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RESEARCH ARTICLE

Sustainable environment quality: moderating role of renewable energy consumption in service sector for selected HDR listed countries

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Abstract

Considering environmental deterioration, an emerging global problem, this study is aimed at determining the impact of the service sector economic activity on environmental quality from the environmental Kuznets curve (EKC) perspective and finding ways to reduce the carbon impact of service sector within the EKC relationship. This study proposes that renewable energy intensity in the economy plays an important role in reducing carbon print of service sector. This study is based on secondary data from 1995 to 2021 for different development-wise categorized country groups leading to 115 countries, according to the Human Development Report (HDR) on the Human Development Index (HDI). Estimated results using panel feasible generalized least squares (FGLS) have confirmed inverted U-shaped for very high HDI and medium HDI and U-shaped EKC for low HDI countries. This study is instrumental in confirming the moderating role of renewable energy in the service sector EKC. Policymakers can plan a gradual reduction of carbon footprint in the service sector by transitioning toward renewable energy.

Keywords Environment quality · Renewable energy · EKC

JEL classification Q5 · Q2 · L8

Introduction

Among emerging challenges of recent times, environmental deterioration is also one (Ukaogo et al., 2020). On the other hand, climate change is also increasing day by day (Houghton, 1992). Basically, economic activities are responsible for this (Wang et al., 2021). However, the desire to achieve high economic growth overnight is the root cause. Among different portions of economic growth, the service sector is growing daily, and its importance is also increasing (Straková et al., 2021). So, this sector has deep implications for environmental quality (Taghvaee et al., 2022) because energy use in this sector is inevitable (Shabani & Shahnazi, 2019).

Figure 1 shows the average CO_2 emissions in each region. It can be seen that there is a huge disparity in terms of comparative emissions among regions, indicating that the assessment of emissions must be based on the different development levels.

Economic activities are increasing gradually (Iqbal et al., 2021). To understand this phenomenon, environmental Kuznets curve (EKC) is a recognized notion (Bibi & Jamil, 2021; Ongan et al., 2022). It describes the framework of economic growth and environmental quality. It reveals both U and inverted U-shaped scenarios (Dogan & Inglesi-Lotz, 2020). Its basic approach is a continuous increase in economic growth, first increasing and then decreasing the environmental pollution. It implies an inverted U-shaped relationship. But it can be U-shaped, which represents the opposite situation. The idea of EKC can be altered based on disaggregated GDP (Hassan et al., 2021). Incorporating the services sector instead of the whole GDP is another aspect of analyzing this impression (Hashmi et al., 2020).

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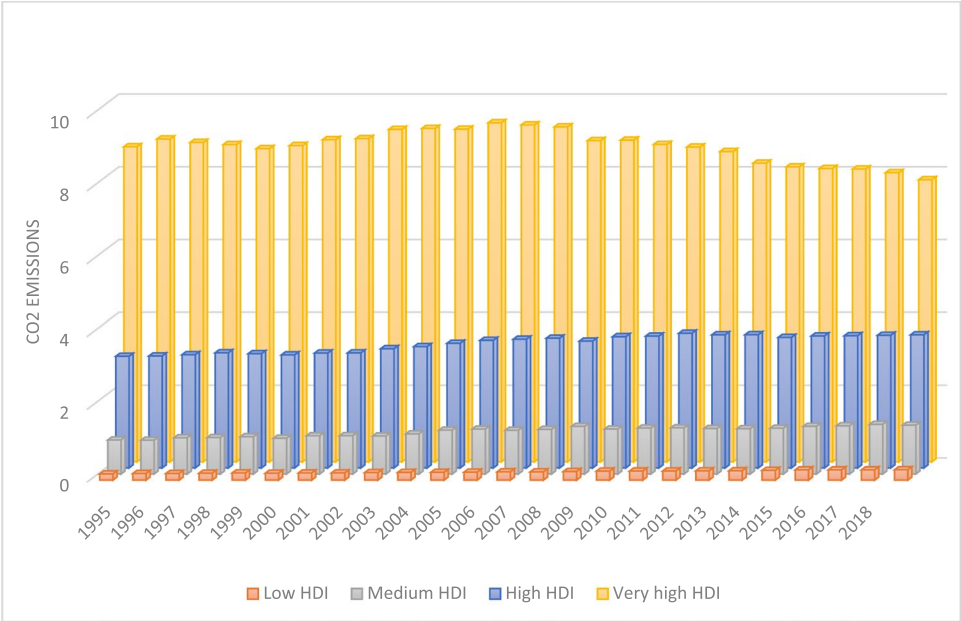

