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The Nexus of Human Capital, Information Communication Technologies and Research and Development Expenditure in Promoting Environmental Sustainability: Does Financial Development Matter?

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ABSTRACT

The present study shows that environmental degradation and environmental sustainability (ES) are two distinct domains of environmental quality. Regrettably, existing researchers interpret the impact of different factors on ES as their findings are based on the explicit measure of the environment (CO_2 or GHG emissions). Therefore, this study contributes to the ongoing environment debate by analyzing the role of human capital (HC), information communication technologies, and research and development expenditures on ES. The study further tests financial development's (FDs) moderating role concerning HC, information communication technologies, R&D expenditures, and ES. The study collects the annual time series data from the panel of four South Asian Economies (Pakistan, India, Sri Lanka, and Nepal) from 1996 to 2018 from WDI and Penn world databases. The findings of DOLS show that HC, information, communication technologies, and R&D expenditures positively contribute to ES and FD, further intensifying the relationship between HC and ES, information and communication technologies, and R&D expenditures ES. The study recommends that increasing HC, information, and communication technologies, R&D expenditures, and FD play a significant role in promoting ES.

Keywords: Human Capital, Information and Communication Technologies, R&D Expenditures, South Asian Economies, Financial Development, Environmental Sustainability

JEL Classifications: Q56, E24, J24, O14, O3, C33

1. INTRODUCTION

Since the 1970s, environmental deterioration (ED) has been the most threatening issue for both developed and developing economies due to its harmful impacts on the global climate. The increased level of carbon emissions (CO_2E) has attracted the attention of different academicians, environmentalists, and policymakers to explore the solutions to deal with different environmental problems at both national and international levels. One well-recognized policy level effort was made through the "Kyoto treaty" to improve the environmental quality (EQ). It is a universal environmental contract signed between the European union and 37 industrialized economies to fight against increased environmental issues. All participants are committed to reducing GHG emissions at the national level by at least 6% from 2008 to 2018 and nearly 18% between 2013 and 2020, using 1990 as a threshold year. Over time, the international authorities have organized many international conferences to reduce GHGE by joint efforts. Meanwhile, in December 2015, 195 nations signed a Paris agreement to adopt the first-ever global and officially obligatory universal environmental deal to set a longer-term objective of restricting the level of global average temperature <1.5°C (Zafar et al., 2019). Consequently, many countries have proposed policies to control the level of GHGE, promote ES, and improve EQ, and hence the debate among different researchers has started.

Many researchers have started exploring the factors that can reduce CO_2E and GHGE in the environment. Many environmentalists mentioned in their studies that ES can be promoted by "internalizing the external effects" via technological progress, R&D expenditures (R&DE), increased knowledge, and substitutability between the traditional and renewable energies (Antonakakis et al., 2017); (Oláh et al., 2020). A stream of researchers collectively solved that reducing the level of GHGE can promote ES. They argued that to minimize CO2E, there is a dire need to promote R&DE. Theoretically, R&D improves economic efficiency, lessens costs, and advances productivity, contributing to ES (Paramati et al., 2021). Particularly, R&D can escalate the effectiveness of renewable energies and advanced technologies by reducing the required raw materials or promoting the efficiency of renewable energy production (Shao et al., 2021). A great share of R&D activities drives towards sustainable economic development, which is beneficial for EQ.

In Addition to R&D activities, human capital (HC) is also considered an important factor that can positively contribute to ES. For instance, educated labor (HC) shows more productivity by using the latest and advanced technologies that less significantly contribute to GHGE. Khan et al. (2021) argued that educated labor is aware of the detrimental effects of outdated machinery and unsustainable method of production; so, they try to avoid the strategies that are harmful to the environment, that resultantly improve the EQ (Wang and Xu, 2021); (Husain Tahir et al., 2021). Like HC, ICTs are another important factor in having significant contributions to the ES. Researchers believe that ICT has altered the process of communication in civilization. Such as, the usage of ICTs in e-business offers an effective means to interact worldwide any time by saving lots of travel and time. It has enhanced accessibility by offering customers the ability to buy online from several websites, limiting physical travel and consequently limiting the level of traffic-generated CO_2 (Nguyen et al., 2020).

