ENVIRONMENTAL SAFETY, LABOUR PROTECTION INVESTIGATING THE IMPACT OF RE CONSUMPTION ON CO 2 EMISSIONS: EVIDENCE FROM THE SAARC COUNTRIES

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INVESTIGATING THE IMPACT OF RE CONSUMPTION ON CO_2 EMISSIONS: EVIDENCE FROM THE SAARC COUNTRIES

Purpose. To study CO_2 emissions through the use of renewable energy (RE) in the countries of the South Asian Association for Regional Co-operation (SAARC) region (Bangladesh, Bhutan, Sri Lanka, India, Pakistan, Afghanistan, Nepal, and the Maldives) using the data between 2002 and 2020.

Methodology. For the purpose of the study, panel estimation methods were employed including Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed-Effect (DFE).

Findings. Hausman test confirms the efficiency of PMG estimation method compared to MG estimation method and DFE estimation method. The results of PMG indicate long-run relationships among the studied variables. Besides, the outcomes of PMG reveal the negative impact of RE on CO_2 emissions in the long-run, while in the short-run, the study did not reveal the impact of RE on CO_2 emissions. In the case of specific countries, the results show that RE features increased CO_2 emissions in a country like Pakistan in the short-run, while RE decreases CO_2 emissions in Bhutan, Nepal and Afghanistan in the short-run.

Originality. The study found the impact of RE consumption on CO_2 emissions in SAARS countries obtained for the first time in the terms of SAARS region.

Practical value. The governments of the SAARC countries can use the results of the study attempting to decrease CO_2 emissions.

Keywords: *renewable energy consumption, CO_2 emissions, SAARC, PMG*

Introduction. In recent time periods, massive changes in climate around the world have been observed because of the vast usage of energy sources (such as fossil fuels) causing dangerous effects not only on the environment but also on human well-being [1]. In recent periods, most countries over the world, mainly developed and developing, have been using an enormous volume of energy for ensuring their economic development. Their activities have intensified CO_2 emissions which lead to several problems such as polluted environments, extreme global warming and so on. The release of excessive CO_2 emissions causes various environmental problems (including higher global temperature, acid rain) for which people around the world have to suffer a lot. Thus, there is a necessity of reducing CO_2 emissions aimed at protecting the environment from hazardous conditions [2].

Given the extreme climate changes around the world, most of the countries, either developed or developing, have given concentration on controlling CO_2 emissions.

The threat of climate change and the growing global warming has not only raised worldwide concerns about the probable environmental hazard but also imposed pressure on the energy-dependent countries, both developed and developing, to restrain CO_2 emissions [3].

Some studies [4] suggested that the dependence of the countries on non-RE sources not only contributes to increased CO_2 emissions but also poses threat to energy security. Due to the environment-friendly feature, countries around the world have shown heightened interest in RE consumption aimed at combatting climate change. Several countries' incentive policies (including tax rebates, subsidies for RE technologies, etc.) have supported their increasing interest in RE [5]. Proper usage of RE resources may contribute to stable economic benefits, eliminate the problem of energy security, and help mitigate climate change. Given the consciousness concerning global climate change and related threats, nations around the world give priority to using RE aimed at reducing CO_2 emissions to combat global warming. Various factors have affected the implementation of RE systems such as the willingness and ability of a country to pay for implementation and the associated technology required for adopting RE systems [5].

Several research studies [6] examined empirically the impact of RE use on CO_2 emissions in various nations throughout the globe. However, few studies [6] examined the said effects by considering data of the SAARC countries. Yet, these studies had considered selected SAARC countries in their research. Thus, this study is an endeavor to explore the impact of RE consumption on CO_2 emissions considering data of all the countries of the SAARC region. Such studies may help to devise pragmatic renewable energy-centric policies in that region.

This study contributes to the burgeoning literatures in various ways. As a starting point, this research examines the effect of RE usage on CO_2 emissions over the whole SAARC area. As far known, no previous studies have examined this issue in the context of the SAARC region by taking into account all of the countries. Second, the study applied several estimation methods (Dynamic Fixed Effect, Mean Group, and Pooled Mean Group), which as far known, may be the first study examining the issue of RE consumption in the substance of the SAARC region, in particular.