Fig. 1 Region-wise CO_2 emissions per capita

The service sector is getting highlighted; in addition, economic growth without a sound services sector is unmanageable (Grubel & Walker, 2019). But the tragedy is that this sector also contributes to environmental deterioration (Shafiq et al., 2020). So, the need to endorse the significance of renewable energy consumption (Wang et al., 2021). Since it can be helpful in carbon remissions (Adebayo & Rjoub, 2021), its moderation in the services sector can help achieve environmental sustainability (Shah et al., 2022a). It will improve the environmental quality as well as pave the way for environmental sustainability through the upgradation of the services sector.

Considering the significance of environmental deterioration, this study will test the non-linear impact of the services sector on carbon dioxide emissions from the EKC perspective. Second, determining and moderating the role of renewable energy consumption is incorporated to attain sustainable environmental quality. In this way, our study will meet the 13th sustainable development goal[1]. Third, the role of technological innovations and financial development is included as controlling factors. Fourth, this study will propose suitable policy implications in the light of imperial findings. Moreover, all this analysis has been done for four development-wise country groups.

After a brief introduction, this study is divided into four more sections. The second section contains a review of existing literature, to recognize the work done so far and literature gap. Third and fourth sections are about data and methodology and some interpretations of estimation, respectively. To finish and conclude, some suitable policies will be proposed for sustainable environmental quality.

Literature review

The EKC phenomenon is not new; actually, this idea is based on Kuznets curve (Todaro, 2015). It describes the relationship between income inequality and economic growth. At the same time, EKC describes the relationship between environmental quality and economic growth. In the beginning, several studies like Grossman and Kruger (1991), Selden and Song (1994), and Stern et al. (1996) have discussed this phenomenon. Later on, many studies have put their efforts to deliver the literature in their own way like Raza and Shah (2018), Hove and Tursoy (2019), Chekour et al. (2020), Bibi and Jamil (2021), and Ongan et al. (2022).

Economic growth represents the value addition of different sectors. So, it is difficult to understand the role of different sectors in environmental quality. Therefore, Arshed et al. (2021a, 2021b) and Hassan et al. (2021) have presented the impact of disaggregated GDP (including industrial, agricultural, and services sectors) on environmental quality from an EKC perspective. Considering service sector specifically, different studies have found different outcomes. Hashmi et al. (2020), Yassin and Aralas (2020), and Sun et al. (2021) have found inverted U-shaped EKC. In the linear analysis, studies like Shafiq et al. (2020) and Taghvaee et al. (2022) have confirmed service sector is responsible for deteriorating the environment, while the findings of Nwani et al. (2022) are opposing this.

[1] https://sdgs.un.org/goals

Table 1 Description of variables

Variable (symbol)	Full form	Source
Environment quality (CO_2)	Carbon dioxide emissions (metric tons per capita)	WDI
Service sector (SV)	Services, value-added (percentage of GDP)	WDI
Service sector square (SV^2)	Square of services, value-added (percentage of GDP)	WDI
Technological innovations (TE)	Total patent applications (resident and non-resident)	WDI
Renewable energy (RE)	Renewable energy consumption (percentage of total final energy consumption)	WDI
Financial development (FD)	Domestic credit to the private sector by banks (percentage of GDP)	WDI

In the present era of advancement, technology and innovation significantly contribute to environmental quality. In this context, considering total patent application a standard instrument of technological innovations, studies like Mensah et al. (2018), Khan et al. (2020a), Erdoğan (2021), and Arshed et al. (2021a) have validated its role in improving environmental quality. But this is one side of the phenomenon, empirical evidence also exists in some studies like Long et al. (2018), Erdoğan et al. (2020), and Ullah et al. (2021) have validated its role in environmental deterioration. Ease of getting finance boots up the economic activities at the household as well as commercial level. Different studies have proxied it using domestic credit to the private sector by banks. Moreover, it has mixed evidence for determining environmental quality. Some studies like Acheampong (2019), Ganda (2021), Petrovićand and Lobanov (2022), and Xu et al. (2022) have authenticated its role in environmental deterioration. While Tsaurai (2019), Habiba and Xinbang (2022), and Shah et al. (2022b) have captured their positive as well as negative impact on environmental quality.