The present study also believes that financial development (FD) is a factor that can strengthen the role of HC, ICTs, and R&DE in ES because the financial sector promotes technological advancement by giving access to capital (Kirikkaleli and Adebayo, 2021); moreover, it intensifies R&D activities that successively improve economic activities (Maskus et al., 2012). It helps build infrastructure to stimulate HC (Kinsella et al., 2010). These factors together contribute to the ES. The classical theory also provides the significant theoretical lenses to expect this strengthening role.

1.1. Research Gap and Novelty

When environmentalists, academicians, and policymakers are answering the question of "how to achieve environmental sustainability (ES)?" by using CO_2 as a proxy of ES, a present study comes into the field with an appropriate measurement of ES suggested by (Ganda, 2019) to examine the role of HC, ICTs, and R&DE in ES by taking FD as a moderating factor. We believe that reduction in CO_2E is necessary but not a sufficient solution to promote ES. However, after reviewing the existing literature, this study aspires to address the following shortcomings to the prevailing environment debate. First, the study shows that ED and ES are two distinct domains/dimensions of EQ (Ahmed et al., 2020); (Ganda, 2019). However, to the best of the authors' knowledge, most of the researchers' focus has remained on environmental deregulation, while the field of ES has remained less focused.

Second, the current study notices that researchers are mistaken while interpreting the role of different factors in ES, as their findings are based on an indicator of environmental pollution (i.e., CO_2 emissions). The present study argues that when there is a different measure for the ES, we make conclusions for ES based on CO_2E. Third, the study finds that most researchers interpret the role of HC, ICTs, and R&DE on ES based on the explicit measure of environment, CO_2E. Fourth, the study observes that classical theory provides strong theoretical justifications about the strengthening role of FD in the nexus between HC, ICTs, R&DE, and ES. However, to the limit of our knowledge, the previous researchers have not empirically tested FD's strengthening/moderating role.

As already discussed that CO2 is not an appropriate measure of ES; rather, it is an indicator of environmental pollution. The present study, therefore, believes that there is a need to re-explore the relationship between HC, ICTs, R&DE, and ES by utilizing an appropriate proxy of ES so that the impact of chosen variables on ES becomes more clear in the context of the South Asian States (Figure 1 shows that why we have selected South Asian countries as population). Moreover, the study also incorporates FD as a moderating factor to empirically prove the theoretical implications of the classical theory.

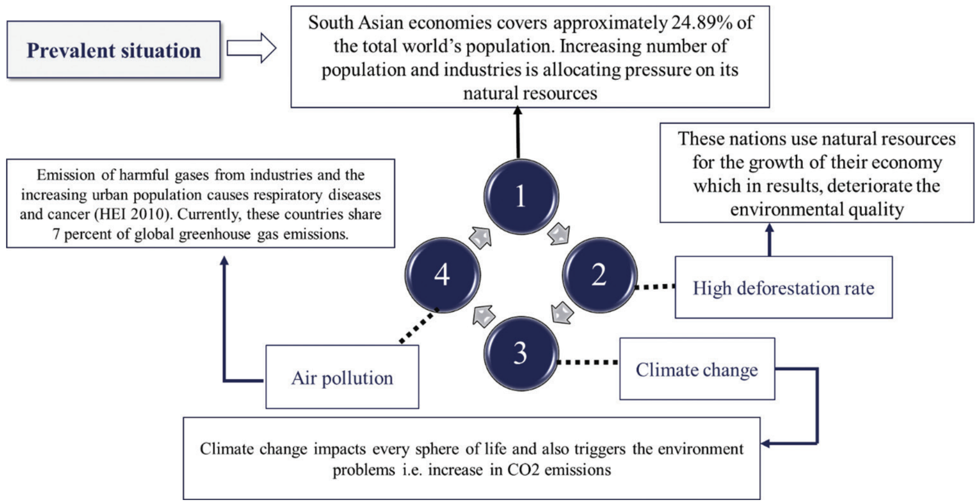
2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1. HC and ES

