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RESEARCH ARTICLE

The impasse of energy consumption coupling with pollution haven hypothesis and environmental Kuznets curve: a case study of South Asian economies

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Abstract
This study investigates the role of energy consumption in environmental degradation and checks the validity of the environmental Kuznets curve (EKC) and pollution haven hypothesis (PHH) for the South Asian economies. The model is also controlled for population growth. The dynamic panel data model is estimated through Fully Modified Ordinary Least Square (FMOLS) rigorously. The results reject the possibility of the existence of EKC but ensure the prevalence of PHH. The study suggests that the South Asian countries should focus on attracting clean foreign investment, whereas the renewable energy production is critical for climate change mitigation. The study also stresses the financial institutions' active role in providing easy loans for promoting research and development in environmentally friendly production practices.

Keywords Environmental degradation · Foreign direct investment · FMOLS · Non-renewable energy consumption

Jel Classification F18 · F64 · K32 · O44

Introduction

Environment, energy, and economic growth are imperative components for the development of a country, wherein the role of foreign direct investment (FDI) is critical in developing economies. However, the phenomenon of shifting production from developed to developing countries due to the availability of cheap labor, abundant natural resources, and flexible environmental laws has raised serious concerns about climate change. According to IEA (2017), energy is a golden thread that connects equity, economic growth, and sustainability. It also highlights the importance of access to energy for achieving Sustainable Development Goals (SDGs). The FDI host countries predominantly rely on thermal energy for production. So, the idea of cleaner production is compromised at the cost of environmental degradation. In this perspective, the environmental Kuznets curve (EKC) and pollution haven hypothesis (PHH) have remained a matter of concern among international development practitioners, academicians, and policymakers.

Since the seminal work by Walter and Ugelow (1979) on PHH, many researchers such as Conrad (2005); Kheder and Zugravu (2008); Al-mulali and Tang (2013); Tang (2015); Zhang (2015) have devoted their efforts to look into its theoretical and empirical underpinning and triumphed effective results. Given that climate change and global warming are the most important issues for the environment and cleaner production, there is a need to deeply look into the environmental aspects of FDI and Gross Domestic Production (GDP). The relocation of China's industry through its Belt and Roads initiative (BRI) makes the South Asian countries important to focus on which are already vulnerable to environmental degradation and climate change.

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For instance, fossil fuel consumption stands at 73.8% in Bangladesh, 73.6% in India, 61.6% in Pakistan, and 50.5% in Sri Lanka that has risen significantly since 1991. On the other hand, CO_2 emissions from electricity and manufacturing are also increased substantially during the same period. It is 69.2% in Bangladesh, 80% in India, 57.5% in Pakistan, and 46.7% in Sri Lanka (World Bank 2019). Furthermore, both the indicators are also strongly correlated with more than 87% correlation in each country. Basic understanding of data makes the South Asian countries an interesting case to look into greater detail. Climate change is now a bigger challenge for the region, whereas these countries are also the signatory of the Paris agreement. The evidence on the influx of FDI on CO_2 emissions has not transpired accord. Keeping in view the gap in the literature, this study aims to investigate the validity of EKC and PHH for South Asian countries through vigorously handing data and methodology aspects. Based on findings, this study emphasizes the need to strengthen environmental laws, sustainable energy solutions, and cleaner production practices.

Sustainable economic growth and preserving the environment are at the core international development agenda. Environmental deterioration increases apprehensions about global warming and climate change (Salahuddin et al. 2019; Kasman and Duman 2015**)**. The term 'sustainable growth' was used in the Brundtland Report developed by the World Commission on Environment and Development in 1987. It indicates a process of development that puts efforts into optimum use of available resources without harming future generations' resources. It undertakes environmental concerns and growth (WCED 1987). Economic growth significantly contributes to environmental degradation, whereas the prime source of capital financing is FDI. It stimulates the growth process by providing advanced technology and spillover effects. FDI also generates productivity gains and introduces new managerial skills (Lee 2013). The past two decades' rapid increase of FDI inflows poses some questions on its cost and related benefits for both academicians and policymakers. Technological improvement may have dual effects, simultaneously affect economic growth and environmental quality.

