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Asymmetric effect of educational expenditure, knowledge spillover, and energy consumption on sustainable development: Nuts and Bolts for policy empirics

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ABSTRACT

Climate change is raising widespread anxiety, especially in countries that are more vulnerable to environmental disasters. Energy use leads to an increase in Greenhouse gases, especially carbon emissions, which is responsible for environmental degradation. Identifying cultural and economic factors that impact sustainability courses is critical in this context for dealing with ecologically demanding challenges. Education and knowledge spillover in the form of foreign direct investment has long been seen as an effective method of disseminating knowledge, ideas, and behaviors that aid in environmental protection and improve ecological consciousness. This study investigates how energy consumption (LEC), educational expenditure (EDEXP), and knowledge spillover (KNO) affect sustainable development (SD) in the case of Pakistan. This study employs the Non-linear Autoregressive Distributive Lag Model (NARDL) over a data span of 41 years i.e., from 1980 to 2021. The estimations unveil that shocks in educational expenditure pose different results. EDEXP_POSE increases sustainability (0.807 units) while EDEXP-NEG decreases sustainability (0.931 units) while KPO_POS and KPO_NEG positively (0.200 units and 0.011 units respectively) affect environmental sustainability. On the other hand, LEC_POS negatively (1.685 units) affects sustainability while LEC_NEG positively (0.867 units) affects Sustainable growth. Energy consumption has a negative impact on sustainability; thus, the government should prioritize the production of renewable energy sources and support the spread of knowledge that is good for the environment. The government may think about putting tariffs on businesses who import non-green technology since it has a significant and advantageous impact on the environment.

1. Introduction

Sustainable development is a shared aim for both industrialized and developing countries because the United States ratified the 2030 Agenda for Sustainable Development [1]. Sustainable development is feasible when governments work to meet the needs of today while maybe not endangering the requirements of future generations [2]. Sustainable development encompasses economic advancement promotion, social welfare enhancement, and environmental preservation. A government's institutional level and quality are inextricably linked to achieving sustainable development goals. The conceptual cornerstone of sustainable development,

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institutional quality, is reflected via both well-structured institutions and well-designed implementation systems. Institutional quality improvements boost a firm's innovation, allowing it to achieve a competitive advantage and so contribute to a nation's long-term success [3]. As a result, sustainable development institutional measurements and indicators have been developed. On the other hand, energy consumption negatively and significantly affects sustainable development.

Given the opposed natures of sustainable management, it shouldn't be surprising that sustainability is often seen as a demanding target [4]. Short-term economic growth is critical for emerging nations with sustainable prosperity. Accelerated sustainable prosperity is typically accompanied by the indiscriminate extraction of a wide range of natural resources, which is likely to influence the natural habitat. In this context, industrialized economies have demonstrated the efficacy of an innovation-centered strategy for attaining sustainable development [5]. Innovation may enhance economic growth [6], alleviate societal difficulties [7], and reduce environmental stress [8], exhibiting the three pillars of sustainable development [9].

Climatic change's devastating effects on the environment and human existence have proven a cause of concern for ecologists, lawmakers, and the public. Nitrogen oxides, chlorofluorocarbons, methane, carbon dioxide (CO_2), and other greenhouse gases contribute considerably to runaway atmospheric heat in the Ground atmosphere [10]. Massive environmental degradation is being caused by the rapid development of economic activity, energy consumption, population, and other human activities [11]. The industrial growth of many countries has had an impact on environmental quality, resulting in health issues, biodiversity loss, and soil degradation [12]. If notions of sustainable development aren't carefully considered, humanity may confront a gloomy and bleak existence [13]. Contemporary experimental evidence is attempting to find specific factors that lessen environmental concerns without jeopardizing productivity expansion [14].

According to the Global Climate Risk Index, Pakistan is the sixth most susceptible economy to global warming [15,16]. Pakistan saw 152 weather extremes over the previous century, lost almost 10,000 lives, and suffered USD 3.8 billion in economic damage as a result of natural disasters [17]. Scholars have identified energy utilization, economic deepening, internationalization, foreign direct investment (FDI), development, industrial expansion, and international tourism as pollutant emission sources in Pakistan [18,19]. Several research on the impacts of environmental factors [20,21] have been undertaken, and their research shows that GDP and FDI are the most commonly used drivers of environmental degradation.

Sustainable development is enabled by technological improvement and innovation [22]. Technological change and innovation are dependent on local government or industry investment in R&D, as well as worldwide dissemination and knowledge and technology spillover [23,24], sometimes known as international knowledge spillover [25]. Trade and FDI from wealthy economies have been seen as the key avenues of transnational knowledge spillover to impoverished countries over the past decade [26]. Previous research has thoroughly investigated the relationship between knowledge spillover and CO_2 emissions, with knowledge spillover classified as either foreign or domestic. FDI-induced technology and information transfer a key sources of international technology spillover. One school of thought claims that FDI technical spillover will benefit the environment. The technology transfer introduced by FDI is used to promote the development of a low-carbon economy [27] and encourages technical assistance for enhanced energy efficiency in host nations [28,29]. Another viewpoint holds that FDI-related technical spillover decreases environmental sustainability. According to the Xu et al. [30], FDI increased the spill over technologies which usually brings the consumption of renewable energy.

Education is an important human characteristic that can impact health and economic success [31]. Increased educational attainment is recognized as one of the sustainable development goals (SDG) components in nations with very low educational attainment [32]. The SDGs connected to education may be met by improving education for all, which will have a detrimental impact on environmental sustainability [33]. The increasing education expenditure by the Pakistani government will help society by producing more educated and environmentally conscious males and girls. Pakistan is dedicated to developing its education sector into a high-quality world market requirement-oriented system in line with SDG 4 (Education Quality). Pakistan has made the following contributions to the SDGs: Primary, lower secondary, and upper secondary education graduation rates were 67%, 47%, and 23%, respectively. Students who take part in learning (one year before the official primary entry age) are 19% by gender, showing a low level of Pre-Primary Education consideration. 60% of persons in a certain age group reach a specified level of proficiency in functional, reading, and numeracy abilities. Enrollments were 55.7 million in 2019–20, up from 53.1 million in 2018–19, indicating a 4.9% increase. By 2020–21, it is predicted to reach 58.5 million. Within the same time frame, the proportion of educators is predicted to rise from 1.83 million to 1.89 million. However, there were 277.5 thousand educational institutions, an increase from 271.8 thousand the previous year, and this figure is expected to rise to 283.7 thousand by 2021. This is part of our commitment to achieve SDG 4 of improving educational access and quality.

Higher education levels come from more education spending. It also promotes economic growth and energy consumption, both of which have an environmental impact [34]. Aside from carbon emissions, education, and labor productivity are strongly linked. Education boosts efficiency, which benefits the economy. Education helps with technical advancements, which aid in the identification of efficient energy sources utilized throughout the manufacturing process, in addition to enhancing the country's economic prosperity [35]. The use of efficient energy sources aids in the reduction of carbon emissions within the environment. Additionally, education does have a major demographic link; enhancing female education would assist to curb population increase, which is an essential strategy for climate change mitigation. If the objective of female higher schooling is met today, this could assist to save the environment 85 gigatons of CO_2 emissions by 2050 by averting the addition of 1.5 billion people to the population through family planning [36].