Several research scholars have conducted their studies on the nexus between HC and environment and indicated the positive relationship between these variables. Researchers argued that HC promotes ES by adopting advanced technologies and increasing productivity (Bashir et al., 2019). Khan (2020) reported the critical role of HC in reducing the level of GHGE. (Wang and Xu, 2021) collected the data of 70 transition economies to estimate the empirical linkage between HC and CO_2E. The study exhibited an indirect link between HC and CO_2E by applying the GMM estimation technique. The study concluded that HC is a pathway towards a low carbon economy which significantly contributes to ES. (Yao et al., 2021) also revealed the significant connection between HC and ES in China as it substantially reduces GHGE. They concluded that HC plays an essential role in improving energy efficiency, making the environment sustainable by reducing GHGE.

Li and Ullah (2021) collected the data from BRICS economies between 1991 and 2019 to explore the association between HC and EQ. The study found that HC reduces CO_2E in South Africa,

Figure 1: Why South Asian Economies? (Author Generated)



Russia, and China. Bano et al. (2018) suggested that environmental deterioration is a critical issue for the Pakistani economy as it results in serious economic problems and concludes a positive relationship between HC and ES. Li and Ouyang (2019) analyzed the dynamic role of HC in reducing CO_2E in the context of China for 1978-2015, with a structural breakpoint of 1992. He applied the ARDL estimation approach and found an "inverted N shape" relationship between HC and CO_2E. He observed a negative (positive) link between HC and CO_2E for 1978-1992 (1992-2015). Yao et al. (2021) also researched the context of China, intending to examine the empirical association between HC and the reduction of CO_2E. Findings exhibited an indirect tradeoff between HC and CO_2E.

The study figures out that most of the researchers make their conclusions about the role of HC on ES based on the explicit measure of the environment (CO_2E). Ahmed, Kousar, Pervaiz, and (Ahmed et al., 2020) argued that ES is different from ED and generally proxied by the Adjusted net savings (excluding certain emission damage), a distinct EQ dimension. Similarly, (Ganda 2019) narrated that CO_2E is not an appropriate measure of ES; rather, it is an indicator of environmental pollution. Hence, the present study proposes a need to conduct more research in the nexus between HC and ES by using its appropriate proxy to get accurate results.

H_1: "There is a significant relationship between HC and ES."

2.2. ICTs and ES

Several studies have examined the influence of ICTs on the environment under different theoretical perspectives. For example, (Cardona et al., 2013) worked under "production theory" theoretical lenses to investigate the empirical linkage between ICTs and EQ. By utilizing Kenya's data, they found a positive impact of ICTs on EQ. They concluded that ICTs increase production efficiency, contributing to sustainable economic progress. (Nguyen et al., 2020) also concluded a direct link between ICTs and EQ. The study indicated that ICTs are related to forming cleaner and environmentally sustainable production processes. Haini (2021) worked for the case of ASEAN economies from 1996 through 2019 and tested the role of ICTs in ES. After applying panel ARDL, the study revealed the significant relationship between ICTs and ES. The study concluded that ICTs expedite online traveling, which resultantly reduces physical traveling and causes a reduction in the level of GHGE, thereby making the environment sustainable.

Similarly, (Avom et al., 2020) also showed a positive connection between ICTs and EQ for Sub-Saharan Africa. They determined that ICTs provide access to smart services and smart agriculture that reduces the CO_2E and improves the EQ. (Cheng et al., 2021) also found a significant relationship between ICTs, growth, and the environment's quality. The study further showed that the economy's financial sector plays a substantial moderating role in the links between chosen variables.

The current study proposes that although ICTs and ES remain a highly debated area among the researchers, to the limit of our knowledge, most research scholars have concluded their findings based on CO_2E and GHGE. Thus there is a dire need to re-explore this nexus by using an appropriate proxy of ES. However, after reviewing the above debate, this study formulates the following hypothesis:

H_2: "There is a significant relationship between ICTs and ES."