Environmental quality is treated as a normal good, so its demand rises with the buildup in earnings. Only a negligible amount is used to spend on environmental goods at the early stage of development. After the industrialization process has fastened, the demand for environmental goods and budget allocation is increased. When GDP grows continuously and reaches some threshold level, its typical outcome is a pollution reduction. The combined effect of this improvement in growth carries an inverted U-shaped relationship with pollution, referred to as EKC. CO_2 emissions are positively related to the GDP and other growth factors before reaching a threshold level. However, in the context of the EKC framework, it is also important to take into consideration the theoretical underpinning for developing the model. Otherwise, it gives a spurious understanding of the inverted U-shaped relationship between environmental degradation and GDP.

Followed by the trade liberalization policy in the 1970s, the last four decades witnessed a drastic increase in FDI net inflows that remained a key element for economic development (Te-Velde and Bezemer 2006). In early 1980, worldwide per capita FDI was US$ 7.74, and during 1996–2000 it increases up to US$ 126.37. This increase has a significant effect on the growth of host countries. However, during the financial crises (2006–2010), annual FDI goes down. Overall, the net FDI inflows are increased from 10.17 billion USD in 1970 to 1.95 trillion USD in 2017 (World Bank 2019). From 1976 to 2011, the per capita energy use is increased from 1547.50 to 1917.98 kg of oil equivalent per capita (IEA 2017).

FDI inflows have been increased in the last two decades in developing countries. FDI may generate positive externalities by introducing advanced technology along with negative externalities (Bosworth et al. 1999; Alfaro 2003; Bustos 2007; Ndikumana and Verick 2008). Developed countries prefer to invest in developing economies to benefit from weak environmental laws, economies of scale, known as the "industrial flight hypothesis", and foreign companies install up-to-date technology and provide better management services. According to the pollution halo hypothesis, FDI that originated from developed to developing countries hurts environmental quality. Another argument is the installation of outdated technology, according to PHH.

Two channels, economic growth and technological progress, are critically important through which FDI can impact CO_2 emissions (Sun et al. 2017). FDI, if accompanied by technology, influences the environment through the scale and structure of the host country. In the case of China, significant evidence is available which shows that FDI inflows are significant contributors to economic growth (Wei and Liu 2001; Yao and Wei 2007; Whalley and Xian 2010). For developing countries, FDI inflows are vital for triumphing growth in the short run. Capital accumulation can bring clean technology, spillovers, productivity gains, and new managerial skills (Lee 2013). According to Jaffe et al. (2002), technological progress can sway CO_2 emissions either positively or negatively. Therefore, empirical verification of the PHH needs to include both of these channels. It also requires investigating the theoretical relationship between CO_2 emissions and the economy that is well characterized in EKC.

The impact of technological progress in a country is dependent on the path, i.e., it depends on whether FDI comes with the clean technology and follows the same path or otherwise (Acemoglu et al. 2012; Omri et al. 2014) whereas it is still inconclusive for the South Asian region. If FDI brings pollution-intensive technologies or focuses on natural resource extraction without compensation, then it causes environmental degradation and compromises cleaner production. The reliance of developing countries on fossil fuels to produce electricity is one major source of CO_2 emissions that resulted in climate change (Callan et al. 2009; Wu and Chen 2017; Shao et al. 2019). Therefore, a much deeper understanding is required that cannot be noticed by investigating the nexus among environment, FDI, energy consumption, and economy.

The literature mostly employs spatial econometric models, input-output models, or granger causality (Dietzenbacher and Mukhopadhyay 2007; Apergis and Payne 2009; Lu et al. 2017). Furthermore, it is hard to find any concrete insight while working in a single country because environmental degradation, energy consumption, and climate change are appropriate to study at the regional level. It is also important to highlight that focusing on CO_2 emissions, economic growth, and FDI without controlling for energy consumption can only give spurious results without any representative implications. Therefore, this study's contributions are twofold; first, the study focuses on a panel of South Asian countries, whereas a rigorous econometric estimation procedure is adopted. For instance, all the variables are checked for the order of integration, and then the panel cointegration test is employed. Afterward, the study used the Fully Modified Ordinary Least Square (FMOLS) method. By doing so, the study gets lead over the literature by appropriately handling the problem of serial correlation and endogeneity, i.e., it includes heterogenous cointegration (Phillips and Hansen 1990; Pedroni 2000; Hamit-Haggar 2012; Ozcan 2013). Second, the study provides evidence (employing data for the period 1990 to 2018) on the nexus among environmental degradation, economy, FDI, and energy consumption within the same model by focusing on the very neighboring region of China (four South Asian countries; Pakistan, India, Bangladesh, and Sri Lanka). It is worth considering given BRI and the already increasing environmental degradation.