Furthermore, the quest for environmental sustainability is complicated by industrialization's ambition, which poses a huge risk to natural ecology. According to some analysts, rising industrialization leads to a rise in energy consumption [37,38]. Depending on the energy source, energy consumption has a variety of environmental consequences [39]. Nonrenewable energy usage, for example, is predicted to increase GHG emissions, posing a threat to environmental sustainability [40]. In general, industrialization is predicted to increase energy consumption, which is a key contributor to environmental deterioration. As a result, the degree of industrialization influences environmental quality. The pursuit of sustainable development leads to the growth of polluting sectors, which have seen an extraordinary spike in recent decades [40]. The environmental consequences of industrialization have far-reaching consequences for human socioeconomic well-being.

Despite increased demand for renewable energy, numerous countries continue to rely on fossil fuels to boost their economic prospects [41]. Increasing crude oil prices are harmful to the environment because they encourage the development and transportation of fossil fuels. The use of fossil fuels increases the intensity of carbon dioxide emissions, putting sustainable development at risk.

This study examines the effects of energy consumption along with knowledge spillover and education expenditure on environmental quality. So, the contribution of this study is multifaceted. Firstly, the research gap regarding knowledge spillover and environmental sustainability in Pakistan is related to the lack of understanding about how knowledge transfer and diffusion mechanisms impact environmental sustainability outcomes in that country. Research on knowledge spillovers and their consequences on the economy has been conducted, but few of this research has specifically examined the connection between knowledge spillovers and environmental sustainability. The study on environmental sustainability in Pakistan that is currently accessible focuses mostly on legal and policy frameworks as well as industry-specific issues including water management, air pollution, and energy. However, little study has been done on the importance of knowledge spillovers in promoting environmentally friendly practices, concepts, and technologies across numerous industries.

Secondly, there are few in-depth studies that quantify Pakistan's energy usage's consequences on the environment. Research needs to examine the effects of various energy sources and consumption patterns on resource depletion, air and water pollution, and greenhouse gas emissions. So, the current research assessed the asymmetric impact of energy consumption on environmental sustainability.

Thirdly, an intricate and under-researched topic is how educational spending affects environmental sustainability in Pakistan. While there is considerable study on the connection between education and environmental sustainability, there aren't many studies specifically looking at how educational spending affects society in Pakistan. This study gap offers a chance to investigate the relationship between Pakistani educational spending and environmental effects. So, the current research incorporates the asymmetric impacts of educational expenditures on environmental sustainability in case of Pakistan.

Furthermore, our research addresses a gap in the literature by adding asymmetries in energy use, educational expenditure, and knowledge spillover on sustainable environment development.

2. *Theoretical underpinning and literature review*

Since the 1980s, some countries have acknowledged sustainable development as a huge development strategy, with the idea of sustainable development understood to include the three primary pillars of economic, social, and environmental components [42]. In this context, the word "triple bottom line" (TBL) was created to underline that sustainable development may be accomplished by achieving an equilibrium among economic success, protection of the environment, and social inclusion [43]. The TBL framework requires each of these three pillars of sustainable development. The availability of sufficient material and financial resources is referred to as economic sustainability [44]. Sustainable growth stresses gender cohesion, cultural variety preservation, and growth in human health and educational capabilities. Environmental quality is maintained through the effective utilization of renewable energy sources, the decrease of greenhouse gas emissions, and the reduction of carbon footprints [45]. Everyone thinks, in theory, that innovation is a crucial engine of long-term success. National governments and academic institutions have begun to study strategies for attaining long-term development effectiveness [46]. They must achieve a tough balance between economic, social, and environmental considerations. To begin, the Romer [47] and Lucas [48] endogenous economic growth model stresses knowledge accumulation as the major engine of economic growth and claims that endogenous technological innovation drives long-term economic growth. The bulk of empirical studies used industrialized economies as their study backdrop and found linkages between progress and economic progress.

Secondly, because societal advancement cannot be isolated from the material foundation provided by economic and social development [49], economic growth is inextricably linked to social development. For example, innovation has resulted in the development of high-yielding grain varieties, as well as more efficient fertilizer and irrigation applications, resulting in a large increase in grain output and a reduction in the social development problem of food shortage [50]. Individuals may gain directly from the use of modern technology, improving their social well-being. Medical technology and advancements, for example, as well as the widespread usage of purifiers, had significantly enhanced human living standards. Thirdly, technological advancement was crucial to eliminating and at least mitigating environmental resource depletion [51]. Environmental innovation, in particular, is seen as critical.

Information spillover has become generally acknowledged as a booster of spatial socioeconomic growth since it improved the population's capital dimension (i.e., human capital). As a result, when outsiders learn about a company's R&D competence, technology spillover occurs regularly. The fundamental idea, on the other hand, could be justified at any cost [52]. Knowledge spillovers often improve economies' skills by increasing information. Information spillovers may contribute to minimizing communication and transformation costs. This cost reduction typically benefits the economy. Because of awareness spillover, the cost of learning new knowledge would be reduced. As the cost of learning decreases, so does the user's ability to absorb and digest information. The consequences of information overload are vast and diverse, resulting in complex networks that are inextricably linked to the rest of the world. Knowledge spillover reduces development costs for other economic players, such as the challenges connected with the complex nature of the innovation era, while also strengthening current skills and standards [53]. Zhao et al. [54] hypothesized that knowledge spillover aids long-term economic transition to a sustainable future in their research study. As key sources of knowledge spillover, FDI inflows and their consequences on the economy, such as economic growth [55], fuel consumption, renewables, capital creation [56], and trade liberalization, have been widely explored in the literature [57]. Furthermore, the research emphasizes the need of Knowledge spill over impact on environmental sustainability [58].

Energy conservation initiatives aimed at reducing environmental degradation, improving energy efficiency, and controlling waste, according to the conservation hypothesis, may not necessarily get an influence on growth rates. The ecological modernization concept has also been defined as reorganizing society to achieve environmental sustainability through efficient manufacturing and energy use. In this sense, the concept serves as a model for the progressive transition from pre-modernity to modernization. Aside from the theoretical framework, some current literature review is presented in Table 1 below.

3. Concluding remarks

Sustainable development is a major objective for developing countries and different indicators play important roles to achieve sustainable development of a country. Based on the above literature on empirical studies of education expenditure, knowledge spillover, and energy consumption, it is concluded that the above indicators have a positive and significant impact on Sustainable development. But previous studies also indicate that rare work has been done on this aspect. The current research adds to the literature since it attempts to investigate the combined impacts of knowledge spillover, energy consumption, and educational expenditure on sustainable development.

4. Methodology

4.1. Model specification

The proposed research aims to determine the asymmetric effects of educational expenditure, knowledge spillover, and energy consumption on sustainable environmental development. Except for globalization and ecological footprints, data for all variables, including education expenditures, knowledge spillover, urbanization, energy consumption, and population density, is derived from the World Development Indicators. Globalization data is obtained from the Swiss Koff Index, while ecological footprints are derived from the Global Footprints Network. The data on energy consumption was transformed into natural logarithms to reduce the influence of data fluctuation [69].

