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Determinants of Carbon Emission- A Study in South Asian Countries

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ABSTRACT- The rapid economic growth of South Asian countries, coupled with rising populations, has led to an increasing demand for energy, thereby posing significant challenges for sustainable development. This paper explores the importance of sustainable energy development in South Asia, highlighting its critical role in ensuring economic stability, environmental protection, and social equity. The United Nations has underscored this through its UNFCCC 2016 targets, transitioning from the Millennium Development Goals to the broader Sustainable Development Goals, with a heightened focus on mitigating climate change. In this context sustainable energy development is very important. This study focuses on the sustainable energy development status of South Asian Association for Regional Cooperation (SAARC) countries—Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. Utilizing 23 years of data (2000-2022), we employed Panel Data Analysis to investigate the determinants influencing carbon intensity in these nations. Our findings reveal that energy intensity, per capita renewable energy consumption and access to electricity significantly increase carbon intensity. Conversely, higher per capita income, a greater share of renewable energy in total consumption and increased per capita energy generation from fossil fuels correlate with a significant reduction in carbon intensity. The results suggest that enhanced collective efforts among SAARC countries are imperative for advancing sustainable renewable energy development.

KEYWORDS: Carbon Intensity, Panel Data Regression, SAARC countries, Sustainable energy development.

I. INTRODUCTION

Development of renewable energy, is a critical for the development of world economy. Human beings are largely dependent upon traditional energy sources which causes pollution and environmental hazards which is detrimental to human health. These energy sources are reasons for global warming and rising level of CO_2 emission. It has been pointed out that there is probable chance that earth's temperature increases 4°C by 2100 and renewable energy have the only way to minimise the problems arisen by non-renewable energy sources [1]. Concerning the above problems, countries targeted towards sustainable economic growth and energy efficiency by taking many steps in different conference of parties (CoP). Due to scarce nature of crude oil, fossil fuel, natural gas and environmental concern, human started to accept different mode of energy sources like biomass, solar, wind, tidal etc. (renewable energy resources). Transition towards renewable energy resources is the key solution for betterment of environmental and economic conditions of countries [2]. Advancement of technology has improved the situation of renewable energy uses. In very early period the cost of renewable energy was very high but after introduction of some innovation and technological improvement the cost has decreased to some extent. LCOE for solar photovoltaic in 2011 was 0.29 USD/kWh which was decreased to 0.06 USD/kWh in 2020 [3, 4]. The trend shows that 49 % electricity will be produced by renewable energy sources and this will reduce the cost of solar energy further 66 % by 2040 [5]. The SAARC countries members (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka) also promote the renewable energy uses. These countries together comprise 21 % of world population and 5.21 % of GDP of world economy (as on 2021) [6]. Share of CO_2 emission of SAARC countries in respect of world is 7.9 % as on 2022 [7].

In the present study we are presenting the status of renewable energy development in SAARC countries and find out the factors affecting the CO_2 emission per unit of GDP (Carbon Intensity) of it. As we know share of renewable energy and renewable electricity consumption per capita is significantly related to GDP, cost of business start-up procedure, economic freedom, level of unemployment etc [5]. The developed countries have modern and advance technologies for clean energy production. Developing countries did not have so much facilities for production of clean energy and technology to improve its quantity. So, their factors or determinant for CO_2 emission are different from developing countries.

II. OBJECTIVES OF THE STUDY

There are two major objectives of the study:

i. To access and state the status of renewable energy development in SAARC countries.
ii. To find out the factors which affects or determine the carbon intensity (CO_2 emission per unit of GDP) of SAARC countries.

III. DATA SOURCES AND METHODOLOGIES

A) Data Sources

In our study we have used the data of 8 counties (All members of SAARC). The selection of country can be justified by their developing nature and are in the same regions. We will find how their activities affect the environment and how carbon intensity determines by the different factors of the country. We have applied the data for 23 years (from 2000 to 2022) and considered the different dimension of data. Tables and figures have used to show the present status of renewable energy development in SAARC countries. For this study we have collected data from World Bank [8] and Energy Information Administration (eia) [9]. The above data sources are belonging to government organisations.

B) Methodologies

Based on the above discussion we have modelled to evaluate the effects of different factors on carbon intensity of SAARC countries. We have considered carbon intensity as dependent variable and several independent variables like SRTEC, PCREC, EI, PCI, FA, TU, AE and PCEFF. We have performed Panel Data Analysis to find the impacts of these on carbon intensity.