Following the introduction, the requisite details about the empirical model, research methodology, and data description are given in the "Research methodology " section. The results are analyzed in the "Research methodology " section, whereas the "Conclusion" section concludes the study by sharing policy recommendations.

Research methodology

This section provides a detailed description of the empirical model in the light of literature for underpinning the theoretical basis. Then, all the steps followed for estimating the model starting from unit root test, Cointegration test, and FMOLS estimation with their justification and description.

Empirical model

Three constituents in the literature emphasize the relationship between FDI, economic growth, and the environment. The first strand emphasizes the soundness of the non-linear relation between environmental degradation and economic growth. This hypothesis forecasts economic development as an explanation for environmental issues without policy involvement (Grossman and Krueger 1991). According to Reibstein (2008), the sustainomics green growth hypothesis is key for objective economic growth with low pollution. Munasinghe (2010) explained how the tunnel effect contributes to developing nations reaching a target growth rate by maintaining low pollution. However, empirical outcomes are questionable. For instance, Selden and Song (1994) and Grossman and Krueger (1995) find EKC to be valid, whereas the results of Holtz-Eakin and Selden (1995) contradict this finding. Friedl and Getzner (2003) find an "N-shaped curve", and Saboori et al. (2012) examined causal links between income and CO_2 emissions and found mixed results. Second, strand examines the relationship between economic growth and FDI inflows by Hermes and Lensink (2003), Ekanayake et al. (2003), Nguyen (2007), Batten and Vo (2009), Tsang and Yip (2007), Anwar and Nguyen (2010). Few of them found a causal relationship between GDP and FDI, whereas others found no causal relationship. The third strand aims to investigate the link between FDI inflows and CO_2 emissions. Many studies, including Smarzynska and Wei (2001), Xing and Kolstad (2002), Eskeland and Harrison (2003), Pao and Tsai (2010), and Zhang (2011) find evidence in favor of the pollution haven hypothesis.

The above-related literature illustrates that FDI is necessary for economic growth, and in return, FDI may have negative impacts on environmental quality. The environment–FDI–growth relationship is investigated for the feedback hypothesis, the unidirectional hypothesis, and the neutrality hypothesis. According to Lee (2013), Ang (2008), and Jaunky (2011) the relation between CO_2 emissions and economic growth is unidirectional. Tsai (1994), Halicioglu (2009), and Soytas and Sari (2009), while examining the feedback hypothesis, witnessed a bidirectional relation. Richmond and Kaufmann (2006) fail to find any relation among FDI, economic growth, and CO_2 emissions. Coondoo and Dinda (2002) and Apergis and Payne (2009) show mixed results causal relationship between income and CO_2. FDI has been originated in both polluted and non-polluted sectors and contributes to boosting growth but with certain compromise on the environmental quality.

Many studies have empirically investigated the impact of per capita GDP, FDI, per capita energy consumption (PCEC) on environmental degradation (e.g., Omri et al. 2014; Beak and Koo 2009; Pao and Tsai 2010). These studies have taken the following algebraic form of an empirical model.

$$lnCO2_{it} = \alpha_1 + \alpha_2 lnGDP_{it} + \alpha_3 lnFDI_{it} + \alpha_4 lnPop_{it} + \alpha_5 PCEC_{it} + \varepsilon_{it} \quad (1)$$