Renewable energy consumption can play an important role in environmental betterment. Literature is vast, and many studies have highlighted its role. But its empirical evidence varies. Studies like Nguyen and Kakinaka (2019), Khan et al. (2020b), Zaman et al. (2021), Yuping et al. (2021), Kirikkaleli and Adebayo (2021), and Mujtaba et al. (2022) have validated its role as environment improver. On the other hand, Khattak et al. (2020), Haldar and Sethi (2021), and Ali et al. (2022) have found that renewable energy consumption can also deteriorate the environment quality. Chen et al. (2019) tried to analyze a comparative analysis of the environmental impact of renewable energy consumption in different regions of China. They found that its impact varies while in different regions. Moreover, the role of renewable energy consumption as a moderator is also considered in the literature, confirming its importance in improving environmental quality. Studies like Sharma et al. (2021), Shah et al. (2022a), Halder and Sethi (2022), and Ehigiamusoe and Dogan (2022) are evidence of renewable energy consumption as a moderator.

Literature concerning EKC is vast, and every study tried to contribute in a dissimilar way. But still gap exists. Many studies have validated the subject matter using economic growth. However, economic growth is the summation of the value addition of different sectors of the economy (Anwar et al., 2019, 2021a; Hassan et al., 2021; Wang et al., 2021). So, it is difficult to identify which sector is excessively harming the environment. On the contrary, this study has selected only a service sector to test its impact on environmental quality in the EKC framework. Though several studies have done this job. But this study is different in that the role of renewable energy consumption as a determinant (Salem et al., 2021) and a moderator is incorporated to highlight the significance of this type of energy consumption in the service sector. In this way, renewable energy consumption in the services sector can be promoted. Studies like Arshed et al. (2022c) used this moderation method to explore the changes in the EKC curve. Our analysis is also distributed into different development-wise country groups so policymakers can easily bring about environmental sustainability in their desired country group.

Data and methodology

Variables and sample

This study is based upon secondary data from 1995 to 2021 for 115 countries, collected from World Development Indicators (WDI). Data is further divided according to the development status proposed by United Nations Development Program (UNDP) on the basis of obtained score in Human Development Index (HDI). There are four categories; very high, high, medium, and low HDI presented in the annual Human Development Report (HDR). It will help analyze the existence of services sector-based EKC in these groups and the role of renewable energy consumption in determining and moderating EKC in the presence of control variables (Table 1). Countries are selected based upon the availability of data (Table 1, Appendix Table 5).

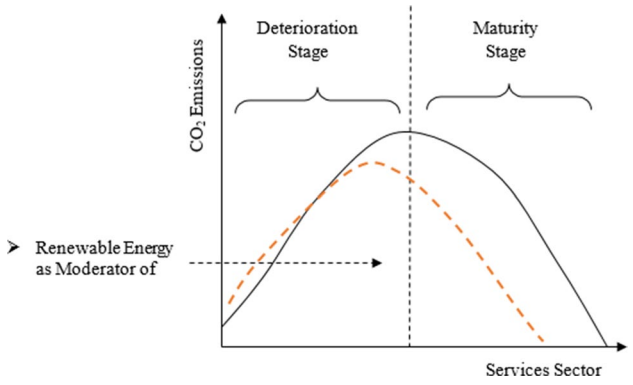

Fig. 2 Theoretical model

Theoretical model

Based on the described variables, equation 1 is presented. Left hand side represents the dependent while right hand side for independent variables where β*s* are the coefficients. Where β_1 and β_2 are the coefficients of the services sector along with its square to test the EKC hypothesis with an inverted U-shaped phenomenon (Fig. 2). While β_3, β_4, and β_5 are the coefficients of renewable energy consumption, technological innovations, and financial development, respectively. This study comprises the moderating role of renewable energy consumption as well. So, β_6 and β_7 are the coefficients of interaction terms of the services sector, its square with renewable energy consumption, respectively. β_6 explains how changes in RE will change β_1, and β_7 explains how changes in RE will change β_2; jointly, they will determine how the EKC curve will be shifted, steepened/flattened, or flipped because of changes in the RE, as shown in Fig. 2 with the red dashed EKC curve.