Literature review. Several studies [7, 8] examined the effects of RE consumption on CO_2 emissions of numerous countries around the world. The empirical studies have been conducted considering data of selected sub-Saharan African countries, developed and developing countries, OECD countries, the SAARC countries, MENA countries, European Union countries, ASEAN countries and so on.

Using a sample of 20 countries over the period of 1990–2017, and applying the panel ARDL model [9], showed that both in the long run and in the short run, overall RE consumption can lead to reducing the CO_2 emissions. The authors suggested that strategies like switching to RE sources from fossil fuels might help slow the rate of environmental degradation.

Using data from 46 nations in sub-Saharan Africa between 1980 and 2015, research [7] examined the impact of RE on carbon emissions. Using RE reduced carbon emissions, according to the study. The authors pointed out that large investment in RE with the successful implementation of environmental regulatory framework may aid in dealing with carbon emissions effectively in the region.

OLS and system-GMM used to data from 85 nations between 1991 and 2012 found that RE usage had a favorable influence on GDP, but a negative impact on CO_2 emissions. In order to ensure long-term economic growth, the authors of the study concluded that RE sources should be given top priority [8].

According to [8], short-term carbon emissions in the SAARC nations (Bangladesh, Pakistan, India, and Nepal) are influenced by energy use. The study suggested that improvement of energy efficiency and optimal energy consumption may help decrease carbon emissions in the region.

Using data from 128 nations between 1990 and 2014, a research showed that the use of RE reduces CO_2 emissions [9]. The authors suggested that every region should encourage RE consumption for controlling CO_2 emissions effectively.

CO_2 emissions are reduced by increasing the percentage of RE use in 25 developing nations from 1996 to 2012, according to the panel FMOLS and panel DOLS estimate techniques. Researchers found that developing nations must focus on the correct use of RE to reduce CO_2 emissions [9].

Considering the data of 12 MENA countries during 1980 and 2012 [9] disclosed that renewable energy, FDI, and international trade result in the decrease in carbon dioxide emissions. Proper utilization of RE and investment in RE resources have been recommended for controlling carbon dioxide emissions and improving the environments in the region.

Applying the Panel VECM and using data of selected ASEAN countries between 1970 and 2013 showed that RE has a detrimental effect on CO_2 emissions, whereas non-RE positively affects CO_2 emissions. The study suggested that improving the RE infrastructure through large investments and RE usage with efficiency may help reduce CO_2 emissions in the ASEAN environment [10].

The study of [10], considering the data of 107 countries from 1990 to 2013 and employing the panel FMOLS and the panel DOLS estimators, discovered positive effect of RE consumption on CO_2 emissions in low-income countries, while in high-income countries, the study found negative relationship. The authors suggested that the RE policies of a country would be consistent with its stage of development.

With the help of heterogeneous panel causality test and the panel FMOLS and using data of 74 countries covering 1990-2015, showed that RE consumption reduces carbon emissions, while non-RE increases carbon emissions. The study suggested that countries with high carbon emissions should increase the usage of RE aimed at controlling carbon emissions [11].

RE reduces CO_2 emissions whereas non-RE raises CO_2 emissions, according to statistics from five SA nations from 1990 to 2014. The authors also stated that in the South Asian (SA) region, increased usage of RE may be an effective strategy to decrease CO_2 emissions [11].

Using the data of five SAARC countries from 1975 to 2010 and applying the panel FMOLS [12] revealed that RE consumption causes CO_2 emissions to decrease in the SAARC region. The study concluded that priorities may be given for the investment in RE for improving the environments in the SAARC region.

The review of aforementioned literature suggests that few studies [13, 14] examined the impact of RE consumption on CO_2 emissions by considering the data of the SAARC countries. However, these studies did not consider all the countries of the SAARC region, rather focusing on the selected countries. Hence, there is no clear picture of whether RE consumption has any impact on CO_2 emissions in the SAARC region. Thus, this study has made an attempt to investigate the impact of RE consumption on CO_2 emissions considering the data of all the countries of the SAARC region. It is expected that the findings of the study may provide better insight into the SAARC region that previous studies lack [15].