To search for the link between target variables, the current paper proposes the succeeding equation (1):

$$\mathrm{SD} = \mathrm{f}(\mathrm{EDEXP}, KNO, \mathrm{LEC}, \mathrm{UBN}, \mathrm{GLOB}, \mathrm{LPOPD}) \tag{1}$$

The current study species the association among edexp, kno, econ, ubn, glob, and popd in a single multivariate structure, accordingly our econometric model is stated in equation (2):

Table 1
A Synopsis of the Past literature.

Author(s) and year	Context	Nature of the study	Relationship
Khan et al. [59]	Time series data from 1965 to 2015 using the ARDL model	Empirical study	+ve between energy consumption & sustainable development
Pao et al. [60]	Panel data of BRIC countries over the period 1971–2005 and cointegration techniques were applied	Empirical study	+ve between energy consumption & Economic growth
Charfeddine & Kahia [61]	Data from 24 countries of the Middle East and North Africa (MENA) region from 1980 to 2015 were used and estimated through a panel vector autoregressive (PVAR) model	Empirical study	A slight influence of energy consumption on sustainable development
Mercan and Sezer [62]	Time series data of Turkey from 1970 to 2012 and used a cointegration approach	Empirical study	+ve between education expenditures & Economic growth
Churchill et al. [63]	Used a sample of 237 estimates drawn from 29 primary studies and conducted a hierarchical meta-regression analysis	Empirical study	+ve government education expenditure And Economic growth
Okoye et al. [64]	Multivariate analysis of variance (MANOVA)	Empirical study	+ve role of govt expenditure on higher education in sustainable development
Riasat et al. [34]	Used data from Pakistan from 1972 to 2010, and Estimated results using bounds testing approach.	Empirical study	+ve impact of education expenditures on sustainable development
Aghion et al. [65]	Use cross-US-states panel data	Empirical study	+ve impact of knowledge spillover on economic growth
Aghion and Jaravel [66]	New empirical work focusing on knowledge spillovers	Theoretical study	+ve role of knowledge spillover in economic growth
Altuwaijri & Kalyanaraman [67],	Primary data sample of 85 firms, OLS Technique used for analysis	Empirical study	+ve relationship between knowledge spillover in economic development
Sara et al. [68]	The secondary annual time series data from 1976 to 2019 are analyzed. ARDL has been used for the estimation of results	Empirical study	+ve impact of Spillovers of Education on sustainable economic growth

$$SD_t = \alpha_0 + \beta_1 EDEXP_t + \beta_2 KNO_t + \beta_3 UBN_t + \beta_4 LEC_t + \beta_5 GLOB_t + \beta_6 LPOPD_t \tag{2}$$

where SD is sustainable development, EDEXP is education expenditure, KNO is knowledge spillover, UBN depicts urbanization LEC is log of energy consumption, GLOB is globalization and LPOPD is log of population density.

4.2. Definitions of variables

4.2.1. Sustainable development

To measure sustainable development, a variety of indicators covering economic, social, and environmental characteristics are produced [70]. Regardless, neither the political nor scientific sectors have reached an agreement on a single index. There is thought to be a lack of a clear path to attaining sustainable development [71]. Based on the main components of sustainable development, we examined the economic perspective with GDP, the aspects through life expectancy, and the environmental aspect through ecological footprints [72]. The index was constructed with the use of principal component analysis (PCA).

4.2.2. Educational expenditure

Educational expenditures account for a sizable portion of a country's social expenditure. Education spending by the general government (current, capital, and transfers) is shown as a percentage of GDP. Education investment is an intervention that has the potential to increase economic development, increase efficiency, promote social inclusion, and reduce social inequality. The proportion of overall monetary support dedicated to education is a crucial decision made by governments, corporations, students, and their families. Spending on schools, universities, and other public and private organizations that provide or support educational services is included in the index. In the current research, we used Government expenditure on education, total (% of GDP), as a proxy for educational expenditure.

4.2.3. Knowledge spillover

Economic knowledge spillover effects in the aggregated nation are dependent on trade liberalization and R&I production [72]. As a result, countries with a higher level of openness and technology productivity may see bigger amounts of spillover effects. Local output is boosted by recruiting foreign consumers and channeling capital flows into the economy through liberalization and domestically creative practices. Other scholars have thoroughly researched the influence of FDI on regional knowledge spillover [73]. Knowledge spillover happens whenever competitors get information created by a corporation via R&D projects. The original innovation, however, cannot be rewarded [74]. In the current research, we used FDI inflows (% of GDP), as a proxy of knowledge spillover.

4.2.4. Urbanization

The movement of people from rural to urban areas, as well as the subsequent decrease in rural population, are all examples of urbanization. It is the process through which towns and cities expand in size as more people move to core locations to live and work. In the current research, we used the urban population (% of the total population) for urbanization.

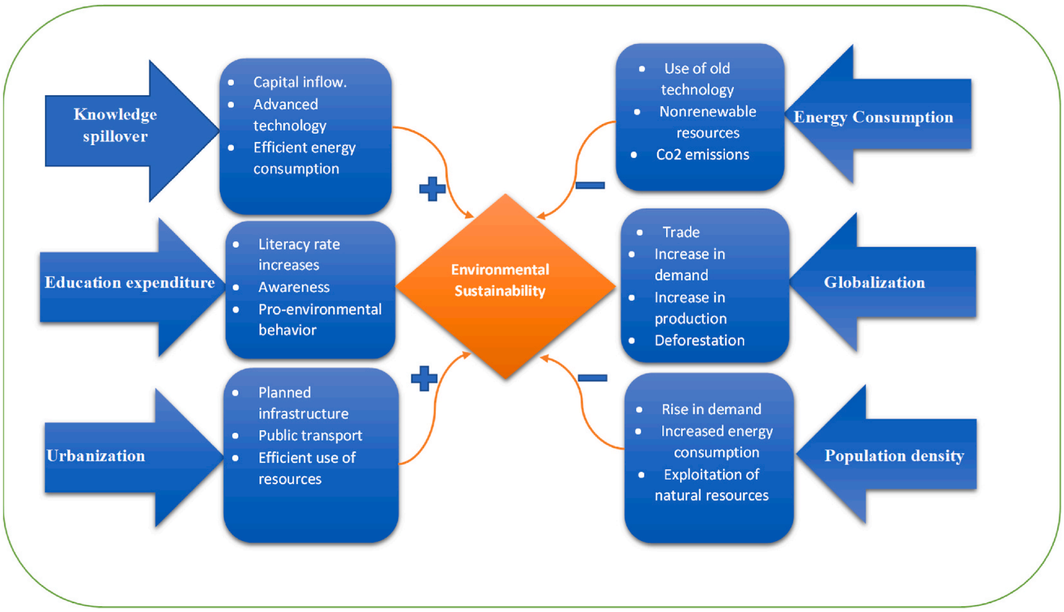


Fig. 1. Transmission mechanism of Study Variables.

4.2.5. Energy consumption

Alam et al. [75] define energy consumption as energy consumption per capita (oil equivalent kilotons). Pakistan's primary energy sources are oil, gas, and coal. These sources not only cause environmental damage but also play a significant part in rising the temperature of the country. In the current research, we used fuel imports (% of merchandise imports) as a proxy for energy consumption.