validated service sector-based EKC. It is assumed that the service sector will affect the environmental quality with both U and inverted U-shaped relationship.

Role of technological innovations and financial development is taken as controlling factors of the model. Mensah et al. (2018), Khan et al. (2020a), and Erdoğan (2021) are those studies which have authenticated the role of technological innovations in environmental quality. This study has assumed that technological innovations can improve environmental quality by reducing carbon emissions. Role of financial for environmental quality is highlighted by Acheampong (2019), Ganda (2021), and Xu et al. (2022) through domestic credit to private sector by banks. This study has assumed that financial development or ease of obtaining finance will provoke economic activities, leading to environmental deterioration.

Renewable energy consumption always reveals favorable impacts on environmental quality. However, our study has incorporated its role to test it as a determinant and a moderator of EKC. Studies like Khan et al. (2020b), Yuping et al. (2021), and Mujtaba et al. (2022) have highlighted its role as an environment improver. This study follows the same assumption to test EKC. Moreover, keeping in view the methodology of Arshed et al. (2021a), (2022a), this study will test its role as a moderator of EKC (similar to Arshed et al., 2022c). Likewise, Shah et al. (2022a), Halder and Sethi (2022), and Ehigiamusoe and Dogan (2022) have already tested the role of renewable energy consumption as a moderator.

Estimation technique

Equation 1 contains coefficients of each independent variable, which are estimated using feasible generalized least square (FGLS). According to Davidson and MacKinnon (1993), through this technique, unobserved heteroscedas-

$$CO_{2it} = \beta_0 + \beta_1 SV_{it} + \beta_2 SV_{it}^{\ 2} + \beta_3 RE_{it} + \beta_4 TE_{it} + \beta_5 FD_{it} + \beta_6 SV_{it}^{\ *} RE_i + \beta_7 SV_{it}^{\ 2*} RE_i + \varepsilon \quad (1)$$

To capture the environmental quality, carbon dioxide (CO_2) as an instrument of environmental quality is being integrated and is representative of environmental quality contrariwise. Among many other studies, some recent studies like Erdoğan et al. (2020), Adebayo and Rjoub (2021), and Ali et al. (2022) have used it as an instrument of environmental quality. Aligned with Chiang and Wainwright (2005) and Iqbal et al. (2019), non-linear impact of the services sector (SV) is incorporated to test EKC hypothesis. In addition, Yassin and Aralas (2020), Arshed et al. (2021a), and Sun et al. (2021) are those studies which have

ticity or differences in the cross sections are incorporated by changes in the standard errors of the estimates. Other panel data estimation techniques like fixed effect (FE) and random effect (RE) deal with cross-sectional differences only explained using changes in the intercept. Accordingly, Arshed et al. (2022b) have argued that FGLS performs better in controlling heteroscedasticity. Moreover, Davidson and MacKinnon (1993) and Maddala and Lahiri (2006) believe that FGLS models can be made robust for cross-sectional dependence, serial autocorrelation, and heteroscedasticity because of modifying cross-sectional specific standard errors.

Results and discussion

Table 2 provides descriptive statistics. Here, we can see that SV, RE, and FD are underdispersed, while CO_2 and TE are underdispersed. Further, after comparing the mean with the median and observing the skewness kurtosis values, the data seem to be statistically not normal. But this study avails central limit theorem to assume data to be asymptotically normal. Similarly, Fig. 3 provides the association between CO_2 and the service sector with quadratic fit at two different levels of renewable energy. It is shown here that an increase in renewable energy shifts the curve downward.