The function can be specified as,

$\underline{ln}CI_{it} = f(lnSRTEC_{it}, lnPCREC_{it}, lnEI_{it}, lnPCI_{it}, lnFA_{it}, lnTU_{it}, lnAE_{it}, lnPCEFF_{it})$

The model can be specified as,

$$\underline{ln}CI_{it} = \alpha + \beta_1 lnSRTECit + \beta_2 lnPCREC_{it} + \beta_3 lnEI_{it} + \beta_4 lnPCI_{it} + \beta_5 lnFA_{it} + \beta_6 lnTU_{it} + \beta_7 lnAE_{it} + \beta_8 lnPCEFF_{it}) + u_{it}$$

Where,

α = intercept

CI_{it} = Carbon Intensity = CO_2 emission per unit of GDP

$SRETC_{it}$ = Share of renewable energy in total consumption

$PCREC_{it}$ = Per capita renewable energy consumption

EI_{it} = Energy intensity = energy required per unit of GDP

PCI_{it} = Per capita income (in 2015 $ PPP)

FA_{it} = Forest area (% of land of country)

TU_{it} = Total unemployment (% of population)

AE_{it} = Access to electricity

$PCEFF_{it}$= Per capita energy generation from fossil fuel

u_{it}= Error term

IV. RESULTS AND DISCUSSION

Mostly SAARC countries are developing in nature. So, the energy demand has been increasing over time as the energy demand by different sectors are high. Table 1 shows the different dimensions of energy production, consumption and CO_2 emission of SAARC countries. From table 1 we can see there are many countries from SAARC which are high producers as well consumers of non-renewable energy except Sri Lanka, Bhutan and Nepal. Among SAARC countries production of energy and consumption of energy is highest in India which is 21.89 Quad Btu and 35.26 Quad Btu respectively. Among SAARC countries Bangladesh, Afghanistan, India and Pakistan are top ranked countries for production of non-renewable energy. They have produced 99.47%, 98.08%, 90.30% and 80.43% of energy respectively from non-renewable energy resources.

When we see the contribution of SAARC countries in energy production from renewable energy sources. We have observed from table 1, Sri Lanka produced its all (100%) energy from renewable energy sources. Nepal and Bhutan are also produced high renewable energy i.e., 97.06% and 91.18% respectively in 2022. All other SAARC countries produced very low renewable energy for their consumption.

From table 1 we find that the energy consumption pattern is different from energy production pattern of SAARC countries. Most of the SAARC countries are dependent upon non-renewable energy for their energy consumption. When we focus upon share of coal in energy consumption then we observed from table 1, share of coal in India is 60.62% (Highest among SAARC countries). Share of natural gas in energy consumption of Bangladesh is highest i.e., 67.53%. Maldives is fully (100%) depending upon petroleum and other liquid for their energy consumption. Share of renewable and nuclear energy in energy consumption is highest in Bhutan which is 75%.

Table 1: Different dimension of energy production, consumption and CO_2 emission of SAARC countries in 2022