4.2.6. Globalization

Globalization refers to the rapid expansion of multinational organizations and transactions (of people, products and services, money, technology, and cultural practices). Globalization has resulted in the stimulation and expansion of relationships between diverse areas and groups all over the world. In this study, we used the KOF Globalization Index to measure globalization.

4.2.7. Population density

Population density is a demographic statistic that measures the number of people per square kilometer of land area. The growing population density was the most reliable predictor of environmental deterioration, with the most densely populated areas causing the most environmental impact [76]. The annual growth in population density is commonly used to explore the relationship between population, environment, and economic development. Furthermore, there is widespread agreement that increasing population density is connected with environmental degradation but not with economic success. In the current research, we used people per square kilometer of land area.

Fig. 1 shows the transmission mechanism of study variables. From the figure, it is clear that knowledge spillover affects environmental sustainability through capital inflows, technology transfer, and efficient energy consumption. Educational expenditure adopts the channel of literacy rate, increased awareness, and pro-environmental behavior. On the other hand, energy consumption affects sustainability via the use of old technology, and non-renewable resources and by increasing CO_2 emissions.

4.3. Econometric technique

The current study seeks to investigate the asymmetries between our research variables. We explore whether positive (negative) shocks in education spending, knowledge spillover, and globalization impact sustainable development in the short- and long-term using non-linear ARDL Model.

Non-linear Model developed for the current study is presented in equation (3):

$$SD_t = \alpha_0 + \beta_t EDEXP_t^+ + \beta_t EDEXP_t^- + \beta_t KNO_t^+ + \beta_t KNO_t^- + \beta_t LEC_t^+ + \beta_t LEC_t^- + \beta_t UBN_t + \beta_t GLOB_t + \beta_t LPOPD_t \tag{3}$$

where β^+ and β^- are the asymmetric parameters and $EDEXP_t^+\ \beta_t KNO_t^+, \beta_t ECON_t^+ and\ LEC^+ a$ re the partial sum process of positive changes in education expenditure, knowledge spillover, and energy consumption: see equation (4),

$$\text{POS} = EDEXP_t^+ = \text{Fig 3} \sum_{k=1}^{t} \Delta EDEXP_t^+ = \sum_{k=1}^{t} \max(EDEXP_k, 0)\Big); \sum_{k=1}^{t} \Delta KNO_t^+ = \sum_{k=1}^{t} \max(KNO_k, 0)\Big); \sum_{k=1}^{t} \Delta LEC_t^+ = \sum_{k=1}^{t} \max(LEC, 0)\Big) \tag{4}$$

while $EDEXP_t^-\ \beta_t KNO^-, \beta_t LEC_t^- a$ re the partial sum process of negative changes in education expenditure, knowledge spillover, and trade liberalization which are shown in equation (5).

$$\text{NEG} = EDEXP_t^- = \sum_{k=1}^{t} \Delta EDEXP_t^- = \sum_{k=1}^{t} \min(EDEXP_k, 0)\Big); \sum_{k=1}^{t} \Delta KNO_t^- = \sum_{k=1}^{t} \min(KNO_k, 0)\Big); \sum_{k=1}^{t} \Delta LEC_t^- = \sum_{k=1}^{t} \min(LEC, 0)\Big) \tag{5}$$

Nonetheless, Eq. (4) and Eq. (5) mentioned earlier can be revamped into the following NARDL model which is represented in equation (6), correspondingly.

$$\begin{aligned} SD_t = {} & \eta_0 + \sum_{i=1}^{q} \eta_1 (SD)_{t-1} + \sum_{i=0}^{q} \eta_2 EDEXP_{t=i}^+ + \sum_{i=0}^{q} \eta_3 EDEXP_{t=i}^- + \sum_{i=0}^{q} \eta_4 KNO_{t=i}^+ + \sum_{i=0}^{q} \eta_5 KNO_{t=i}^- + \sum_{i=0}^{q} \eta_6 LEC_{t=i}^- + \sum_{i=0}^{q} \eta_7 LEC_{t=i}^+ \\ & + \sum_{i=0}^{q} \eta_8 URB_{t-i} + + \sum_{i=0}^{q} \eta_9 GLOB_{t-i} + \sum_{i=0}^{q} \eta_{10} LPOPD_{t-i} + \gamma_1 (SD)_t + \gamma_2 EDEXP_t^+ + \gamma_3 EDEXP_t^- + \gamma_4 KNO_t^+ + \gamma_5 KNO_t^- \\ & + \gamma_6 LEC_t^+ + \gamma_7 LEC_t^- + \gamma_8 URB_t + \gamma_9 GLOB_t + \gamma_{10} LPOPD_t + \in_t \end{aligned} \tag{6}$$

where, i = lag identity; t = time; η_0 = Intercept; λ = Long run coefficient.

The Bounds test is used in the NARDL to analyze non-linear cointegration. In NARDL, the F-stat must be bigger than both the lower and upper limit critical values to reject the null hypothesis. Furthermore, the study employs a variety of diagnostic measures to assess the stability of the asymmetrical models. The WALD test was used in the asymmetrical ARDL approach to validate the long-term asymmetrical impact.

5. Result and discussion

5.1. Descriptive statistics

Table 2 display summary statistics of amid variables including environmental sustainability, educational expenditure, Knowledge spillover, globalization, energy consumption, population density, and Urbanization. The outcome affirms that SD has the lowest mean value while GLOB has the highest mean value. Further, GLOB and LEC recorded the highest and lowest standard deviation value respectively. It is also observed from Table 2 that SD, EDEXP, LEC, LPOD, GLOB, and URB is platykurtic. While KNO is leptokurtic.

Table 3 portrays the result of the correlation among research parameters. Results unveil that all research parameters are positively associated with environmental sustainability.

5.2. Unit root tests

We employ the Augmented Dickey-Fuller (Fisher-ADF) tests to estimate the existence of unit root across the series (Table 4). The results show that KNO and LPOPD show stationarity at level, meaning that they are integrated of order zero I (0) and do not need to be differentiated. However, the other variables, which included the SD, EDEXP, GLOB, LEC, and URB, were stable after initial differencing, suggesting that they are integrated of order one I (1).

5.3. Structural break unit root test

We have applied Zivot and Andrews (77) test and results were presented in Table 5. From results it is found that with the single unknown break, EDEXP, GLOB, KNO, and LPOPD have unit roots at level with intercept and trend. On the other hand, ES, LEC, and URB are found to be stationary at first difference. It was confirmed that study variables are found to be stationary at mixed levels. This implies that series have a different level of integration. The robustness of the results is validated by applying Zivot and Andrews [77] with a single unknown structural break. Our findings indicate that variables are integrated at I(0) and I(1). So, we can go for NARDL analysis.

5.3.1. Bound test

Table 6 displays the results of the ARDL model's bound test. The F-stat values of our bound results for models 1, 2, and 3 are 8.596, 11.370, and 9.629, respectively, indicating long-term cointegration between the variables in all three models, and these values are more than the upper bound values of 3.21, 3.15, and 3.90.

