition, the findings contradict

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Phan et al. (2021). Based on the estimated coefficients for long-term FG (In FG), a 1% increase in economic globalization (In FG) will result in a 0.128% growth in CO_2 pollution, which is statistically noteworthy and beneficial.

Economic globalization's potential long-term negative repercussions on South Africa's ecological health will certainly raise opposition to it. The chemical composition of the items that comprise a great deal of the exported goods from South Africa may be one element contributing to the possibility of environmental harm resulting from economic globalization. The increase in interest in these products is sure to exacerbate the nation's ecological space because South Africa possesses a financial benefit in shipping and manufacturing of items that necessitate an enormous quantity of environmentally friendly assets, including woodlands, ruthenium, aluminum, metallic substances, as well as minerals.

Table 5. Test For Frequency-Domain Correlation

Orientation of a correlation	Long-term $\omega_{i=0.05}$	Medium-term $\omega_{i=1.50}$	Short-term $\omega_{i=2.50}$
InGDP →$InCO_2$	<9.72> (0.00)***	<8.81 > (0.00)***	<9.45 > (0.03)**
InUEP **→$InCO_2$**	<5.76> (0.00)***	<7.04 > (0.00)***	<8.38 > (0.00)***
InGDPS →$InCO_2$	< 4.53> (0.06)*	<6.31 > (0.02)**	<6.01 > (0.02)**
InFD →$InCO_2$	< 9.76> (0.00)***	<8.06 > (0.00)***	<7.35 > (0.00)***
InSD → $InCO_2$	< 4.19> (0.07)*	<6.03 > (0.03)**	<646 > (0.04)**
InFG → $InCO_2$	<5.51 > (0.03)**	<8.63 > (0.00)***	<8.71 > (0.00)***

Note: *, ** as well as *** show statistical significance at 10%, 5% and 1% stages, accordingly

This is why South African ecology has become gravely harmed by the continual collection of such things for shipment to growing worldwide marketplaces. Sun and Razzaq's (2022) conceptual underpinning states that energy-intensive sectors, including manufacturing and logistics, which require an enormous amount of power, are the primary drivers of emissions, could be employed to clarify our findings. Our findings correspond with the emission harbor theory of Safi et al. (2022), which states that impoverished nations like South Africa enjoy an advantageous edge when manufacturing pollutant-heavy goods. In contrast, wealthier nations possess a competitive benefit in generating disinfecting goods. Furthermore, wealthier nations often distribute pollutants to underdeveloped countries via economic globalization mechanisms that include trade with other nations, FDI, and portfolio investing. Safi et al. (2022) found that countries with poor infrastructure commonly produce substantial quantities of harmful substances due to their dependence on filthy manufacturing practices corresponding with and contributing to current research.

Our findings back up Si et al. (2018) contention that worldwide commerce liberalization is damaging and hurts Pakistan's ecological situation. Su et al. (2021) identified a link between increased CO_2 pollution in the G-7 and commerce facilitation, providing more empirical evidence for this idea. Sun et al. (2022), who demonstrated that increased commerce liberalization harms ecosystems in 66 emerging nations, reached comparable outcomes. Our results contradict those of Lingyan et al. (2022), who found that more transparency in commerce strengthens environmental quality in the G-20, 48 Sub-Saharan African nations, G-7 financial markets, and African nations, in that order. This work uses a frequency-based correlation test to explore the correlation connection within variables (refer to Table 5). To test the correlation connection among variables at three various operations, we selected a frequency level of 0.75 for the long term, 1.50 for the medium run, and 2.50 for the short term. The results of all three trials show that UEP, FG, SD, and FD cause CO_2 pollution.

On the other hand, GDP has only a medium to long-term effect on CO2 pollution. Therefore, any modifications to UEP, FG, SDI, or FD policies might have immediate to long-term implications

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on CO_2 pollution. In addition, each GDP policy surprise has a medium to long-term impact on CO_2 pollution. This research uses the SSR approach to verify that the findings are trustworthy. Table A1 (refer to Appendix A1) yields findings congruent to what was achieved with the DOLS, FMOLS, and CCR approaches.