Purpose. CO_2 emissions have increased significantly in the SAARC region and are now one of the major concerns for this region. The study examines the effect of RE consumption on CO_2 exudation in the SAARC countries (Afghanistan, India, Nepal, Bangladesh, Bhutan, Sri Lanka, Pakistan, and the Maldives) between 2002 and 2020.

Methods. In the study, the panel ARDL model is applied for investigating the effect of RE consumption on CO_2 exudation in the SAARC regions (Afghanistan, Nepal, Bangladesh, India, Bhutan, the Maldives, Pakistan, and Sri Lanka). Data on CO_2 emissions, total population, Real GDP, and RE consumption are used over the period from 2002 to 2020 of the mentioned countries. The selection of the variables of the mentioned time period is driven by data availability on the relevant variables of the SAARC countries. The data of the variables have been obtained from World Development Indicators [16].

It is possible to express the study's empirical model as follows

$$LCO_{2it} = \beta_0 + \beta_1 LRGDP_{it} + \beta_2 LPOP_{it} + \beta_3 LRE_{it} + v_{it}, \quad (1)$$

where CO_2 indicates CO_2 emissions (kt), RGDP is Real Gross Domestic Product (constant 2010 US$), POP denotes total population, and RE represents renewable energy consumption (% of total final energy consumption). All the variables were transformed in logarithmic forms to handle the probable heteroscedasticity problem.

In the study, numerous tests were conducted, i.e., panel unit root tests as well as panel estimation methods. The panel estimation methods comprise three estimators: Dynamic Fixed-Effect (DFE), Mean Group (MG), and Pooled Mean Group (PMG).

Panel Unit Root Test. In the study, various panel unit root tests were used for examining the stationarity issues of the panel data. Individual time series in the panel incorporates a unit root against the alternative of being stationary. IPS test suggests a standardized t-bar test statistic averaged across the groups. The p-values are from unit root tests for every cross-section (i) with a view to testing the unit root in panel data. The test was treated to be nonparametric and distributed as χ^2 having $2N$ degrees of freedom.

Panel Estimation Method. The first estimation method is Pooled Mean Group (PMG) having the benefit of detecting dynamic short-run and long-run relationships. There is a wide range of heterogeneity in short-run coefficients, including the eigenvectors of the short-run coefficients, as well as the speed of adjustment to the long-run equilibrium values and error variances. The PMG estimation method cannot estimate long-run coefficients for each entity. The second estimation method is Mean Group (MG), which can estimate long-run as well as short-run coefficients for each entity. The third estimation method is the Dynamic Fixed Effect (DFE). It can be mentioned that the DFE estimation method can only estimate overall long-run as well as short-run coefficients.

The long-run relationship between the variables applying the MG estimation method can be expressed as follows

$$LCO_{2it} = \theta_i + \beta_{0i} LCO_{2i,t-1} + \beta_{1i} LRGDP_{i,t-1} + \\ + \beta_{2i} LPOP_{i,t-1} + \beta_{3i} LRE_{i,t-1} + \varepsilon_{it}. \quad (2)$$

From (2), it is apparent that the MG estimation method having a high order of lag considers estimation of long-run average parameters.

The long-run relationship between the variables employing the PMG estimation method and DFE estimation method can be expressed as given below

$$LCO_{2it} = \alpha_i + \sum_{j=1}^{p} \lambda_{ij} LCO_{2i,t-j} + \sum_{j=0}^{q} \delta_{1ij} LRGDP_{i,t-j} + \\ + \sum_{j=0}^{r} \delta_{2ij} LPOP_{i,t-j} + \sum_{j=0}^{s} \delta_{3ij} LRE_{i,t-j} + \varepsilon_{it}. \quad (3)$$

In (3), i denotes the number of regions (1, 2, 3,..., 8); t denotes the number of years (2002–2020); (p, q, r, s) indicate the optimum time lag; α_i refers to the countries specific effect; ε_{it} denotes the error terms.