5.4. Empirical results

Table 7 depicts the short-run results of NARDL models. We have used three models to check the asymmetric impact of EDEXP, KNO, and LEC on sustainable development. According to short-run findings of model 1, EDEXP, LPOPD, and GLOB show a negative while URB, LEC, and KNO show positive relation with environmental sustainability. Results of Model 2 indicate that EDEXP, LPOPD, GLOB, LEC, and KNO have a negative influence on sustainable development while URB shows a positive impact. Model 3 findings positively confirm the negative influence of EDEXP, LPOPD, GLOB, LEC, and KNO while the influence of URB on SDs.

The ECM coefficient values for the three models, according to the results, are (−0.173), (−0.475), and (−0.605). The yearly deviation adjustments for models 1, 2, and 3 are around 17%, 47%, and 60%, respectively, according to these ECM figures. This shows the consistency and speed with which the three models can be adjusted. According to the ECM value, the prior year's shocks generated disequilibrium in comparison to the current year's long-run equilibrium.

Regardless of whether an economy is developed or developing, sustainable development (SD) promotes social advancement, economic advancement, and a healthy environment. The concepts of sustainable development, which have had a considerable influence on international accords as well as domestic strategies and programs aimed at ecologically friendly economic activities, are currently utilized as a guide for policymakers worldwide. A crucial component of sustainable development is ensuring an intrinsic link between the protracted sustainability of the environment and the economy. SD presents a roadmap that includes environmental

Table 2
Results of descriptive statistics.

	SD	EDEXP	KNO	GLOB	LEC	LPOPD	URB
Mean	0.000	2.501	0.885	45.570	1.377	2.270	32.905
Median	−0.240	2.535	0.675	46.545	1.390	2.285	33.080
Maximum	2.020	3.280	3.670	54.670	1.560	2.470	37.440
Minimum	−1.380	1.530	0.100	33.100	1.150	2.020	28.070
Std. Dev.	1.000	0.451	0.775	8.050	0.104	0.135	2.738
Skewness	0.470	−0.109	2.317	−0.309	−0.254	−0.230	−0.110
Kurtosis	2.073	2.178	8.027	1.551	2.188	1.864	1.850
Jarque-Bera	3.054	1.264	81.796	4.343	1.607	2.629	2.400
Probability	0.217	0.532	0.000	0.114	0.448	0.269	0.301

Table 3
Correlation matrix.

	SD	KPO	EDEXP	GLOB	LEC	URB	LPOPD
SD	1						
KPO	0.247	1					
EDEXP	0.370*	0.126	1				
GLOB	0.912***	0.460**	0.155	1			
LEC	0.367*	0.061	−0.359**	0.4175*	1		
URB	0.976***	0.316**	0.303*	0.9659***	0.341**	1	
LPOPD	0.991***	0.279*	0.314**	0.9511***	0.374**	0.995***	1

Table 4
Results of Unit root Test.

	ADF	
Variables	Level	1st Difference
SD	–	−4.0707***
EDEXP	–	−5.5417***
KNO	−3.0433**	–
GLOB	–	−4.9267***
LEC	–	−6.1792***
LPOPD	−3.6352***	–
URB	–	−3.128**

(*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%.

Table 5
Zivot-Andrews Structural Break Unit Root test Results.

	I(0)		I(1)	
	t-stat	Break Points	t-stat	Break Point
ES	−2.606	1997	−6.592**	2000
EDEXP	−4.855***	1999	−6.112	1989
GLOB	−5.036***	2005	−6.858**	1989
KNO	−5.181***	2004	−5.835***	2008
LEC	−1.344	2008	−4.572**	2010
LPOPD	−3.297**	1999	−9.288*	2014
URB	−2.147	1988	−6.611*	1999

(*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%.

Table 6
Results of the F-bound test.

Null Hypothesis: No levels of relationship				
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic		10%	1.92	2.89
	8.596	5%	2.17	3.21
	11.370	2.50%	2.43	3.51
	9.629	1%	2.73	3.90

policies and development strategies to guarantee that current demands are addressed without risking those of future generations. Therefore, this study focused on the impact of several factors that determines the sustainability of the environment. The NARDL model is used to analyze the asymmetrical effect of educational expenditure, knowledge spillover, and globalization along with fuel import, urbanization, and population density on sustainable development.

Long run results of the study are mentioned in Table 8. According to our results, the increase in educational expenditure positively influences sustainable development while the decline in the educational expenditure shows negative relation with SD in all three models. One of the elements of economies' sustainable development goals (SDGs) is a higher level of education [32]. That SDG enhances adults' education levels while also influencing the environment [33]. Increased educational spending improves education quality, which boosts economic development and energy demand, eventually affecting the environment. On the other hand, labor productivity is also related to education when there are more educated and skilled laborers their productivity increase and hence boost economic growth. Education has also supported technological innovation as well as economic progress [35], which has aided in the discovery of renewable energy sources employed in the manufacturing process. The use of these sustainable kinds of energy

Table 7
Short-run results.

Variable	Model 1	Model 2	Model 3
URB	0.304***	0.484***	0.757***
	(-2.560)	(-4.141)	(-5.138)
GLOB	−0.013*	−0.014	−0.031***
	(-1.527)	(-1.147)	(-2.103)
D(LPOPD)	−4.680**	−2.475	−3.277*
	(-1.844)	(-1.070)	(-1.466)
D(LEC)	0.063	0.089	
	(-0.515)	(-0.801)	
KNO	0.006		
	(-0.370)		
EDEXP_POS	0.140***	0.022	0.060
	(-2.380)	(-0.361)	(-0.741)
D(EDEXP_NEG)	−0.074*	−0.014	−0.066
	(-1.363)	(-0.251)	(-0.994)
KNO_POS		0.095***	0.109***
		(-3.250)	(-3.236)
D(KNO_NEG)		−0.054	−0.078***
		(-1.702)	(-2.460)
D(LEC_POS)			−0.127
			(-0.536)
LEC_NEG			0.525***
			(-2.192)
CointEq(-1)*	−0.173***	−0.475***	−0.605***
	(-9.9732)	(-12.434)	(-12.504)

(*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%.
(Parenthesis represents the value of t-statistics).

Table 8
Long-run results.