2.3. R&DE and ES

Various researchers have attempted to dig out the role of R&DE in improving the EQ. They believed that R&DE plays a crucial role in improving EQ or limiting the ED. (Artha et al., 2021) utilized the data of Austria for 1996-2006, intending to examine the impact of R&DE on the CO_2E. Findings exhibited a negative tradeoff between R&DE and CO_2E. Khan et al. (2021) also supported the encouraging role of R&DEin enlightening the EQ by controlling the level of CO_2E. The findings of the study were based on the empirical evidence of Canada. (Paramati et al., 2021) studied 25 European economies and checked the nexus between R&DE and ES. By utilizing 1998-2014, the study established the positive connection between R&DE and ES. They argued that R&DE endorses environmentally friendly sources of energies and technologies that contribute enough to the reduction of CO_2E, which resultantly promotes ES.

Petrović and Lobanov (2020) gathered data from 16 OECD economies and tested the influence of R&DE on CO_2E. The findings claimed that 1% of the increase in R&DE leads to the reduction of CO_2E by 0.10%-0.16%. Awaworyi Churchill et al. (2019) also examined the R&DE-Environment nexus by using the data of G7 economies. The study applied different "parametric and non-parametric econometric approaches" to estimate the empirical findings. The study results indicated that R&DE has a significant impact on EQ (Shao et al., 2021) also scrutinized the role of R&DE on the level of CO_2E. They tested "how does R&DE contribute to carbon neutrality?". Findings showed that R&DE plays an important role in the reduction of CO_2E. Apergis et al. (2013) also confirmed that R&DE has a prominent influence on the worldwide ecological footprint. In addition, they depicted an indirect connection between R&DE and CO_2E in both developed and developing economies.

The present study found that several scholars have emphasized the role of R&DE in promoting EQ. However, to the best of our knowledge, previous findings were based on the explicit measure of carbon dioxide emission, an indicator of environmental pollution. Therefore, the present study generates a need to re-explore the R&DE and ES nexus by utilizing the appropriate measure of ES. However, after studying the above debate, the study constructs that:

H_3: "There is a significant relationship between R&DE and ES."

2.4. Moderating Role of FD

The importance of FD has been recognized by (Schumpeter, 1911) for the very first time. Schumpeter argued that capital is essential in promoting economic growth and providing sustainable growth. Over time, many researchers recognized the importance of the financial sector. They had started conducting studies on the finance-growth nexus. However, during the 19th century, when environmental deterioration was a threatening peak issue, the researchers have diverted their attention from finance-growth nexus to the finance-sustainability nexus. They had started exploring the role of FD from different angles. Researchers documented that the financial sector promotes technological progress by providing access to the capital (Kirikkaleli and Adebayo, 2021); (Moghadam and Dehbashi, 2018), and on the other hand, it escalates the R&D activities and consecutively improves the economic activities (Maskus et al., 2012); (Hsu et al., 2014).

It also helps build the infrastructure to promote HC (Kinsella et al., 2010). All these factors collectively contribute to the ES. Therefore, the present study proposed that development in the financial sector of an economy plays a strengthening role in the nexus between HC, ICTs, R and R&DE, and ES. To the best of our knowledge, the strengthening role of FD has not been tested by the existing researchers. However, this moderating role is justifiable under the theoretical lenses of economic theory, which states that development in an effective financial system is a prerequisite for sustainable economic growth (Shahbaz et al., 2021). However, reviewing the above works, this study formulates that:

H_4: "There is a significant relationship between FD and ES."

H_{5a}: "FD significantly moderates the relationship between HC and ES."

H_{5b}: "FD significantly moderates the relationship between ICTs and ES."

H_{5c}: "FD significantly moderates the relationship between R&DE and ES."