Where FDI represents foreign direct investment inflow, economic growth is measured by a change in real GDP. However, some studies have used per capita real GDP instead of GDP in their empirical studies because per capita GDP gives the true representation of the individual behavior towards emission (e,g., Agarwal 2012; Choe 2003; Li and Liu 2005). The literature terms the non-linear relation between environmental degradation and per capita GDP as EKC that can be captured by introducing the square of per capita GDP into the empirical model. As an interesting fact, it is critical for developing a model that is rigorous both theoretically and empirically to yield valid results. The study has taken the lead over the literature to capture the PHH by introducing the square of FDI as an independent variable. By doing so, both the linear and non-linear relationship between environmental degradation and FDI is captured efficiently. The third important aspect is to complement the model by including per capita energy consumption for understanding the individual behavior and the significance of fuel mix to deal with environmental degradation. Furthermore, investigating the PHH without complementing it with per capita energy consumption can be misleading because of the regression equation's spurious nature.

PCEC, along with FDI and per capita GDP, is used by Linh and Lin (2014), Khan et al. (2014), and Tamazian and Rao (2010), whereas Liu et al. 2015 have used total population in the model. In some studies, it is found that the immediate impact of FDI is to degrade the environment in the initial phase of economic growth, but once per capita GDP reaches the threshold level, the effects on the environment start falling (Badri and Parvizkhanlu 2014; Aliyu 2005; Levinson and Taylor 2008; Eskeland and Harrison 2003). Following Javid and Sharif (2016), Nasir and Rehman (2011) and Nasir et al. (2019) along with others, this non-linear relationship between per capita GDP and pollution is named EKC that is captured by introducing the squared term of per capita GDP.

$$lnCO2_{it} = \beta_1 + \beta_2 lnPCGDP_{it} + \beta_3 lnPCGDP^2{}_{it} + \beta_4 lnFDI_{it} + \beta_5 lnFDI^2{}_{it} + \beta_6 lnPop_{it} + \beta_7 PCEC_{it} + \varepsilon_{it} \quad (2)$$

where β's shows regression estimators. Following Badri and Parvizkhanlu (2014), the validity of the existence of the non-linear relationship of EKC is checked by including both FDI and its square. Energy consumption is included in the model because energy consumption may harm environmental quality. So the expected signs of β's are, $\beta2 > 0$, $\beta3 > 0$, $\beta4 < 0$, $\beta5 > 0$ and $\beta6 > 0$.

Panel unit root and co-integration test

The panel unit root tests are applied to examine the stationarity of variables, where the null hypothesis is that there is a unit root. When there is a panel, it is essential to check the cross-sectional dependency before applying the unit root test (Ulucak and Khan 2020). Otherwise, the results are not reliable (Pesaran 2004). Three cross-sectional dependency tests are Friedman Chi-square, Pearson CD Normal, and Pearson LM Normal. The selection of unit root test(s) depends on the presence or absence of cross-sectional dependency, wherein the Covariate Augmented Dicky Fuller test (CADF) is one among the candidate tests.

Based on unit root results, the Johnsen Cointegration test is used to check the cointegration in panel series. According to Maddala and Wu (1999), advance panel cointegration tests are more useful than the traditional Pedroni (1997, 1999, 2004), and these techniques are developed to investigate the long-run relationship between series. In the present study, Pedroni and Kao residual co-integration tests are used. Both of the tests are built on the residual-based two-step cointegration tests proposed by Engle and Granger (1987). If cointegration exists among the variables, then FMOLS is the most appropriate technique for efficient estimators instead of OLS.

Econometric methodology

When the integration of the variables is exclusively ordered, the OLS estimator does not give useful estimates. In this case, FMOLS developed by Pedroni (2001) sort out this problem and calculate the values of long-run estimates. The FMOLS technique provides estimates consistently. The panel FMOLS estimate Eq. (2) and $y_{it} = y_{i,t-1} + e_{it}$. The innovating vector $\omega_{it} = (\mu_{it}, e_{it})'$ is I(0) with asymptotic long-run covariance vector Ω is defined as follows:

$$\Omega_i = \begin{bmatrix} \Omega_{11i} & \Omega_{12i} \\ \Omega_{21i} & \Omega_{22i} \end{bmatrix}$$