Variable	Model 1	Model 2	Model 3
URB	1.754**	1.018***	1.250***
	(-3.152)	−5.773	(-0.202)
GLOB	−0.080*	−0.100***	−0.133***
	(-1.702)	(-6.156)	(-0.018)
LPOPD	−41.432***	−14.603***	−15.083**
	(-2.480)	(-2.900)	(5.241)
LEC	−1.017	−0.517*	–
	(-0.949)	(-1.703)	
KNO	0.038	–	–
	(-0.382)		
EDEXP_POS	0.807***	0.046	0.307***
	(-2.283)	(-0.356)	(-0.130)
EDEXP_NEG	−0.931***	−0.364***	−0.624***
	(-2.128)	(-3.447)	(-0.145)
KNO_POS	–	0.200***	0.180***
		(-4.652)	(-0.034)
KNO_NEG	–	0.011	0.056**
		(-0.323)	(-0.031)
LEC_POS -		–	−1.685***
			(-0.542)
LEC_NEG	–	–	0.867***
			(-0.369)
C	37.541*	3.407	5.735
	(-1.751)	(-0.570)	(-0.320)

(*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1% (parenthesis represents the value of t-statistics).

contributes to the preservation of the environmental quality. Increasing educational investment increases education and so assists in population decrease, which is an important technique for dealing with climate change. People throughout the world will benefit if the higher education goal is met tomorrow. Quality education will cultivate appropriate leadership as well as the capacity to participate in climate policy choices. An area with a higher proportion of educated legislators will work harder to produce environmentally friendly legislation and ratify international environmental treaties. According to York [78], countries with a higher percentage of educated lawmakers are more environmentally conscious and sign more environmental treaties than countries with a lower percentage of educated legislators. The well-informed and educated population uses liquefied petroleum gas (LPG) for cooking and heating, which helps to reduce carbon emissions in the environment [79] helping in the reduction of environmental deterioration.

According to the findings, the knowledge of KNO shows a positive but insignificant impact on SD in model 1. However, the increase in KNO_POS and decrease in KNO_NEG both in models 2 and 3 also show a positive relation with sustainable development. The rise in KNO shows a more prominent effect on environmental sustainability than a decline in KNO shows a smaller impact. This positive influence of KNO on environmental sustainability is through green technology spillovers and resource optimization allocation in the host country. knowledge spillover can be beneficial in upgrading industrial structures and optimizing energy structures, thereby limiting carbon dioxide production. Khurshid et al. [80] looked at the effect of knowledge spillover on environmental sustainability. They observed that information spillover was helpful to environmental sustainability in general. The impact was heterogeneous, and foreign direct investment had a positive impact on environmental quality. Even if knowledge spillover does not utilize the most environmentally friendly technology, it is more likely to use a technology that is more environmentally friendly than what local companies in poor countries now use. Furthermore, through technology spillovers, multinational corporations are likely to transfer green technologies to local businesses, resulting in lower total emissions. Environmentally friendly or green technologies and practices may be transmitted to developing countries because of knowledge spillover, boosting environmental sustainability [81,82]. Foreign enterprises are more ecologically sensitive than domestic equivalents, according to Zhou [23] since they deploy better environmentally friendly practices and cutting-edge technology.

According to our findings, the LEC negatively impacts the SD in model 1. The rise in LEC in model 3 shows negative relation with SD while the decline in LEC shows a positive influence on LEC. This negative link emerges because we continue to use ancient techniques and do not have completely outfitted energy-efficient machinery. Furthermore, fossil fuels are largely employed to fulfil energy demand, and there own burning had significant environmental implications. Choices to utilize fossil fuels usually result in the emission of pollutants that enter the atmosphere, lowering environmental quality [83]. However, it has been suggested that switching to renewable energy sources will enhance the environmental quality [84]. To maintain the coherence of the environment and economic growth, it is vital to investigate alternatives to reducing dependency on fossil fuels. Electricity is the most often used energy source in the production of national outputs. Emerging economies have traditionally generated power using local fossil fuel resources. Furthermore, a significant portion of our fossil fuel imports have been utilized to generate power [85]. Because of growing reliance on fossil fuels, gas emissions have grown, harming environmental quality [86]. Thus, it is assumed that replacing traditional fossil fuels with more contemporary and cleaner alternatives is an effective approach to restoring global environmental balance [87].

GLOB in all three models shows negative relation with sustainable development. Deforestation is one way that GLOB has negatively affected the environment. Deforestation is frequently attributed to globalization as its primary cause. Significant environmental harm has resulted from both ecosystem mitigation as a result of human development and resource exploitation as a result of increased demand. Deforestation is rampant over the world, with the logging industry spurred by the need for disposable goods. Deforestation reduces global biological variety, whether induced by expansion or increasing demand [88]. Many chemicals have been introduced into the soil because of globalization and industrialization, resulting in a wide range of noxious weeds and plants. This hazardous waste has had a tremendous impact on plants by altering their genetic composition [14,89]. This has put pressure on readily accessible land and water supplies. Mountains are being chiseled away in a variety of places to make space for a road or tunnel that will pass through them. Large tracts of bare land have been encroached upon to construct new structures [90]. These improvements may be appealing to people while simultaneously having a harmful impact on the environment [91]. As a result, rising levels of economic globalization use more natural resources, contributing to the deterioration of the environment. It supports the findings of Langnel and Amegavi [92]. Economic growth cannot be achieved without the use of energy, which severely depletes the environment and reduces the possibility of sustainable development. Economic globalization is an unavoidable phenomenon in the development of the world economy.

Sustainable development is positively influenced by URB in all three models used in the study. Our results are supported by the findings of Dogan and Seker [93], according to these studies the negative impact of pollution can only exists for a short period, they argued that an environmental issue that results from industrial production or energy consumption in urban areas may be mitigated by enhanced environmental prudential legislation, technological procedures, and structural changes. Other scholars like [94] contend that urbanization density increases the effective use of public infrastructure (such as transportation and other utilities), reducing energy use and emissions. Planned urbanization can reduce greenhouse gas emissions and air pollution, particularly in the transportation sector. Mass transit can be beneficial. Shorter commuting distances can be achieved in small, well-planned cities [95].

LPOPD shows a negative relation with sustainable development in models 1,2, and 3. These findings imply that high per-capita energy consumption and GHG emissions are the main channels through which a growing population affects the environmental quality (the carbon footprint). These results also demonstrate that the growing population aggravates climatic changes by increasing ecological pressure on natural resources due to the country's high population density and its ongoing rapid growth in urban, coastal, suburban, and ecologically vulnerable zones [96]. According to Birdsall [97] the rise in the population increases the energy demand and deforestation that resulted in carbon emissions and greenhouse gases. Similarly, Ehrlich and Holdren [98], suggested that not just population increase, but also human conduct toward the environment, resource depletion, and consumption of natural resources,

Table 9
Results of wald test for asymmetry.

	EDEXP		KPO		LEC	
t-statistic	6.080	0.000	2.200	0.039	−2.296	0.029
F-statistic	36.963	0.000	4.838	0.039	5.273	0.029
Chi-square	36.963	0.000	4.838	0.028	5.273	0.022

should be considered in tandem with environmental deterioration. Our findings are consistent with the findings of Ponce and Marshall [99],and Adusah-Poku [100] that population expansion or size has a negative impact on carbon emissions or the sustainability of the ecosystem.

Table 9 shows the outcome of the asymmetric effect of positive and negative fluctuations of EDEXP, KPO, and LEC. From the results, it is confirmed that there is an asymmetric relationship between EDEXP, KPO, LEC, and SD. The findings reveal that both had a distinct impact, and the findings are extremely significant.

We also derived asymmetric multiplier effects of education expenditure, knowledge spillover, and energy consumption on sustainable development. Fig. 2 exhibits an asymmetric association between education expenditure on sustainable development while Fig. 3 demonstrates that asymmetries also hold between FDI and sustainable development. Fig. 4 shows the asymmetric relationship between energy consumption and sustainable development. Multipliers graphs confirm that in case of EDEXP and LEC, negative shocks are prominent than positive shocks while in case of KNO, positive shocks are more prominent that negative shocks.