2.5. Theoretical Framework

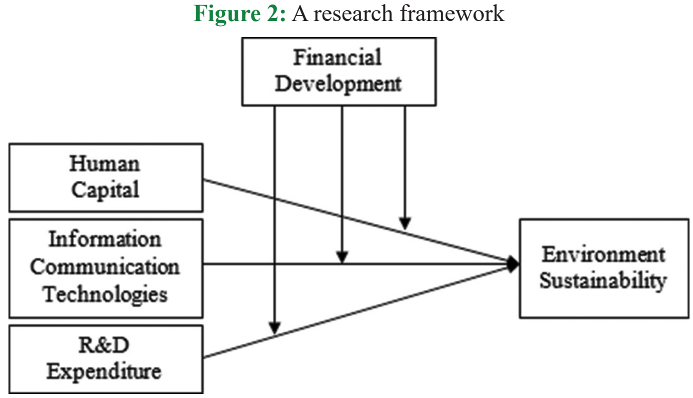
We justify the underpinning linkage among the variables of interest with the help of classical theory. This theory states that sustainable growth increases through the sustainable production of goods and services; this entails technology and human, physical and financial capital (Solow, 1956). The theory argues that technological innovation enhances economic productivity and improves EQ, contributing to less significant GHG emissions (Du et al., 2019). This study strongly believes that HC, ICTs, and R&DE provide the means to access environmentally friendly sources and advanced technologies, which is beneficial for EQ. For instance, educated labor (HC) shows more productivity using the latest and advanced technologies, having less significant contributions in GHGE. Educated labor is aware of the detrimental effects of outdated machinery and unsustainable method of production (Khan, 2020); (Wang and Xu, 2021). ICTs also advance the usage of progressive technologies, which allow people to make "online transactions," which resultantly reduces physical traveling and consequently reduces the level of traffic-generated CO_2 (Nguyen et al., 2020).

Similarly, R&DE also provides access to advanced and updated technologies, renewable machinery, etc., which is advantageous for the EQ and promotes the ES (Petrović and Lobanov, 2020). We further believe that the provision of financial capital or the development in the financial sector strengthens the role of HC, ICTs, and R&DE in ES. The graphical representation of the research framework of the underlying study is displayed in Figure 2.

3. RESEARCH METHODOLOGY

The present study has two main objectives: first, the study plans to investigate the impact of HC, ICTs, and R&DE on ES. Second, it analyzes "either FD plays any strengthening role in the association

Figure 2: A research framework



between HC, ICTs, R&DE, and ES?" The functional form of the econometric model to achieve the study's first (second) objective is presented in equation 1 (2-4). The selection of variables has been made through the trial and error method by dropping out variables to solve the problem of multicollinearity inducing specification bias.

$$ES_{it} = f(HC_{it}, ICTs_{it}, R\&DE_{it}, FD_{it}, u_{it}) \quad (1)$$

$$ES_{it} = f(HC_{it}, ICTs_{it}, R\&DE_{it}, FD_{it}*HC_{it}, u_{it}) \quad (2)$$

$$ES_{it} = f(HC_{it}, ICTs_{it}, R\&DE_{it}, FD_{it}*ICTs_{it}, u_{it}) \quad (3)$$

$$ES_{it} = f(HC_{it}, ICTs_{it}, R\&DE_{it}, FD_{it}*R\&DE_{it}, u_{it}) \quad (4)$$

Where: "ES is environmental sustainability, HC is human capital, ICTs is information and communication technologies, R&DE is research and development expenditures, *i* denotes cross-sections, *t* is time period, and *u* is a stochastic term."

3.1. Data and Variables

The authors collected the annual time series data from the panel of 4 countries in South Asia (Pakistan, India, Sri Lanka, Nepal) between 1996 and 2018 from WDI and Penn world. Four economies (Maldives, Bangladesh, Afghanistan, and Bhutan) were excluded from the sample because of data unavailability. The study uses ES as an outcome, HC, ICTs, and R&DE as explanatory, while FD as a moderating variable by considering the literature's support. Table 1 reports the operationalization of study variables.

3.2. Estimation Procedure

The analysis begins by testing the problem of cross-sectional dependency (CSD), as this problem is very common in panel data because of mutual shocks and unknown factors in cross-sections (Pesaran, 2021). The study applies Breusch and Pagan's (1980) test to diagnose this problem. This is the best practical test to detect the problem of CSD with small-cross sectional units and finite time dimensions (Shahbaz et al., 2021). After this, the study tests stationarity properties of data by employing CIPS. The most common advantage of CIPS is that it tests the stationarity properties under the null hypothesis of "non-stationary" by considering the problem of CSD. After confirming the integrated order, the study employs Westerlund co-integration to analyze the long-run relation. This co-integration approach tests the long-run relationship in the presence of CSD, even for the case of a small sample size. This approach adjusts the dependence across the cross-sections by using "bootstrapped approach" to evaluate the standard errors of four test statistics; *"Gt, Ga, Pt, and Pa,"* out of which two test statistics (Ga and Gt) are group mean statistics while other two test statistics (Pt, and Pa) are panel-mean test statistics. Group means statistics are estimated under the null hypothesis of "non-co-integration" against a comparatively adjustable alternative hypothesis of "co-integration among the panel series in at least one of the cross-sectional units." Whereas panel means statistic is estimated under the null hypothesis of "non-co-integration" against a rigorous alternative hypothesis of "co-integration among the panel series in all the cross-sectional units." Thus, the rejection of the null hypothesis indicates the co-integration relation among the variables of interest. This research uses the following equations to test the co-integration relation among variables.