Using an error correction model, the short-term connection between the variables may be stated as

$$\Delta LCO_{2it} = \alpha_i + \Phi_i (LCO_{2i,t-1} - \lambda_1 LRGDP_{i,t-1} - \lambda_2 LPOP_{i,t-1} - \\ - \lambda_3 LRE_{i,t-1}) + \sum_{j=1}^{p} \lambda_{ij} \Delta LCO_{2i,t-j} + \sum_{j=0}^{q} \delta_{1ij} \Delta LRGDP_{i,t-j} + \\ + \sum_{j=0}^{r} \delta_{2ij} \Delta LPOP_{i,t-j} + \sum_{j=0}^{s} \delta_{3ij} \Delta LRE_{i,t-j} + \varepsilon_{it}, \quad (4)$$

where λ_i represents long-run parameters; ϕ_i denotes the parameter of the error-correction term (ECT), measuring the speed of adjustment to the long-term equilibrium of LCO_2 because of changes in *LRGDP*, *LPOP*, and *LRE*; ϕ_i shows the presence of a long-run relationship between the variables.

For determining the preferred or appropriate estimation method (PMG or MG or DFE), the Hausman test can be conducted. In choosing between PMG and MG, if the null hypothesis cannot be rejected, PMG estimation method is chosen. If the null hypothesis can be rejected, MG estimation method is chosen. Next, in choosing between PMG and DFE, if the null hypothesis cannot be rejected, PMG estimation method is chosen. If the null hypothesis can be rejected, then DFE estimation method is chosen.

Results. The descriptive statistics of the variables are presented in Table 1 (calculation based on [13]). It is apparent that average CO_2 emissions in the SAARC region during the study period is 232,218.2 kt. It ranges from 308.02 to 2,337,749 kt. The average population (POP) in the SAARC region during the study period is 200.08 million. It ranges from 0.294 million to 1,310.15 million. The average RGDP is US$238,803.7 million. It ranges from US$795.87 to US$2,294,947 million. The average RE is 50.31 percent. It ranges from 0.90 to 93.45 percent.

The standard deviations indicate higher variation in the data across countries and over time of CO_2 emissions.

Table 2 presents the results of various panel unit root tests of LCO_2, *LPOP*, *LRGDP* and *LRE*.

From Table 2, it is apparent that *LPOP* is stationary at level, $I(0)$. However, LCO_2, *LRGDP* and *LRE* are stationary at first difference, $I(1)$. Thus, the panel ARDL estimation method can be applied.

The long-run estimation results employing PMG, MG and DFE are presented in Table 3. The results indicate that RE has negative effect on CO_2 emissions in the long-run, implying that higher RE can cause CO_2 emissions to reduce.

Besides, the outcomes of PMG, MG and DFE suggest that RGDP has positive impact on CO_2 emissions in long-run, indicating that RGDP can increase CO_2 emissions. But, total population (POP) has no influence on CO_2 emissions in the long-run.

Table 4 presents the short-run estimation results using PMG, MG and DFE, which confirmed that the values of ECT are found to be negative and significant, implying the long-run relationships among the variables.

The outcomes of PMG and DFE show that POP leads to decrease in CO_2 emissions in the short-run. However, RE has decreased CO_2 emissions in the short-run as confirmed by

Table 1

Descriptive statistics

Variable	Description	Unit	Obs.	Mean	Max.	Min.	Std. Dev.
CO_2	CO_2 emissions	kt	112	232218.2	2337749	308.02	550402.5
POP	Total Population	Million	112	200.08	1310.15	0.294	387.82
RGDP	Real Gross Domestic Product	Million US$	112	238803.7	2294947	795.87	519507
RE	RE consumption (% of total final energy consumption)	Percentage	112	50.31	93.45	0.90	28.47

Table 2

Panel unit root tests

Variable	LCO_2		*LPOP*		*LRGDP*		*LRE*	
Test	Level	*I*st diff.	Level	*I*st diff.	Level	*I*st diff.	Level	1st diff.
Levin, Lin & Chu t	–0.08	–16.55***	–9.33***	–7.52***	–0.09	–6.13***	–0.45	–2.96***
Im, Pesaran and Shin W-stat	3.36	–10.25***	–5.51***	–9.0***	2.70	–5.15***	1.81	–3.81***
ADF-Fisher Chi-square	4.86	63.66***	80.83***	75.94***	3.17	54.59***	8.92	42.26***
PP-Fisher Chi-square	14.8	69.97***	66.9***	23.25	7.34	68.70***	9.02	53.96***