CONCLUSION

The paper aimed to examine the awareness of unpredictability in economic policy, fiscal decentralization, and innovative approaches for preserving the environment in South Africa. Technological advances have significantly expanded worldwide output and economic involvement, resulting in an essential rise in the worldwide consumption of energy from fossil fuels and a significant increase in environmental worries. Because of recently invented environmentally friendly innovations, the financial system has changed towards traditional sources of energy and forward environmentally friendly energy resources such as energy from plants. Sustainable solutions have significantly enhanced the long-term viability of ecosystems in industrialized nations since the commencement of the fourth industrial revolution. Innovations have a tremendous influence on ecological and artificial environmental issues. As a result, through the period known as the fourth industrial revolution, the significance of environmentally conscious development has expanded. In addition to a more significant increase in CO_2 pollution, scholars are investigating the elements that influence CO_2 pollution. Several research have been undertaken to determine the main factors of environmental deterioration. Despite environmentally friendly construction, commercial production, and financial markets worldwide, analysts often neglect a country's political system because of its uncertain indirect influence on cutting pollution. Utilising South Africa as an illustration, this research investigated the combined effects of unpredictability in economic policy (UEP), fiscal decentralization, and sustainable development on CO_2 pollution in a setting of economic globalization, GDP, and GDP squared. Recognizing the relationship among these variables is critical for developing strategies to ensure environmental sustainability.

The following are the robust research results: (i) Long-term cointegration of economic policy unpredictability, economic globalization, GDP, sustainable development, fiscal decentralization, and CO_2 pollutions; (ii) fiscal decentralization and sustainable development bring to improved environmentally friendly long-term viability and (iii) unpredictability of economic policies and economic globalization deteriorate environmental quality. (iv) Economic expansion worsens the harm to the environment; however, its square promotes its improvement, demonstrating the EKC theory; (v) In both the immediate and long run, each policy surprises in unpredictability in economic policy, fiscal decentralization, sustainable development, and economic globalization has an impact on CO_2 pollutions; (vi) in the long and intermediate run, any policy shocks in GDP affects CO_2 pollutions.

Prospective for future study areas. Regardless of the reality that the present study investigated the combined impact of unpredictability in economic policies, fiscal decentralization, and sustainable development on CO_2 pollution under the conditions of economic globalization, GDP, as well as its square, there currently are a few areas that require to be increased in future research. First, we discovered that each of these characteristics substantially influences deciding how environmentally friendly the South African environment is. This study's findings may apply to various countries, localities, and social groups. Second, this inquiry covers a wide range of topics, and its breadth is extensive. Only available in South Africa.

Furthermore, when speaking of time, the present study mainly spans the years 1961 to 2021. Future research can enhance the approach by integrating other components and conducting a panel data analysis of African and emerging nations. Third, the process determining fiscal decentralization

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influences CO_2 pollution could be studied. Finally, more research is required to identify how the complimentary impacts of fiscal decentralization, unpredictability in economic policy, and sustainable development affect CO_2 pollution.

REFERENCES

Cai, H., Tong, Z., Xu, S., Chen, S., Zhu, P. & Liu, W. (2022). Fiscal decentralization, government behavior, and environmental pollution: Evidence from China. *Frontiers in Environmental Science,* 10**,** 901079. https://doi.org/10.3389/fenvs.2022.901079

Chen, X. & Chang, C.-P. (2020). Fiscal decentralization, environmental regulation, and pollution: a spatial investigation. *Environmental Science and Pollution Research,* p. 27**,** 31946–31968. https://doi.org/10.1007/s11356-020-09522-5

Cubas, J. M., Stel, H., Ofuchi, E. M., Neto, M. A. M. & Morales, R. E. (2020). Visualization of two-phase gas-liquid flow in a radial centrifugal pump with a vaned diffuser. *Journal of Petroleum Science and Engineering,* 187**,** 106848. https://doi.org/10.1016/j.petrol.2019.106848

Du, J. & Sun, Y. (2021). The nonlinear impact of fiscal decentralization on carbon emissions: from the perspective of biased technological progress. *Environmental Science and Pollution Research,* 28**,** 29890-29899. https://doi.org/10.1007/s11356-021-12833-w

Farzanegan, M. R. & Mennel, T. (2012). Fiscal Decentralization And Pollution: Institutions Matter. Magks Joint Discussion Paper Series in Economics.