Estimated results using FGLS are presented in Table 3. The estimates are based on 59 countries and 1135 observations for very high HDI, 28 countries and 572 observations for high HDI, 23 countries and 349 observations for medium HDI, and 14 countries and 183 observations for low HDI group. The significant Wald test for all groups indicated that the model is a fit.

So, very high and medium development groups are revealing inverted U-shaped while low HDI has U-shaped service sector-based EKC. But this hypothesis does not validate for high HDI countries as the square term reflects insignificant results. Studies like Hashmi et al. (2020), Yassin and Aralas (2020), and Sun et al. (2021) have confirmed inverted U-shaped, whereas Arshed et al. (2021a) have confirmed U-shaped EKC based upon services sector. An inverted U-shape implies that progress in services sector deteriorates environment quality, but after achieving maturity, it becomes an environment improver. It means that countries where an inverted U-shaped is found prioritize economic growth, environmental deterioration, and focus more on productivity growth. After completion of the stages to maturity, this sector becomes sustainable and supports for environmental sustainability. On the other hand, U-shaped reflects its reverse process.

This study has included the role of technological innovations and financial development as controlling factors of the model. Estimated results have confirmed that technological innovations and financial development are improving environment quality only in very high and low HDI groups, respectively. But these findings are statistically insignificant. Other groups are suffering from environmental deterioration caused by these. Maybe the concentration of these groups toward environmental betterment through technological innovations is insufficient. This finding is consistent with Erdoğan et al. (2020) and Ullah et al. (2021). On the other hand, financial development may lead to expansion in economic activities through production and consumption. Studies like Ganda (2021) and Xu et al. (2022) have presented identical findings.

Renewable energy consumption is improving environmental quality in very high and low HDI groups, while other groups face opposite situations. As this type of energy is obtained through natural resources, this is the reason why it has good and bad effects on the environment, as discussed by Khan et al. (2020a), Zaman et al. (2021), and Mujtaba et al. (2022). On the contrary, high and medium HDI countries are facing opposite situation as discussed by Haldar and Sethi (2021) and Ali et al. (2022). May be these groups are suffering from low efficiency of renewable resources. Moreover, renewable resources are not sufficient enough to produce electricity at large scale. Except for very high HDI group, the rest is in the struggling phase, and they required huge amount of energy. So, renewable energy is not revealing desirable results. Except for significantly high HDI, all the groups show significant cross-product coefficients.

Table 2 Descriptive statistics

Stats	CO_2	SV	RE	TE	FD
Mean	4.364	53.183	33.221	0.244	44.383
P_{50}	2.517	53.651	23.920	0.058	32.854
SD	5.091	11.519	30.023	0.548	39.717
Min	0.000	9.685	0.000	0.000	0.000
Max	31.125	82.353	98.340	4.374	304.575
Skewness	1.920	-0.256	0.696	4.038	1.573
Kurtosis	7.355	3.003	2.142	21.545	5.969
Very high HDI					
Mean	8.675	75.140	0.434	15.201	59.698
High HDI					
Mean	3.421	52.718	19.070	0.066	37.497
Medium HDI					
Mean	1.167	48.709	46.969	0.016	26.722
Low HDI					
Mean	0.227	44.488	74.156	0.002	12.249