The auto covariances vector, Γ_i, and $x_{it} = (y_{it}, z_{it})$ is I(1) and y_{it}, z_{it} are cointegrated. The panel FMOLS estimators for the coefficient β are defined as follows:

$$\widehat{\beta} = N^{-1} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} y_{it} - \overline{y} \right) \left(\sum_{t=1}^{T} y_{it} - \overline{y} \right) z_{it}^{*} - T \acute{\eta}_i \quad (3)$$

where,

$$z_{it}^{*} = (z_{it} - \overline{z}) - \frac{\widehat{L}_{21i}}{\widehat{L}_{22i}} \Delta y_{it}, \quad \acute{\eta}_i \equiv \acute{\Gamma}_{21i} + \widehat{\Omega}_{21i}^{0} - \frac{\widehat{L}_{21i}}{\widehat{L}_{22i}} \left(\acute{\Gamma}_{22i} + \widehat{\Omega}_{22i}^{0} \right)$$

and $\widehat{L}_i$ is a lower triangular decomposition of $\widehat{\Omega}_i^{0}$.

Data and variable description

In the present study, we use CO_2 as the dependent variable, whereas FDI, per capita energy consumption, per capita GDP, and population are used as independent variables. The data is taken from the World Development Indicators database of the

World Bank from 1990 to 2017 for all four countries: Bangladesh, India, Pakistan, and Sri Lanka.

Results and discussion

This section offers the empirical analysis of PHH and EKC for four major South Asian economies. As a first step, this section tests the cross-sectional dependence for selected South Asian countries that is a preliminary step to decide the appropriate unit root test. Then, after discussing the results of the unit root test, Pedroni and Kao residual co-integration test is applied and analyzed. The results reveal that the data set used in the study has cross-sectional independence, all the variables are found integrated of order one, and there exists a long-run relationship among the variables. After evaluating the preliminary tests, FMOLS results are analyzed to provide insight into the long-run elasticity wherein CO_2 emissions conform to the dependent variable.

Given the fact that working on environmental degradation wherein energy is taken as a source, limits the research to preferably focusing on panel data to study the regional outlook. The panel data approach allows for inclusive econometric analysis for small data sets. Furthermore, it is beneficial because of having less collinearity, more degree of freedom, controlling heterogeneity, the adjustment speed to changes in economic policy, identification efficiency, and measuring the economic issues (Baltagi 2005). However, it is important for panel data studies to reconnoiter the cross-sectional dependence at the first stage so that the estimation procedure is planned accordingly. Among the candidate tests, Pesaran (2004) scaled LM test, Pesaran (2004) CD test, and Friedman (1937), Chi-square test is employed. Pesaran (2004) LM test is best suited for large time and cross-sectional settings, whereas the Pesaran (2004) CD test is appropriate for small-time series and cross-sections. Results in Table 1 reveals that cross-sectional dependence does not exist. Therefore, the estimation can be proceeded, keeping in view the independence of cross-section.

Keeping the cross-sectional independence, CADF, suggested by Hansen (1995), is applied to test for the panel unit root. The CADF test is selected for three reasons. First, it is feasible for power gains in case of inferior size performances, as simulations reported by Elliott and Jansson (2003). Second, due to the familiarity of its framework with that of the ADF test, the computational burden relevant to *P*-values is simple. Third, it presumes that economic phenomena are not univariate in the real world and that the use of appropriate information leads to precise and efficient results. Moreover, the unit root test is required to check the order of integration of the variables, so that decision on whether to move for the Cointegration test or not is made. The results in Table 2 do not reject the unit root in all variables at a level, whereas all the variables become stationary at the first difference even at 1% level of significance. Therefore, it is established that all the variables are integrated of order one, that is, I(1), and the Cointegration test can be applied. In case Cointegration exists, then long-run relation can be modeled through employing FMOLS.

For the purpose to check the cointegration, Pedroni (2004) and Kao (1999) tests are used because of their suitability in the presence of cross-sectional independence. Otherwise, Westerlund (2007) could have been preferred. The results of the Pedroni test, in Table 3, confirm the existence of cointegration in two out of four panels at a 1% level of significance. Further, two out of three group tests also indorse the aura of panel cointegration at a 1% significance level. On the other hand, the Kao test also confirms the existence of panel cointegration at a 1% significance level. Therefore, the estimation can be pursued without transforming the variables into the first difference. There is no chance of a spurious relationship identified by estimating the long-run elasticities by employing FMOLS.