$$\Delta ES_{it} = \beta_{0i} + \sum_{i=1}^{q} \beta_i \Delta ES_{i,t-i} + \sum_{i=1}^{q} \varphi_i \Delta X_{i,t-i} + \propto_i ECM_{i,t-i} + e_{it} \quad (5)$$

$$\Delta ES_{it} = \partial_{0i} + \sum_{i=1}^{q} \beta_i \Delta ES_{i,t-i} + \sum_{i=1}^{q} \varphi_i \Delta X_{i,t-i} + \propto_i ECM_{i,t-i} + e_{it} \quad (6)$$

$$\Delta ES_{it} = \alpha_{0i} + \sum_{i=1}^{q} \beta_i \Delta ES_{i,t-i} + \sum_{i=1}^{q} \varphi_i \Delta X_{i,t-i} + \propto_i ECM_{i,t-i} + e_{it} \quad (7)$$

$$\Delta ES_{it} = \gamma_{0i} + \sum_{i=1}^{q} \beta_i \Delta ES_{i,t-i} + \sum_{i=1}^{q} \varphi_i \Delta X_{i,t-i} + \propto_i ECM_{i,t-i} + e_{it} \quad (8)$$

Where: "ES is environmental sustainability, X is a vector of independent variables, β_{0i}, ∂_{0i}, α_{0i}, and γ_{0i} are intercepts $\propto_i$ is the speed of adjustment, on which the decision of rejection or acceptance of null hypothesis is based."

After testing the co-integrating relation, the study proceeds with dynamic ordinary least squares (DOLS) to test the hypothesized relationships. The reason to proceed with DOLS is that OLS provides inefficient results in the presence of co-integration. DOLS is a continent approach that provides efficient results in co-integration and deals with many econometric errors such as endogeneity, CSD, and heterogeneity. It also has a built-in property to deal with small sample biasness.

4. EMPIRICAL RESULTS

Table 2 reports the variables' descriptive measures, the significant probability values of Jarque-Bera indicate the presence of CSD. Results of Pesaran CSD are presented in Table 3, confirming that problem of CSD exists in the data (shown by significant P-values). Table 3 also exhibits the results of the correlation matrix used to detect the problem of multicollinearity. Results demonstrate that the data for the present study are free from multicollinearity as the coefficient of correlation between two explanatory variables is <0.80.

Table 1: Measurement of variables

Variables	Measurement	References
Environmental sustainability	"National adjusted net savings (excluding particular emissions) % of GNI"	(Ahmed et al., 2020)
Human capital	"HC Index, based on years of schooling and returns to education."	(Asghar et al., 2020)
Information and communication technologies	"Individuals using the internet (% of the population)"	(Lu, 2018)
Research and development expenditures	"Research and development expenditure (% of GDP)"	(Shahbaz et al., 2021)
Financial development	"Domestic credit to the private sector (% of GDP)"	(Ahmed et al., 2020)

The study applies CIPS to analyze the static properties of the data. Results are reported in Table 4, showing that all the variables are non-stationary at level (as shown by insignificant test statistics). At the same time, they become stationary at the first difference by rejecting the null hypothesis of "non-stationary series" at the level of 1%.

Westerlund co-integration test is the recommended test when all the variables are integrated of order 1; I (1) in the presence of CSD. Results are reported in Table 5, which shows a significant co-integrating relation among the variables of interest.