Note: *** indicates significance level of 1 percent

Table 3

Long-run estimation results

Variable	PMG		MG		DFE	
	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.
LPOP	0.05	0.840	0.25	0.822	0.53	0.623
LRGDP	0.50^{***}	0.000	0.50^{**}	0.027	0.87^{***}	0.006
LRE	-1.02^{***}	0.000	-3.19^{**}	0.036	-0.99^{***}	0.000

Note: ** and *** indicate significance levels of 5 percent and 1 percent, respectively

Table 4

Short-run estimation results

Variable	PMG		MG		DFE	
	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.
ECT	-0.71^{***}	0.000	-1.22^{***}	0.000	-0.24^{***}	0.000
$\Delta LPOP$	-14.32^{*}	0.074	−33.411	0.123	-5.91^{***}	0.008
$\Delta LRGDP$	0.11	0.858	−0.475	0.460	0.084	0.697
ΔLRE	−2.09	0.150	0.687	0.388	-0.835^{***}	0.000

Note: * and *** indicate significance levels of 10 percent and 1 percent, respectively

DFE. But, RGDP has no influence on CO_2 emissions in the short-run as suggested by PMG, MG and DFE.

From Table 5, the result confirms that PMG is preferred to MG.

From Table 6, the result of the Hausman Test (PMG vs. DFE) also states that PMG is preferred to DFE.

From Tables 5 and 6, it is confirmed that PMG is preferred to MG and DFE.

Table 7 presents the results of short-run estimation in specific countries. In the short run, POP decreases CO_2 emissions in Bangladesh, Nepal and Pakistan.

In the short-run, *RGDP* positively affects CO_2 emissions in Afghanistan, while *RGDP* negatively affects CO_2 emissions in Bangladesh, and Pakistan. However, RE decreases CO_2 emissions in Afghanistan, Bhutan and Nepal, whereas RE increases CO_2 emissions in Pakistan.

The present study represents the effect of RE consumption on CO_2 exudation in the SAARC countries (Afghanistan, Nepal, Bangladesh, India, Bhutan, the Maldives, Pakistan, and Sri Lanka) between 2002 and 2020. PMG estimation method is preferred to MG estimation method and DFE estimation method as confirmed by Hausman test. The results of PMG indicate the long-run relationships among the variables. Besides, the outcomes of PMG suggest that RE has negative impact on CO_2 exudation in the long-run, while RE does not affect CO_2 emissions in the short-run. The findings of short-run estimation in specific countries show that in the short-run,

Table 5

Hausman Test (PMG vs. MG)

Test	Statistic	Prob.	Decision
Hausman test	0.67	0.8808	PMG is preferred

Table 6

Hausman Test (PMG vs. DFE)

Test	Statistic	Prob.	Decision
Hausman test	0.02	0.9992	PMG is preferred

Table 7

Short-run estimation results in specific countries

Country name	$\Delta LPOP$		$\Delta LRGDP$		ΔLRE	
	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.
Afghanistan	−5.90	0.123	0.733^{**}	0.031	-1.037^{***}	0.000
Bangladesh	-9.17^{***}	0.003	-1.43^{**}	0.024	0.112	0.730
Bhutan	−5.18	0.528	0.19	0.777	-11.91^{***}	0.000
India	3.28	0.479	−0.67	0.109	−0.43	0.214
Sri Lanka	−5.51	0.638	−0.51	0.652	−0.30	0.550
Maldives	−2.18	0.331	−0.04	0.759	−0.45	0.126
Nepal	-22.48^{***}	0.002	4.28	0.121	-3.06^{*}	0.075
Pakistan	-67.41^{**}	0.020	-1.60^{***}	0.000	0.36^{*}	0.077

Note: *, ** and *** indicate significance levels of 10 percent, 5 percent and 1 percent, respectively

RE increases CO_2 exudation in Pakistan, while RE decreases CO_2 emissions in Afghanistan, Bhutan and Nepal.