5.4.1. Development FDI on sustainable development

In addition, we also conducted diagnostic analyses such as Jarque-Bera (normality test), LM- Breusch-Godfrey test (serial Correlation), and Breusch-Pagan (Heteroscedasticity) which are presented in Table 10. The χ^2 value of LM and Breusch-Pagan-Godfrey (0.2827 and 0.5625 respectively) shows that there is no problem of serial correlation and heteroscedasticity problems. On the other hand, the results of the Jarque-Bera test (0.9871) show the residual normality of our model. Furthermore, the value of the Ramsey RESET test (0.1819) confirms that our model is correctly specified.

Additionally, we also reported detailed symmetric Granger causality estimates in Table 11. From the resulting outcome, it is clear that most of the variables have unidirectional causality.

The Cholskey impulse response function examines how a single temporal shock to innovations affects endogenous factors like future and present value. Table 12 presents the results of impulse response functions. The results show that EDEXP has an effect in the first, second, and third periods but has a negative effect from the third through the ninth periods. The KNO impact is favourable at all other times, but it is negative in the second, eighth, and tenth periods. Similar to this, LEC has a negative impact throughout the third, fifth, seventh, and ninth periods before changing to a positive impact over the remaining periods.

The results of the Variance decomposition are shown in Table 13. The findings indicated that the most significant variation in environmental sustainability is related to LEC, which accounts for 39% of the other variables. This shows that an increase in consumption of energy has a long-term negative impact on environmental sustainability. In case of URB, ES is significantly affected by URB in period 8 while GLOB in period 10 leads then other variables to change the ES by 9.1%.

5.4.2. Stability test

The CUSUM test identified us to indicate whether the coefficient of the variables is changing systematically or not. CUSUM Square graphs for all three models are shown in Fig. 5. The CUSUMSQ tests show that the blue line for all three models is in between the two red lines which confirms that the models are reliable.

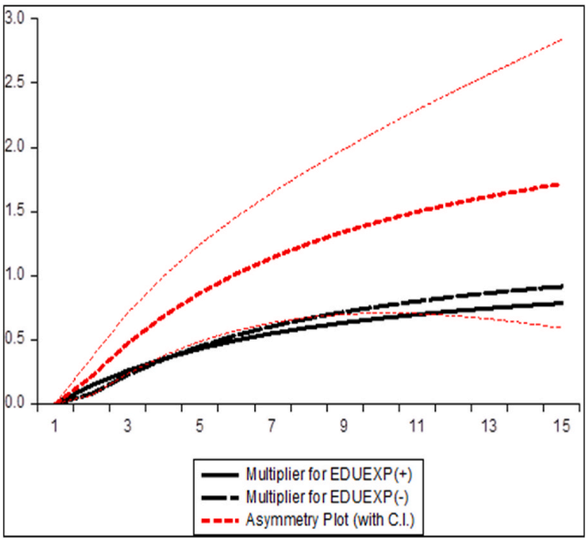


Fig. 2. Asymmetric dynamic multipliers effects of.

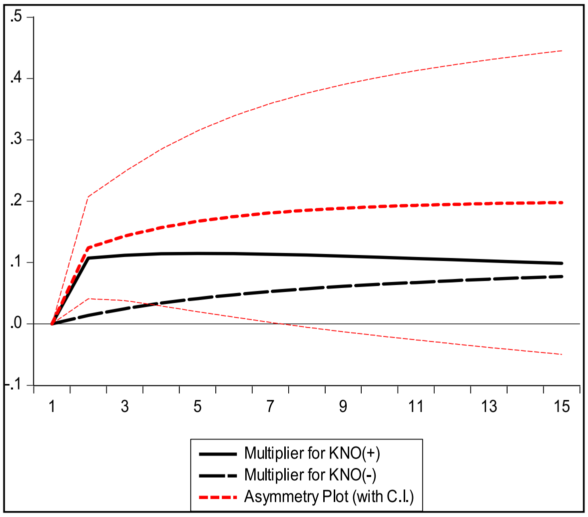


Fig. 3. Asymmetric dynamic multipliers effects of Education Expenditure on Sustainable.

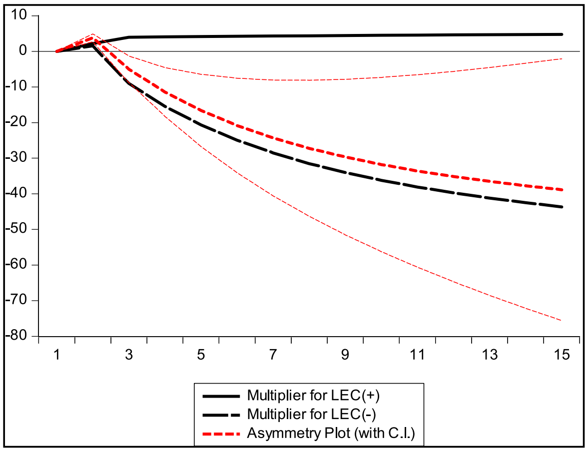


Fig. 4. Asymmetric dynamic multipliers effects of Fuel consumption on Sustainable development.

Table 10
Diagnostic analysis.

	Serial Correlation x^2 (p-value)	Heteroscedasticity x^2 (p-value)	Normality x^2 (p-value)	Model specification x^2 (p-value)
LM test	0.2827			
Breusch-Pagan-Godfrey		0.5625		
Jarque–Bera			0.9871	
Ramsey RESET test				0.1819

6. Conclusion

Environmental degradation can be a barrier to sustainable development because of climate change induced by the usage of fossil fuels and forest fires. CO_2 and greenhouse gas emissions into the atmosphere lead to climate change and, as a result, global warming. Natural resources may suffer as a result of global warming, causing governments and politicians to be worried about how to handle the problem. This study is therefore aimed at examining empirical relationships of knowledge spillover, education expenditure, and energy consumption with sustainable development. Annual time series data spanning from 19 to 20 are employed for empirical investigation. This study employs NARDL techniques in three different models to analyze the impact of these variables along with some other controlled variables including urbanization, population density, and globalization.

According to the NARDL estimate, education investment has a beneficial impact on sustainable environmental development.

Table 11
Pair wise granger causality test result.

Null Hypothesis:	F-Statistic	Prob.
URB ≠ SD	0.284	0.886
SD ≠ URB	3.017	0.034
LEC ≠ SD	3.581	0.017
SD ≠ LEC	1.993	0.122
URB ≠ EDEXP	4.915	0.004
EDEXP ≠ URB	0.060	0.993
LPOPD ≠ EDEXP	2.482	0.066
EDEXP ≠ LPOPD	0.490	0.743
LEC ≠ KNO	3.027	0.034
KNO ≠ LEC	4.203	0.008
LEC ≠ GLOB	3.363	0.022
GLOB ≠ LEC	1.768	0.162
LPOPD ≠ URB	3.115	0.030
URB ≠ LPOPD	2.142	0.101
LEC ≠ URB	1.489	0.231
URB ≠ LEC	2.681	0.051
LEC ≠ LPOPD	0.217	0.927
LPOPD ≠ LEC	2.177	0.097

Table 12
Impulse response of ES.