OLS estimators failed to provide efficient estimators in the presence of co-integration among variables. In that case, FMOLS is the most appropriate technique for acquiring efficient estimators. It is also helpful to remove the problem of heterogeneity and endogeneity. Two variants of the model are estimated, with and without GDP per capita square. In both models in Table 4, per capita GDP, FDI inflows, per capita energy consumption, and population significantly impact carbon emissions, leading to implications for climate change. A rise of 1% in each of per capita GDP, FDI inflows, per capita energy consumption, and population leads to 0.486%,

Table 1 Cross-sectional dependence test for Asian countries

Test	Static	Prob.
Pearson LM Normal	1.457484	0.1450
Pearson CD Normal	0.911022	0.3623
Friedman Chi-square	28.32266	0.3945

Table 2 CADF unit root test results for selected South Asian countries

	At level		1st difference	
Variables	Statistic	Prob.	Statistic	Prob.
$lnCO2_{it}$	9.3510	1.0000	−3.04941	0.0011
$lnPCGDP_{it}$	4.7851	1.0000	−3.77548	0.0001
$lnFDI_{it}$	3.1288	0.9991	−9.57690	0.0000
$lnPCEC_{it}$	4.5507	1.0000	−5.24220	0.0000
$lnPOP_{it}$	2.7046	0.9966	−2.53327	0.0057

Table 3 Co-integration in panel series for South Asian countries

	Statistic	Prob.
Pedroni residual co-integration		
Panel v-statistic	0.565893	0.2857
Panel rho-statistic	−0.067222	0.4732
Panel PP-statistic	−2.562394	0.0052
Panel ADF-statistic	−2.883012	0.0020
Group rho-statistic	1.143659	0.8736
Group PP-statistic	−5.048043	0.0000
Group ADF-statistic	−2.690542	0.0036
KAO co-integration		
ADF	−4.011046	0.0000

0.982%, 0.0023%, and 0.982% increase in CO_2 emissions, respectively. Acharyya (2009), Shahbaz et al. (2015), Zakarya et al. (2015), Kivyiro and Arminen (2014), and Behera and Dash (2017) also found similar results. Lau et al. (2014) who worked for China and Malaysia, respectively, found positive impact of FDI on environmental degradation. Few panel data studies for developing countries such as Bhattacharya et al. (2016) and Shahbaz et al. (2013) and for European countries also witnessed positive impact of FDI on environmental degradation. However, few studies including Pao and Tsai (2010), Zhang and Zhou (2016), Nasir et al. (2019) witnessed the negative impact of FDI on environmental degradation. After inclusion of per capita GDP square in the model, the CO_2 emissions are now more elastic to changes in per capita GDP and increased from 0.486 to 1.729, whereas it is still significant at 5% level of significance. The coefficients of other variables do not change much when per capita GDP square is included in the model.

The impact of per capita GDP square on CO_2 emissions is insignificant even at a 10% level of significance. Hence, the results do not provide evidence in favor of the existence of EKC for four selected South Asian countries. It might be because these countries are at the initial stage of development. Furthermore, the role of technological innovations, environmental and economic policies could be the possible reasons that propagate the non-existence of EKC (Roca et al. 2001).

Table 4 FMOLS results with CO_2 emissions as a dependent variable

Variables	Coefficient	*P*-value	Coefficient	*P*-value
$lnPCGDP_{it}$	0.486456	0.0005***	1.729310	0.0446**
$lnPCGDP^2_{it}$	-	-	−0.080546	0.1468
$lnFDI_{it}$	0.682377	0.0000***	0.717694	0.0000***
$lnFDI^2_{it}$	−0.017014	0.0000***	−0.018517	0.0000***
$PCEC_{it}$	0.002392	0.0002***	0.002572	0.0000***
$LNPOP_{it}$	0.982696	0.0000***	0.903549	0.0000***

However, the possibility of EKC cannot be rejected in the future if these countries take environmental quality as a priority to ensure sustainable economic growth. Dogan and Inglesi-Lotz (2020) and Dogan et al. (2017) give evidence in support of EKC hypothesis for the countries that are relying more on renewable energy. Looking into the significant and positive impact of FDI inflows on CO_2 emissions reveals the prevalence of PHH, whereas a square of FDI inflows reveals the negative impact on CO_2 emissions. However, the impact of FDI and its square ranges from 0.682 to 0.717 and −0.017 to −0.0285, respectively. Therefore, it is evident that the relationship between FDI and CO_2 emissions in selected South Asian countries is inverted U-shaped.