The empirical findings of the study lead to some policy implications that are expected to be addressed by the policymakers. A transfer to RE from non-RE may be a good move in order to lessen environmental decay. Besides, fiscal incentives (for example, tax reductions or subsidies) may be given to the companies using RE in their production processes. Countries in the SAARC region may need to go for huge investments in RE projects in expectation of reducing CO_2 emissions in the region. Various donor agencies (such as Word Bank, IMF, and others) may provide financial supports on the construction of RE infrastructure in the SAARC countries. Countries may also seek technological as well as research and development (R&D) supports needed for establishing RE systems from developed countries.

Conclusion. The present study investigates the impact of RE consumption on CO_2 emissions in the SAARC countries (Afghanistan, Nepal, Bangladesh, India, Bhutan, the Maldives, Pakistan, and Sri Lanka) covering 2002–2020 through applying the panel ARDL model. Numerous panel unit root tests were conducted in which the results indicate that *LPOP* is stationary at level, $I(0)$, while LCO_2, *LRGDP* and *LRE* are stationary at first difference, $I(1)$, thereby the panel ARDL model can be applied. The results of Hausman test confirm that PMG estimation method is preferred to MG estimation method and DFE estimation method. The results of PMG suggest that RE has negative effect on CO_2 emissions in the long-run, implying that higher RE can cause CO_2 emissions to reduce. The probable reason may be that RE consumption is found to be effective in decreasing CO_2 emissions. However, the results of PMG suggest that RGDP has positive impact on CO_2 emissions in long-run, indicating that RGDP can increase CO_2 emissions. The results of PMG confirm the values of error correction term (ECT) to be negative and significant, implying the long-run relationships among the variables. The outcomes of PMG show that POP leads to reducing CO_2 emissions in the short-run.

The results of short-run estimation in specific countries suggest that in the short-run, POP reduces CO_2 emissions in Bangladesh, Nepal and Pakistan. RGDP has positive impact on CO_2 emissions in Afghanistan, while RGDP negatively affects CO_2 emissions in Bangladesh, and Pakistan. However, RE increases CO_2 emissions in Pakistan, while RE decreases CO_2 emissions in Afghanistan, Bhutan and Nepal.

In further study, more variables may be incorporated with the longer period to make the result more comprehensive. Besides, future studies may be conducted considering the regional comparison.

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Дослідження впливу споживання відновленої енергії на викиди CO_2: докази країн ПААРС

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Мета. Дослідити викиди CO_2 шляхом використання відновлюваної енергії (ВЕ) у країнах Південноазіатської асоціації регіонального співробітництва (ПААРС) (Бангладеш, Бутан, Шрі-Ланка, Індія, Пакистан, Афганістан, Непал і Мальдіви) з використанням даних за 2002–2020 роки.

Методика. З метою дослідження були використані методи панельної оцінки, включаючи об'єднану середню групу (PMG), середню групу (MG) і динамічний фіксований ефект (DFE)

Результати. Тест Хаусмана підтверджує ефективність методу оцінки PMG у порівнянні з методом оцінки DFE та методом оцінки MG. Результати методу оцінки PMG вказують, серед досліджуваних змінних, на довгострокові зв'язки. Крім того, результати методу оцінки PMG розкривають негативний вплив ВЕ на викиди CO_2 у довгостроковій перспективі, тоді як дослідження не виявило впливу ВЕ на викиди CO_2 у короткостроковій перспективі. У випадку конкретних країн результати показують, що ВЕ має збільшені викиди CO_2 у такій країні як Пакистан у короткостроковій перспективі, тоді як ВЕ зменшив викиди CO_2 у Непалі, Бутані та Афганістані в короткостроковій перспективі.

Наукова новизна. У дослідженні було з'ясовано вплив споживання ВЕ на викиди CO_2 у країнах ПААРС, отримані вперше в контексті регіону ПААРС.

Практична значимість. Уряди країн ПААРС можуть використовувати результати дослідження, намагаючись зменшити викиди CO_2.

Ключові слова: *споживання відновлюваної енергії, викиди CO_2, ПААРС, PMG*

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