Period	ES	EDEXP	GLOB	KNO	LEC	URB	LPOD
1	0.044	0.000	0.000	0.000	0.000	0.000	0.000
2	0.030	0.005	−0.011	−0.003	0.026	0.006	0.004
3	0.059	−0.002	0.004	0.001	−0.010	0.001	0.003
4	0.001	−0.004	−0.013	0.000	0.016	0.012	0.007
5	0.038	−0.016	0.013	0.010	−0.048	0.003	0.000
6	−0.048	−0.011	−0.019	0.003	0.011	0.020	0.003
7	0.041	−0.020	0.022	0.013	−0.079	0.002	−0.008
8	−0.080	−0.004	−0.035	−0.005	0.039	0.028	0.000
9	0.093	−0.016	0.033	0.010	−0.104	−0.006	−0.015
10	−0.109	0.010	−0.063	−0.020	0.099	0.037	0.004

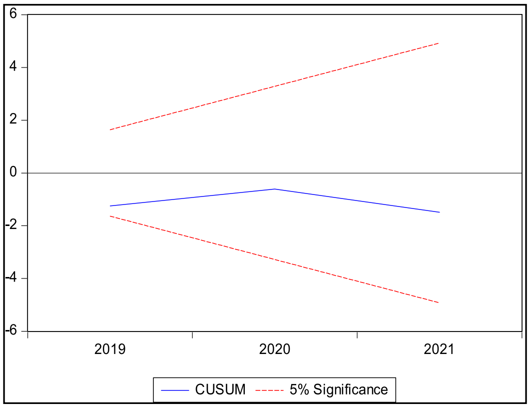
Table 13
Variance decomposition of ES.

Period	S.E.	ES	EDEXP	GLOB	KNO	LEC	URB	LPOPD
1	0.044	100.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.061	76.517	0.556	3.314	0.273	18.092	0.909	0.339
3	0.086	86.088	0.326	1.900	0.167	10.732	0.483	0.303
4	0.090	79.247	0.504	3.880	0.157	13.084	2.288	0.840
5	0.111	63.716	2.312	3.855	0.856	27.153	1.559	0.550
6	0.125	65.142	2.591	5.248	0.717	22.096	3.720	0.486
7	0.157	48.130	3.244	5.236	1.127	39.306	2.362	0.593
8	0.186	52.757	2.351	7.341	0.879	32.357	3.894	0.422
9	0.236	48.172	1.917	6.476	0.713	39.586	2.495	0.641
10	0.289	46.488	1.404	9.120	0.951	38.317	3.270	0.450

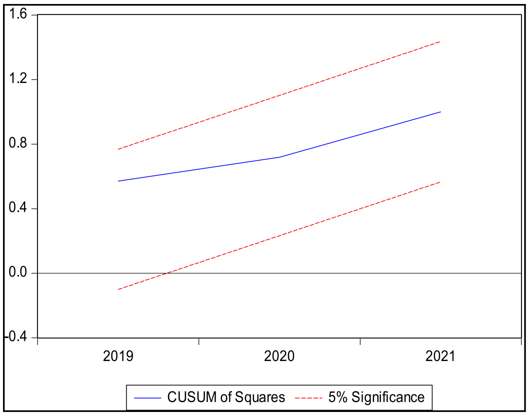
According to the findings of this research, increasing educational expenditures improve the environmental quality while lowering educational expenditure worsens environmental sustainability. Education also contributed to technological innovation besides improving economic growth [35], which later help to find the efficient sources of energy that are being utilized in the production process. The use of these efficient energy sources contributes to lower degradation of environmental quality.

The result of the study explores the positive impact of knowledge spillover on sustainable development. Knowledge spillover can help modernize industrial structures and optimize energy structures, thereby limiting greenhouse gases and carbon dioxide emissions. This positive influence of knowledge spillover on environmental sustainability is achieved through green technology spillovers and resource allocation optimization in the host country.

A rise in energy consumption, on the other hand, has a negative impact on sustainable development, whilst a decrease in consumption has a positive impact on environmental sustainability. The majority of energy demand is met by burning fossil fuels, that had negative environmental consequences. Using fossil fuels, for example, leads in pollution discharges into the atmosphere, which lowers environmental quality. Furthermore, a major portion of our fossil fuel imports have been utilized to generate power, which pollutes the environment.



a



b

Fig. 5. a and b *CUSUM and CUSUMQ graphs.*

The other controlled variables including population density and globalization have a detrimental effect on the environment. However, urbanization shows positive relation with sustainable development.

6.1. Policy recommendations

Because of the findings in our study educational expenditure, knowledge spillover, and urbanization play a significant role in achieving environmental sustainability. However, energy consumption, Globalization, and population growth adversely influence the environment. Considering these results following recommendations are listed that could help in achieving sustainable development by enhancing environmental quality.

1. Educational expenditure offers the best long-term potential to alleviate environmental degradation. Because an educated person recognises the importance of resolving issues such as sustainable development, environmental diversity, and degradation, a youth must be educated towards the level from which they can comprehend environmental legislation and act fast to maintain a sustainable environment. As a result, the government's investment in education must be increased. To ensure that enough individuals benefit from education, education funding and academic institutions should be raised. A well-educated people understand and recognises the need of environmental preservation. As a result, they safeguard it and raise public awareness. The government may take appropriate steps to ensure that education is free for low-income and impoverished individuals.
2. Energy consumption has a negative impact on environmental sustainability due to the generation of electricity and the widespread use of fossil fuels and other non-renewable resources. The use of resources for producing renewable energy, such as wind, solar, and hydel, should therefore be the government's main priority. Utilizing renewable resources will lower production costs and significantly lessen environmental degradation.
3. Because knowledge spillover has a positive and large impact on the environment, policymakers should support environmentally friendly knowledge spillover and prohibit pollution-haven knowledge spillover or knowledge spillover that causes environmental damage. As a result, exporting renewable technologies as a result of FDI inflows is critical. To avoid environmental degradation, the government is considering imposing extra charges upon companies that import non-green technologies.
4. The rapidly rising population is an issue of environmental degradation. Environmental stresses associated with population expansion include biodiversity loss, cutting of forests, air and water pollution, and greater pressure on agricultural land. Massive consumption, the use of natural resources, an increase in economic activity, and the production of waste all contribute to these strains.
5. As a result, population control practices must be implemented by the government. Public education is essential to ensure that people are ecologically aware. The government may try to increase environmental awareness among the public by implementing several promotional strategies. The private organization may also organize events to inform people about ecological issues and the negative repercussions of deforestation and environmental deterioration.

Author contribution statement

Conceived and designed the experiments: Nabila Khurshid; Kashif Ali.
Performed experiments: Nabila Khurshid, Fozia Munir, Jamila Khurshid, Fozia Munir.
Analyzed and interpreted the data: Nabila Khurshid; Jamila Khurshid; Fozia Munir; Kashif Ali.
Contributed reagents, materials, analysis tools or data: Nabila Khurshid, Jamila Khurshid.
Wrote the paper: Nabila Khurshid; Jamila Khurshid; Fozia Munir; Kashif Ali.

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Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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