Table 6 presents the results of DOLS, which shows that the coefficient of HC (11.8077) in model 1 indicates the positive relationship between HC and ES. Result states that a 1-unit increase in HC results in an increase of 11.8077 units in ES at the level of 1%. The coefficient of HC in models 2-4 also reveals similar findings. 1st hypothesis of the study is, therefore, accepted. The interaction term HC*FD in model 2 shows that the positive connection between HC and ES strengthens when FD is incorporated as a moderating factor in the model. This is so because when the study incorporates FD as a moderating factor in model 2 to test the combined effect of HC and FD on ES (shown by the interaction term of HC*FD), the coefficient of this combined effect appears to be more prominent as compared to the main effect. Thus, hypothesis-5a of the study is also accepted. The coefficient of ICTs in model 1 (3.8770) indicates that ICTs positively contribute to the ES. Result exhibits that 1-unit inclination in ICTs leads towards an increase of 3.8770 units in ES. The coefficient of ICTs in models 2-4 also reveals a positive affiliation between ICTs and ES. Thus, the 2nd hypothesis of the study is acknowledged. However, this positive affiliation between ICTs and ES is significantly influenced by FD, as the interaction term of ICTs*FD in model 3 appears to be higher in terms of its magnitude and significance, which indicates that FD intensifies the relation between ICTs and ES. Hence, hypothesis-5b is supported.

The coefficient of R&DE in model 1 (16.0242) exhibits a positive connection between R&DE and ES at a 1% level of significance.

Table 2: Descriptive statistics

Particulars	ES	FD	HC	ICTs	R&DE
Mean	19.8097	36.8898	1.9807	6.9978	0.4081
Median	19.8861	33.1514	1.7997	5.1200	0.2460
Maximum	42.0820	69.8408	2.8966	21.4035	0.8587
Minimum	6.4690	15.3860	1.3541	0.0045	0.0998
Std. Dev.	9.0674	13.6829	0.4707	6.6525	0.2892
Skewness	0.6721	0.3792	1.0374	0.6547	0.2577
Kurtosis	3.3468	2.1874	2.7904	2.1834	1.2495
Jarque-Bera	4.5780	2.9348	10.3291	5.6557	7.9081
Probability	0.0013	0.0305	0.0057	0.0591	0.0191

Table 3: Correlation matrix

Variables	Peseran CD	ES	FD	HC	ICTS	R&DE
ES	9.3745*	1				
FD	6.7374*	0.1017	1			
HC	7.0026*	0.0312	0.0983	1		
ICTS	7.2431*	0.4343	0.6373	0.2373	1	
R&DE	9.0174*	−0.1548	0.1289	−0.1861	−0.1095	1

*Denotes significant at 1% and shows the presence of cross-sectional dependency

Table 4: CIPS unit root test

Variables	Level		First Difference		Order of Integration
	Without Trend	With Trend	Without Trend	With Trend	
ES	−1.3763	−1.3428	−3.7557*	−3.2664*	I (1)
FD	−1.5684	−1.6634	−4.0264*	−4.9365*	I (1)
HC	−1.2376	−1.2244	−4.4766*	−5.2261*	I (1)
ICTs	−1.0937	−1.0335	−3.2974*	−3.0027*	I (1)
R&DE	−1.2364	−1.3344	−2.9964*	−3.5374*	I (1)

*Shows the level of significance at 1%

Table 5: Westerlund co-integration test

Model 1	Gt	Ga	Pt	Pa	Decision
Statistic	−5.2655**	−5.2854***	−4.3752***	−5.5484***	Co-integration exists
R.P.V	0.0352	0.000	0.0004	0.000	
Model 2	**Gt**	**Ga**	**Pt**	**Pa**	
Statistic	−2.3854*	1.2845	−4.2442***	−4.2745***	Co-integration exists
R.P.V	0.0735	0.2238	0.0000	0.0011	
Model 3	**Gt**	**Ga**	**Pt**	**Pa**	
Statistic	1.3745	−4.2767**	−3.9927**	−4.2745***	Co-integration exists
R.P.V	0.8374	0.0462	0.0453	0.0000	
Model 4	**Gt**	**Ga**	**Pt**	**Pa**	
Statistic	0.1272	−3.3745***	−3.2874***	−7.8331****	Co-integration exist
R.P.V	0.2223	0.0017	0.0000	0.0000	