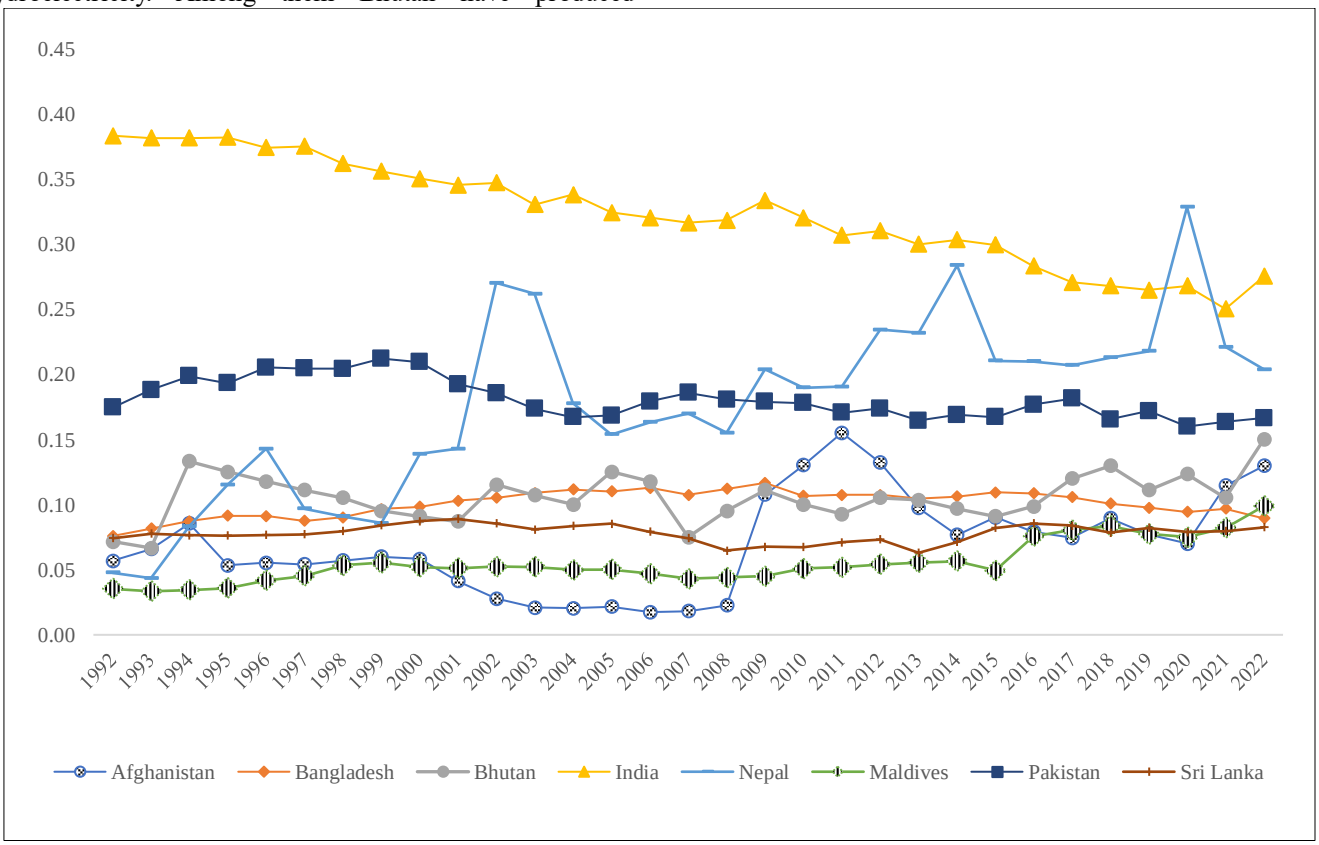
	Afghanistan	**Bangladesh**	**Bhutan**	**India**	**Maldives**	**Nepal**	**Pakistan**	**Sri Lanka**
Production amount of energy (QBtu)	0.10	0.95	0.03	21.89	0.00	0.03	1.98	0.02
Percentage share of different sources in energy production								
Coal (%)	98.08	1.58	8.82	78.06	0.00	2.94	12.94	0.00
Natural gas (%)	0.00	95.68	0.00	5.60	0.00	0.00	57.18	0.00
Petroleum and other liquids (%)	0.00	2.22	0.00	6.63	0.00	0.00	10.31	0.00
Nuclear, renewables and other (%)	1.92	0.53	91.18	9.70	0.00	97.06	19.57	100.00
Total production (%)	100.00	100.00	100.00	100.00	0.00	100.00	100.00	100.00
Consumption amount of energy (QBtu)	0.11	1.66	0.05	35.26	0.03	0.18	3.51	0.32
Percentage share of different sources in energy consumption								
Coal (%)	30.00	9.47	8.33	60.62	0.00	12.22	21.49	15.87
Natural gas (%)	0.00	67.53	0.00	6.29	0.00	0.00	40.47	0.00
Petroleum and other liquids (%)	50.00	20.88	14.58	27.24	100.00	66.11	26.89	77.14
Nuclear, renewables and other (%)	20.00	2.11	75.00	5.87	0.00	21.11	11.16	6.98
Total comsumption (%)	100.00	100.00	100.00	100.02	100.00	100.00	100.00	100.00
Renewable Electricity Production								
Total electricity generation (billion kWh)	0.83	102.00	9.00	1760.28	0.85	9.81	168.52	12.02

Renewables (billion kWh)	0.70	1.33	9.00	375.26	0.06	9.81	40.97	6.32
Renewables including hydroelectricity (%)	88.57	59.40	100.00	46.22	0.00	98.57	84.40	77.37
Non-hydroelectric renewables in total electricity generation (%)	11.43	40.60	0.00	53.78	100.00	1.43	15.60	22.78
Emission								
Co2 emission (Mmtonnes CO2)	7.00	100.00	1.20	2805.00	2.20	11.00	213.00	22.00
Annual CO2 emission per capita (MT)	0.17	0.58	1.52	1.96	4.22	0.36	0.89	1.00