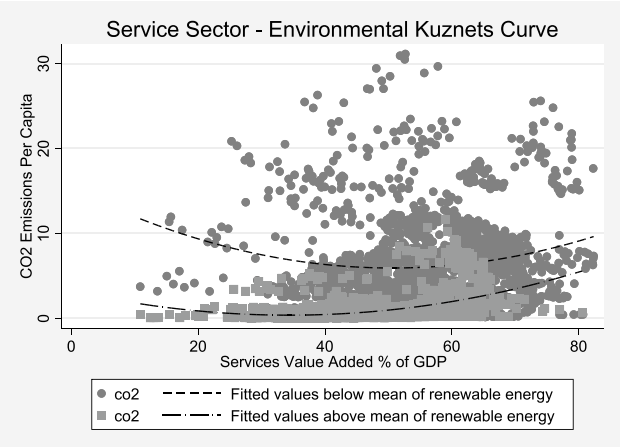

Fig. 3 Association pattern of EKC with moderator

Table 3 FGLS based estimated results

	Very high HDI		High HDI		Medium HDI		Low HDI	
Variables	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.
SV	0.410	0.00**	0.064	0.06*	0.116	0.00**	-0.036	0.00**
SV^2	-0.004	0.00**	-0.0004	0.214	-0.001	0.00**	0.0005	0.00**
RE	-0.335	0.00**	0.004	0.811	0.025	0.00**	-0.016	0.00**
TE	-0.085	0.318	3.463	0.00**	6.851	0.00**	2.054	0.00**
FD	0.002	0.00**	0.011	0.00**	0.005	0.00**	-0.0006	0.19
SV*RE	0.007	0.06*	-0.001	0.35	-0.001	0.00**	0.0004	0.00**
SV^2*RE	-6e-05	0.06*	5.29e-06	0.64	1.52e-05	0.00**	-6.94e-06	0.00**
Countries	59		28		23		14	
Obs	1135		572		349		183	
Wald (prob.)	60984 (0.00)**		24394 (0.00)**		83851 (0.00)**		133643 (0.00)**	

**Significant at 5%; *significant at 10%

Moreover, diagrams have confirmed the downward shifting of EKC using renewable energy consumption in services sector.

Table 4 provides the different quantile values of renewable energy for different levels of HDI countries. This data has been used to calculate the different levels of policy intervention in terms of renewable energy. This study has used this information to assess whether changes in the policy intervention via renewable energy will lead to changes in the EKC curve. It is also noted in the table that the high percentiles of high HDI countries have low renewable energy proportion as compared to the high percentiles of low HDI countries; hence, a foundation model like services EKC is needed to assess the effects of renewable energy on economic activity related emissions.

Figures 4, 5, 6, and 7 provide the service sector EKC curve for different HDI and renewable energy levels. For the case of very high and high HDI countries, it can be seen that an increase in renewable energy shifts the inverted U shape service EKC downward. Hence, these countries can reduce the level of CO_2 in the services sector by focusing on renewable energy. Specifically, the high HDI countries are showing a huge gain in terms of fall in emissions by adopting renewable energy for service sector.

Table 4 Category wise percentiles of renewable energy consumption

Percentiles	Very high HDI	High HDI	Medium HDI	Low HDI
P_{10}	0.120	1.080	9.760	42.210
P_{20}	2.020	2.355	23.170	53.146
P_{30}	4.440	4.910	31.740	72.710
P_{40}	7.290	8.975	36.995	79.010
P_{50}	10.210	12.724	47.850	82.190
P_{60}	15.700	17.433	54.507	86.005
P_{70}	21.045	22.980	64.412	88.420
P_{80}	27.230	32.320	73.937	91.338
P_{90}	35.490	46.995	81.540	94.180

For the case of medium HDI countries, an increase in renewable energy tends to flip the inverted U shape to a U shape relationship. This shows that if the medium HDI countries pursue renewable energy, they can gain a lot for their services sector. Beyond 20% share of services sector to GDP, there is a great deviation between the EKC curves because of changes in renewable energy. This points to a potential carbon absorbing policy intervention. Lastly, in the case of low HDI countries, the national renewable energy policy has greatly reduced CO_2 emissions when the country has a renewable energy proportion higher than the 10 percentile.

All in all, these figures confirm that without or low levels of renewable energy, it would take a higher level of services sector to reach the turning point of EKC and it would also have a higher net CO_2 emission compared to higher renewable energy levels.