*,** and *** shows the significance at the level of 10%, 5%, and 1% respectively

Table 6: Panel dynamic ordinary least square

Variables	Model 1: ES	Model 2: ES	Model 3: ES	Model 4: ES
Constant	2.9364**	1.8263**	0.5234*	0.1173**
HC	11.8077***	16.8064***	10.7739**	11.4073***
ICTS	3.8770**	5.1081*	9.0933**	9.2247**
R&DE	16.0242***	9.8278**	10.8916***	17.1481***
FD	1.0894***	--	--	--
HC*FD	--	24.2432***	--	--
ICTs*FD	--	--	11.7345***	--
R&DE*FD	--	--	--	25.8345***
R^2	0.7655	0.8045	0.8227	0.8832
Adj. R^2	0.7563	0.7919	0.8112	0.8683

*,** and *** shows the significance at the level of 10%, 5%, and 1% respectively

Result states that a 1-unit rise in R&DE results in 16.0242 units in ES. The coefficient of R&DE, reported in models 2-4, also reveals similar findings. Thus, the 3rd hypothesis is sustained. The affiliation between R&DE and ES is strengthened by incorporating moderator FD, as the interaction term of R&DE*FD in model 4 is greater in magnitude than the main effect on ES. Hence, hypothesis-5c is retained. The coefficient of FD in model 1 (1.0894) reveals a positive link between FD and ES which indicates that 1-unit of an upsurge in FD tends to rise ES by 1.0894 units. The coefficient of FD in models 2-4 also presents the same results. The hypothesis-5d is also accepted. The value of adjusted R^2 in model 1 shows that 75.63% variation in ES is collectively explained by HC, ICTs, R&DE, and FD. Comparing this value with model 2-4, the magnitude of Adjusted R^2 increases, confirming the significant moderating role of FD.

5. CONCLUSION

Environmental deterioration is the most threatening issue for both developed and developing economies due to its harmful impacts on the global climate. The increased level of carbon releases has attracted the attention of different academicians, environmentalists, and policymakers to explore solutions to deal with different environmental problems. The present study also contributes to the current environmental debate by providing crucial solutions to environmental issues. At the crucial period, when different environmentalists, academicians, and policymakers are answering the question of "how to achieve ES?" by using carbon emissions as a proxy of ES, the present study comes into the field with an appropriate measurement of ES to examine the impact of HC, ICTs, and R&DE on ES by incorporating FD as a moderator. We believe that a reduction in the level of CO_2E is necessary but not a sufficient solution to promote ES. We have collected panel data of four South Asian Economies (Pakistan, India, Sri Lanka, Nepal) for 1996-2018.

The findings of DOLS show that HC, ICTs, and R&DE positively contribute to the ES and FD, further intensifying the relation between HC and ES, ICTs and ES, and R&DE and ES. Results of the study are supported by prior studies (Bashir et al., 2019); (Khan, 2020); (Haini, 2021); (Artha et al., 2021); (Shao et al., 2021) classical theory. However, this moderating role is justifiable under the theoretical lenses of economic theory, which states that development in an effective financial system is a prerequisite for sustainable economic growth (Shahbaz et al., 2021).

The study recommends that the Government of South Asian economies increase spending on R&D to promote ES. It will improve the affordability of the renewable of environmentally friendly technologies having less significant contributions to the level of GHGE. The study further suggests that South Asian economies should bring more innovations in their energy sector to reduce GHGE. R&D, along with proper policy thresholds, is also required in the ICTs sector to reduce CO_2E. We also recommend introducing projects like green ICTs as an alternative to expand energy efficiency, which will promote ES. The spending on R&D tends to be an efficient tool to limit ED and promote ES. In addition to this, the study suggests that the Government of South Asian economies should revise the budget for education as the educated civilization is the strength of a nation, and it contributes well to the sustainable economy. These educated minds can control the environmental conditions of South Asian economies because they favor the adoption of advanced, innovative, and energy-efficient technologies. Moreover, South Asian economies should organize awareness and training programs about the threatening issue of carbon emissions to make development projects a focal point in the future.

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