Source: Energy Information Administration, 2024 (eia)

Among SAARC countries India is biggest country with large population so its energy demand is also high. Electricity production in India is much higher than other SAARC countries which is 1760.28 billion kWh. There is classification in electricity production from renewable sources. One is electricity production from hydroelectricity and other is non-hydroelectricity e.g., electricity from wind, solar, biomass and solid waste etc. Except Maldives all SAARC countries have produced renewable electricity from hydroelectricity. Among them Bhutan have produced renewable electricity totally from hydroelectricity i.e., 100%. After Bhutan, Nepal has produced 98.57% of renewable electricity from hydroelectricity. Maldives have produced its 100% renewable electricity from non-hydroelectricity.

CO_2 emission among SAARC countries is highest in India i.e., 2805 Mmtonnes and after India, Pakistan had 213 Mmtonnes of CO_2 emission. But when we focus about annual CO_2 emission per capita then Maldives is in top rank i.e., 4.22 MT per capita.



Source: Energy Information Administration (Various Years)

Figure 1: Carbon Intensity (CO_2 Emission per unit of GDP) (Kg/2015$ GDP PPP) of South Asian countries

From figure 1 we can see carbon intensity of India among SAARC countries is always higher than other countries. Due to high potential for growth, CO_2 emission is always high in India [10]. Appreciable thing is that carbon intensity of India has been decreasing over time till 2022 but still it is higher than other countries. Carbon intensity of India, Pakistan and Bangladesh have been continuously decreasing overtime. Carbon intensity of Afghanistan, Nepal and Maldives have been slowly increasing. It is lowest in Sri Lanka in 2022.

We have performed Panel Data Analysis to find the determinants of carbon intensity (CO_2 emission per unit of GDP) of SAARC countries. For this firstly we have performed Fixed Effect Model (FEM) and Random Effect Model (REM) in STATA after that Hausman specification test have been used to select between Fixed Effect Model (FEM) and Random Effect Model (REM). Hausman specification test result [A] indicates that random effect regression is more suitable for our model. When Hausman specification test indicates for REM then we have to used Breush and Pagan LM test to confirm REM is better model or not. As Breush and Pagan LM test for REM [B] shows insignificant result so, we have to use Pooled OLS. We have used the software STATA 15.0 for Pooled OLS regression. The result are as follows:

Table 2: Result of Pooled OLS regression of SAARC countries

Source	SS	df	MS	Number of obs	=	184
Model	67.7712403	8	8.47140504	F(8, 175)	=	224.35
Residual	6.60791849	175	.037759534	Prob > F	=	0.0000
				R-squared	=	0.9112
Total	74.3791588	183	.406443491	Adj R-squared	=	0.9071
				Root MSE	=	.19432

lnci	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnsretc	-.1168596	.0204913	-5.70	0.000	-.1573016	-.0764177
lnPCREC	.0455587	.0100298	4.54	0.000	.0257638	.0653537
lnei	1.052781	.0458717	22.95	0.000	.9622483	1.143314
lnpci	-.2518043	.0504688	-4.99	0.000	-.3514102	-.1521985
lnfa	.0135001	.014778	0.91	0.362	-.0156659	.0426662
lntu	.0203667	.0224121	0.91	0.365	-.0238661	.0645995
lnae	.1372702	.0473094	2.90	0.004	.0438997	.2306407
lnpceff	-.0179834	.0047312	-3.80	0.000	-.027321	-.0086459
_cons	-10.0153	.2459665	-40.72	0.000	-10.50074	-9.529857

Source: Estimation from STATA

From table 2, we have found that share of renewable energy in total consumption (SRETC), per capita renewable energy consumption (PCREC), energy intensity (EI), per capita income (PCI), access to electricity (AE) and per capita energy generation from fossil fuel (PCEFF) had statistically significant influence on carbon intensity. Energy intensity has most positive impact among variables. As it increased by 1 % carbon intensity of country on an average increased by 1.052781%. It is easy to understand that as energy intensity increases, carbon intensity of country automatically increases. Per capita income had most negative impact on carbon intensity among given variables, as it rose by 1% carbon intensity on an average decreased by 0.2518043 %. It can be justified, as PCI of any country increases, they became economically well and educated also. So, they will better understand the impact of carbon emission on health, environment and overall economic. They will be more concern about energy resources which they are using in their daily life and thus PCI and carbon intensity negatively related.