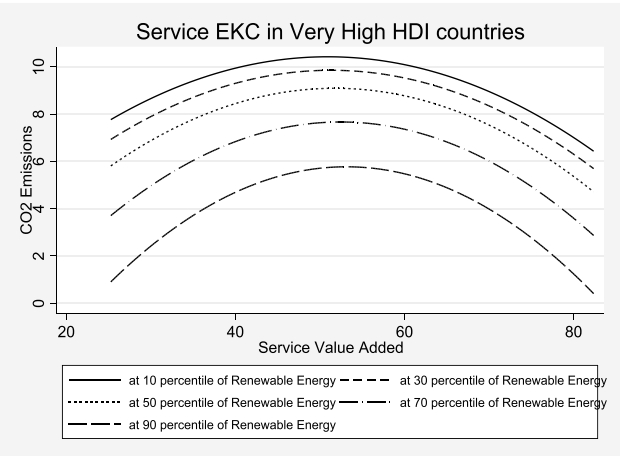

Fig. 4 EKC in very high HDI countries

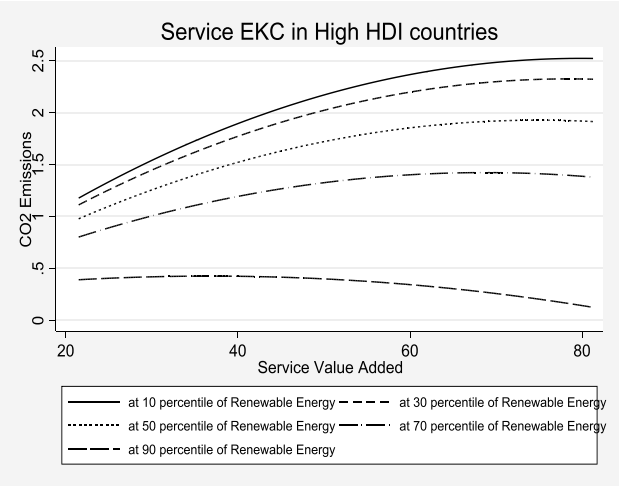

Fig. 5 EKC in high HDI countries

Conclusion and policy implication

This study is aimed at testing the non-linear impact of the services sector on environment quality from an EKC perspective. Estimated results have confirmed inverted U-shaped EKC for very high and medium countries, while U-shaped for low HDI countries. EKC hypothesis does not validate for high HDI countries; however, service sector has significantly responsible for environmental deterioration. Renewable energy consumption is improving environmental quality in very high and low HDI countries while other groups suffer. Technological innovations are deteriorating the environment in these groups. Moreover, financial development is worsening the environmental quality of all the groups. The moderating role of renewable energy consumption is incorporated. Estimated results have confirmed significant results. Moreover, quadratic plots authenticate it. It is confirmed that incorporating renewable energy consumption in the service sector can bring about environmental sustainability.

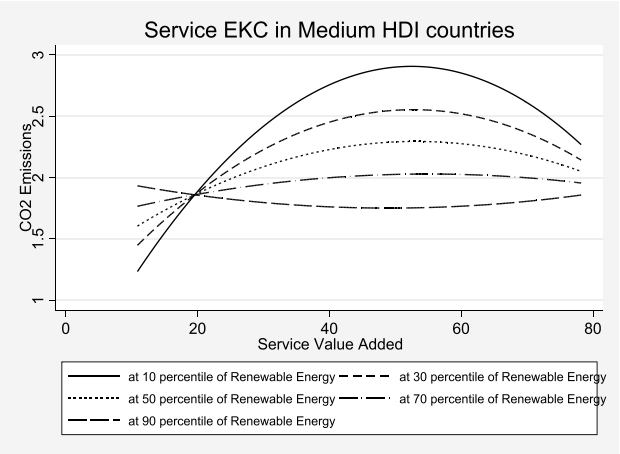

Fig. 6 EKC in medium HDI countries

Estimated results have highlighted a path to improve environmental quality and to achieve sustainability for these development groups. Regarding technological innovations, a sufficient amount should be allocated to the stakeholders. All sectors of the economy should adopt updated technology and never neglect the importance of innovations at the commercial level. All groups are suffering from financial development. Monetary authorities should adopt a strict monetary policy to tackle this situation, so there is a need to reduce the money supply. The reason is that expansion in money supply boosts economic activities, leading to environmental deterioration. On the other hand, low HDI countries should concentrate on the opposite framework.

For the sustainable service sector, there is a need to adopt renewable energy consumption. Very high and low HDI country groups are the direct beneficiaries because it is reducing carbon emissions; but in other groups, the situation is the opposite. So, these countries should pay considerable attention to upgrade their energy sector. The service sector is crucial for economic growth and development and requires massive energy consumption. It is confirmed that only renewable energy consumption will support bringing about environmental sustainability. Every country should invest a momentous amount to produce renewable energy. Moreover, service sector institutions should act through a self-help basis to install this technology. The government should also subsidize its import and pave the way for this energy consumption. The program should be telecasted to aware the people; moreover, different heads of different departments of the services sector play their roles (Table 5 in the Appendix).