Guo, S., Wen, L., Wu, Y., Yue, X. & Fan, G. (2020). Fiscal decentralization and local environmental pollution in China. *International Journal of Environmental Research and Public Health,* pp. 17**,** 8661. https://doi.org/10.3390/ijerph17228661

Hao, Y., Chen, Y.-F., Liao, H. & Wei, Y.-M. (2020). China's fiscal decentralization and environmental quality: theory and an empirical study. *Environment and Development Economics,* pp. 25**,** 159–181. https://doi.org/10.1017/S1355770X19000263

Ji, X., Umar, M., Ali, S., Ali, W., Tang, K. & Khan, Z. (2021). Does fiscal decentralization and eco-innovation promote a sustainable environment? A case study of selected fiscally decentralized countries. *Sustainable Development,* 29**,** 79-88. https://doi.org/10.3390/en12061078

Jiang, Q., Heng, Y., Liu, X., Zhang, W., Bois, G. & Si, Q. (2019). A review of design considerations of centrifugal pump capability for handling inlet gas-liquid two-phase flows. *Energies,* pp. 12**,** 1078. https://doi.org/10.3390/en12061078

Khan, Z., Ali, S., Dong, K. & Li, R. Y. M. (2021). How does fiscal decentralization affect CO2 emissions? The roles of institutions and human capital. *Energy Economics,* 94**,** 105060. https://doi.org/10.1016/j.eneco.2020.105060

Kuai, P., Yang, S., Tao, A. & Khan, Z. D. (2019). Environmental effects of Chinese-style fiscal decentralization and the sustainability implications. *Journal of Cleaner Production,* 239**,** 118089. https://doi.org/10.1016/j.jclepro.2019.118089

Lingyan, M., Zhao, Z., Malik, H. A., Razzaq, A., An, H. & Hassan, M. (2022). Asymmetric impact of fiscal decentralization and environmental innovation on carbon emissions: Evidence from highly decentralized countries. *Energy & Environment,* 33**,** 752-782. https://doi.org/10.1177/0958305X211018453

Qin, F. (2022). Fiscal Expenditure Structure, Vertical Fiscal Imbalance and Environmental Pollution. *International Journal of Environmental Research and Public Health,* pp. 19**,** 8106. https://doi.org/10.3390/ijerph19138106

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Que, W., Zhang, Y., Liu, S. & Yang, C. (2018). The spatial effect of fiscal decentralization and factor market segmentation on environmental pollution. *Journal of Cleaner Production,* pp. 184**,** 402–413. https://doi.org/10.1016/j.jclepro.2018.02.285

Safi, A., Wang, Q.-S. & Wahab, S. (2022). Revisiting the nexus between fiscal decentralization and environment: evidence from fiscally decentralized economies. *Environmental Science and Pollution Research,* 29**,** 58053-58064. https://doi.org/10.1007/s11356-022-19860-1

Shahbaz, M., Rizvi, S. K. A., Dong, K. & Vo, X. V. (2022). Fiscal decentralization as new determinant of renewable energy demand in China: The role of income inequality and urbanization. *Renewable Energy,* 187**,** 68-80. https://doi.org/10.1016/j.renene.2022.01.064

Shan, S., Ahmad, M., Tan, Z., Adebayo, T. S., Li, R. Y. M. & Kirikkaleli, D. (2021). The role of energy prices and nonlinear fiscal decentralization in limiting carbon emissions: tracking environmental sustainability. *Energy,* 234**,** 121243. https://doi.org/10.1016/j.energy.2021.121243

Si, Q., Bois, G., Jiang, Q., He, W., Ali, A. & Yuan, S. (2018). Investigation on the handling ability of centrifugal pumps under air–water two-phase inflow: Model and experimental validation. *Energies,* pp. 11**,** 3048. https://doi.org/10.3390/en11113048

Song, J., Geng, L., Fahad, S. & Liu, L. (2022). Fiscal decentralization and economic growth revisited: an empirical analysis of poverty governance. *Environmental Science and Pollution Research,* 29**,** 28020-28030. https://doi.org/10.1007/s11356-021-18470-7