Share of renewable energy consumption and per capita energy generation from fossil fuel had a negative impact on carbon intensity, as they rose by 1% the carbon intensity of country on an average decreased by 0.1168596 % and 0.0179834 % respectively. It is very simple that increment in share of renewable energy consumption decreases the amount of carbon intensity of any country. But it is important to understand the negative impact of per capita energy generation from fossil fuel on carbon intensity. It can be understood though an example as PCEFF increases, ultimately there is improvement in technology, enhancement in innovation and R&D which create growth and development, hence increase in efficiency of production. So, carbon intensity decreases.

Per capita renewable energy consumption and access to electricity had a positive impact on carbon intensity. As it rose by 1% the carbon intensity on an average increased by 0.0455587 % and 0.1372702% respectively. Per capita renewable energy consumption had positive impact on carbon intensity. As we know renewable energy is intermittent sources for energy requirement for now. It has been not possible to substitute the traditional energy sources for its demand. It means that when per capita renewable energy consumption will high it is automatic that energy generation from traditional sources are also high. When energy generation from traditional sources will greater then PCREC will have positive impact on carbon intensity. Access to electricity also have a positive impact on carbon intensity. As the sources for electricity generation has not defined so, access to electricity will increase the carbon intensity of any country.

Forest area and total unemployment of country have insignificant impact on carbon intensity.

V. CONCLUSION

There is a problem with SAARC countries that most of the countries are dependent on unidirectional source for their energy demand. Many of them is intended on fossil fuel for their energy consumption except Bhutan. They should improve renewables in energy mix. As Afghanistan, Bhutan, Nepal and Sri Lanka have a good potential for hydroelectricity production. Instead of hydroelectricity potential, Afghanistan and India have been produced 98.08 % and 78.06 % energy production respectively from coal. Due to high energy demand in India, there is production crisis from coal which will create energy insecurity in future [11]. So, Afghanistan and India should improve its technology and energy efficiency for its energy production. Bhutan, Nepal and Sri Lanka should continue their energy production from renewable energy sources for their energy demand but they should improve their energy consumption from renewable energy sources.

As CO_2 emission intensity and renewable electricity is significantly related to each other so to achieve sustainable development goals countries should emphasis on renewable energy development [12]. All SAARC countries should give emphasis on energy efficiency and energy security through development of technology, making strong energy infrastructure and create a good energy trade (by developing an opportunity for share of renewable energy) among SAARC countries. These are only possible through collaboration among SAARC countries and emphasis on abundant resources of respective country. Legal trade treaty and implementing policy will be required.

Our paper attempt to find the determinants of carbon intensity of SAARC countries through the study of 23 years data of 8 SAARC countries. The variables PCREC, EI, AE, SRETC,

PCI and PCEFF have found significant for dependent variable carbon intensity. It has been found that higher PCREC, EI and AE encourage the carbon intensity. So, government should take steps to control energy intensity by increasing its efficiency. It has also been found that higher SRETC, PCI and PCEFF have been discouraged carbon intensity. So, government should take steps and make policy to increase SRETC and PCI.

VI. APPENDIX

Appendix A

Table 3: Hausman Test result

	---- Coefficients ----			
	(b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lnsretc	-.0301332	-.1168596	.0867265	.0364942
lnpcrec	.0132645	.0455587	-.0322943	.0123877
lnei	.7561654	1.052781	-.2966159	.0520436
lnpci	-.0611915	-.2518043	.1906128	.0323794
lnfa	-.3222247	.0135001	-.3357248	.5084285
lntu	-.0331682	.0203667	-.0535349	.0239758
lnae	-.0821084	.1372702	-.2193786	.016567
lnpceff	.2073242	-.0179834	.2253076	.0383503

```
b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg
Test:  Ho:  difference in coefficients not systematic
chi2(8) = (b-B)'[(V_b-V_B)^(-1)](b-B)
        =         4.53
Prob>chi2 =       0.8062
V_b-V_B is not positive definite)
```

Appendix B

Table 4: Breusch and Pagan LM test result

Breusch and Pagan Lagrangian multiplier test for random effects

lnci[countryid,t] = Xb + u[countryid] + e[countryid,t]

Estimated results:

	Var	sd = sqrt(Var)
lnci	.4064435	.6375292
e	.0192783	.1388463
u	0	0

Test: Var(u) = 0

```
chibar2(01)     =      0.00
Prob > chibar2 =   1.0000
```

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest between them and with any third party

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