Future studies can explore in the similar domain by using the emissions from the service sector only and use of dynamic threshold models to find how the threshold has changed in time because of the changes in the data of the independent variable and the moderator.

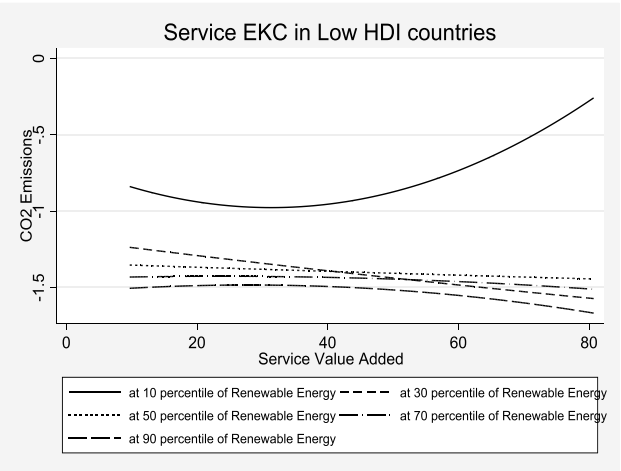

Fig. 7 EKC in low HDI countries

Appendix

Table 5 List of selected countries

No.	Very high HDI	No.	High HDI	No.	Medium HDI	No.	Low HDI
1	Argentina	1	Algeria	1	Angola	1	Burundi
2	Australia	2	Armenia	2	Bangladesh	2	Congo, Dem. Rep.
3	Austria	3	Bosnia and Herzegovina	3	Bhutan	3	Ethiopia
4	Bahamas, The	4	Brazil	4	Bolivia	4	Haiti
5	Belarus	5	Bulgaria	5	Botswana	5	Madagascar
6	Belgium	6	Cabo Verde	6	Cambodia	6	Mozambique
7	Brunei Darussalam	7	China	7	El Salvador	7	Nigeria
8	Canada	8	Colombia	8	Ghana	8	Pakistan
9	Chile	9	Dominican Republic	9	Honduras	9	Sudan
10	Costa Rica	10	Ecuador	10	India	10	Uganda
11	Croatia	11	Egypt	11	Iraq		
12	Cyprus	12	Indonesia	12	Kenya		
13	Czechia	13	Iran	13	Kyrgyz Republic		
14	Estonia	14	Jamaica	14	Lao PDR		
15	Finland	15	Jordan	15	Morocco		
16	France	16	Lebanon	16	Namibia		
17	Georgia	17	Mexico	17	Nepal		
18	Germany	18	Moldova	18	Nicaragua		
19	Greece	19	Mongolia	19	Philippines		
20	Hungary	20	North Macedonia	20	Syrian Arab Republic		
21	Iceland	21	Paraguay	21	Zimbabwe		
22	Ireland	22	Peru				
23	Israel	23	South Africa				
24	Italy	24	Sri Lanka				
25	Japan	25	Tunisia				
26	Kazakhstan	26	Ukraine				
27	Korea, Rep.	27	Uzbekistan				
28	Kuwait						
29	Latvia						
30	Lithuania						
31	Luxembourg						
32	Malaysia						
33	Malta						
34	Mauritius						
35	Montenegro						
36	Netherlands						
37	New Zealand						
38	Oman						
39	Panama						
40	Poland						
41	Portugal						
42	Romania						
43	Russian Federation						
44	Saudi Arabia						
45	Serbia						
46	Singapore						

Table 5 (continued)

No.	Very high HDI	No.	High HDI	No.	Medium HDI	No.	Low HDI
47	Slovak Republic						
48	Slovenia						
49	Spain						
50	Sweden						
51	Switzerland						
52	Thailand						
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Data Availability The data sources of variables are mentioned in Section 3.1.

Declarations

Ethical approval There is no need for ethical approval because this study is not using patient and/or animal data.

Consent to participate Not applicable.

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