Su, C.-W., Umar, M. & Khan, Z. (2021). Does fiscal decentralization and eco-innovation promote renewable energy consumption? Analyzing the role of political risk. *Science of The Total Environment,* 751**,** 142220. https://doi.org/10.1016/j.scitotenv.2020.142220

Sun, Y., Gao, P. & Razzaq, A. (2023). How does fiscal decentralization lead to the transition of renewable energy and a sustainable environment? Evidence from highly decentralized economies. *Renewable Energy,* 206**,** 1064-1074. https://doi.org/10.1016/j.renene.2023.02.069

Sun, Y., Guan, W., Razzaq, A., Shahzad, M. & An, N. B. (2022). Transition towards ecological sustainability through fiscal decentralization, renewable energy and green investment in OECD countries. *Renewable Energy,* 190**,** 385-395. https://doi.org/10.1016/j.renene.2022.03.099

Sun, Y. & Razzaq, A. (2022). Composite fiscal decentralization and green innovation: Imperative strategy for institutional reforms and sustainable development in OECD countries. *Sustainable Development,* 30**,** 944-957. https://doi.org/10.1002/sd.2292

The Phan, C., Jain, V., Purnomo, E. P., Islam, M. M., Mughal, N., Guerrero, J. W. G. & Ullah, S. (2021). Controlling environmental pollution: Dynamic role of fiscal decentralization in CO 2 emission in Asian economies. *Environmental Science and Pollution Research,* 28**,** 65150-65159. https://doi.org/10.1007/s11356-021-15256-9

Tufail, M., Song, L., Adebayo, T. S., Kirikkaleli, D. & Khan, S. (2021). Do fiscal decentralization and natural resources rent curb carbon emissions? Evidence from developed countries. *Environmental Science and Pollution Research,* 28**,** 49179-49190. https://doi.org/10.1007/s11356-021-13865-y

Udeagha, M. C. & Breitenbach, M. C. (2023). Can fiscal decentralization be the route to the race to zero emissions in South Africa? Fresh policy insights from novel dynamic autoregressive distributed lag simulations approach. *Environmental Science and Pollution Research,* 30**,** 46446-46474. https://doi.org/10.1007/s11356-023-25306-z

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Udeagha, M. C. & Breitenbach, M. C. (2023). Revisiting the nexus between fiscal decentralization and CO2 emissions in South Africa: fresh policy insights. *Financial Innovation,* 9**,** 1-46. https://doi.org/10.1186/s40854-023-00453-x

Udeagha, M. C. & Ngepah, N. (2022). Dynamic ARDL simulations effects of fiscal decentralization, green technological innovation, trade openness, and institutional quality on environmental sustainability: evidence from South Africa. *Sustainability,* 14**,** 10268. https://doi.org/10.3390/su141610268

Wang, F., Rani, T. & Razzaq, A. (2023). Environmental impact of fiscal decentralization, green technology innovation and institution's efficiency in developed countries using advance panel modeling. *Energy & Environment,* 34**,** 1006-1030. https://doi.org/10.1177/0958305X221074727

Xia, J., Li, R. Y. M., Zhan, X., Song, L. & Bai, W. (2022). A study on the impact of fiscal decentralization on carbon emissions with U-shape and regulatory effect. *Frontiers in Environmental Science,* p. 10**,** 964327. https://doi.org/10.3389/fenvs.2022.964327

Yuan, R., Li, C., Ahmed Memon, J., Ali, M. & Nawaz, M. A. (2022). The nexus between fiscal decentralization and environmental sustainability in Japan. *Frontiers in Environmental Science,* p. 10**,** 905461. https://doi.org/10.3389/fenvs.2022.905461

Zhang, C., Zhou, D., Wang, Q., Ding, H. & Zhao, S. (2022). Will fiscal decentralization stimulate renewable energy development? Evidence from China. *Energy Policy,* p. 164**,** 112893. https://doi.org/10.1016/j.enpol.2022.112893

Zhao, L., Shao, K. & Ye, J. (2022). The impact of fiscal decentralization on environmental pollution and the transmission mechanism based on promotion incentive perspective. *Environmental Science and Pollution Research,* p. 29**,** 86634–86650. https://doi.org/10.1007/s11356-022-21762-1