The results reveal that selected South Asian countries are at compromising stage in view of economic growth to be sustainable, that is, FDI is a source of environmental degradation. If these countries do not target clean FDI then they will be prone to the negative implications of climate change. Kasman and Duman (2015) suggest to focus on environmental quality and sustainable economic growth to avoid climate change consequences. As a natural candidate, these countries require more energy for industry oriented growth but the lack of focus on renewable energy sources should not be an option. Therefore, FDI can be used as a source to enhance productivity, as advocated by Lee (2013). But at the same time, technological advancement for energy production, and to decrease the share of fossil fuels is a much needed area to attract FDI.

Conclusion

Countries around the globe are more interested to achieve sustainable development by attracting environmental friendly FDI and improving technological capabilities. However, it does not seem true in case of developing countries, especially the South Asian countries, where the CO_2 emissions are at record level. Therefore, this study offers an investigation about the unique determinants of CO_2 emissions for the South Asian countries. Following a rigorous estimation process, this study provides evidence about the non-existance of EKC or the inverted U-shaped relationship between per capita GDP and CO_2 emissions. The PHH is not rejected but there exists a U-shaped relationship between FDI and CO_2 emissions. It points out that CO_2 emissions will decrease with the increase in FDI inflows after a threshold point is achieved in these countries. It is true that energy consumption cannot be avoided for development but environmental friendly energy policy can be beneficial for long-run sustainability. Therefore, strong regulatory regime with more focus on renewables should be a matter of understanding.

From a policy point of view, this study has important implications. First, it is important to look into the prevailing fuel mix in all the selected countries that are dominated by fossil fuels with a strong correlation with CO_2 emissions.

Accordingly, the results uncover that energy use positively contributes to carbon emissions in the long run. Therefore, the policymakers of these countries, being signatories of the Paris Agreement, should change their respective energy policies to shift their focus on renewable energy resources so that long-run sustainability can be achieved. All these countries are rich in hydel, wind, and solar resources, which can be harvested through micro and macro policy perspective. It will not only ensure climate change mitigation through less CO_2 emissions, but it will also indirectly deal with the energy inequalities. Second, there is a need to focus on a balance between environmental degradation and economic growth. The unfortunate reality is that the South Asian countries that share common features of mounting environmental degradation, and lax regulatory environment, rely on FDI inflows for economic growth and high population growth. Therefore, policymakers should pursue clean FDI with vigorous environmental management so that sustainable development can be ensured. It can be made realistic by incentivizing clean FDI, whereas financial institutions' role can also be important for providing financial support to the high-tech industry.

Third, FDI in power development infrastructure has primarily been focused on producing electricity through fossil fuels that damage the environment and lead to high costs for the consumers. So, it results in two-edge sword; damaging effect for the environment and loss of competitiveness due to the high cost of electricity. Therefore, the governments of the sample countries should emphasize attracting FDI for clean energy production. Fourth, energy security and off-grid renewable-based solutions for high energy demanding areas such as industrial clusters or Special Economic Zones, transport and energy poor localities can be an important policy initiative to deal with the environmental degradation. Fifth, benchmarking of environmental standards for manufacuring plants and equipments is necessary to promote green technologies and reducing CO_2 emissions. Lastly, a rigorous awareness campaign is necessary to educate people about the environmental consequences of their social, economic, and environmental practices and prevailing policies.

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Data availability Data is available from the authors on request.

Declarations

Ethics approval and consent to participate All ethical standard has been followed in this research paper. No formal approval is required. The research is not on human and animal subjects.

Consent for publication We are willing to publish the research paper in the *Environmental Science and Pollution Research*.

Competing interests The authors declare no competing interests.

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