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A system-GMM approach to examine the renewable energy consumption, agriculture and economic growth's impact on CO_2 emission in the SAARC region

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Abstract This study aims to investigate the relationship between renewable energy consumption, agriculture, economic growth, and CO_2 emission in the South Asian Association for Regional Cooperation (SAARC) countries. We used annual cross-sectional data from 2000 to 2017 and applied panel fixed effect regression and two-step system Generalized Method of Moments (GMM) estimator to check the robustness of the variables. Results of panel fixed regression indicate that the value of renewable energy consumption has a significant but negative effect, whereas economic growth shows substantial positive relation with carbon dioxide (CO_2) emission, while no relationship exists between agriculture and CO_2 under this method. However, agriculture and renewable energy consumption have a negative and considerable association in GMM estimation, and the impact of economic growth is positive and significant. The results imply that renewable energy consumption and agriculture with emission-free methods were essential drivers in lessen the CO_2 emission, and regional cooperation may accelerate the progress to achieve ecological benefits and sustainable atmosphere in the SAARC countries. Furthermore, in the future, most of the regional states are planning to invest in non-renewable energy to impulse economic growth and to meet the necessary energy demands of growing population that will bring more CO_2 in the environment.

Keywords Climate change · Economic growth · Agriculture · System GMM · Renewable energy consumption · SAARC countries

JEL Classification C23 · O47 · O13 · Q15 · Q54

Abbreviations

FDI	Foreign direct investment
REC	Renewable energy consumption
AVA	Agriculture value added
AMOS	Analysis of a moment structures
EU	European Union
WB	World Bank
SAARC	South Asian Association for Regional Cooperation
IEA	International energy agency
EPA	Environmental protection agency
APIM	Asia-Pacific integrated model
CGE	Computable general equilibrium
SVAR	Structural vector autoregressive approach
FMOLS	Fully modified ordinary least squares
GMM	Generalized method of moments
PMG	Pooled mean group
VECM	Vector error correction model

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EKC	Environment Kuznets curve
ARDL	Autoregressive distributed lag
GC	Granger causality
IAA	Innovative accounting approach

Introduction

Climate change emerged as an area of serious worry during the last two decades, which affected the social and ecological conditions globally. The continuous rise in the level of carbon emission (CO_2) raised the warm level and carried long-term variations in the climate. The increase in CO_2 produces many issues in terms of the population's health and environmental quality (Shi 2003). However, these setbacks of CO_2 do not affect a single country instead of problematic for the whole region and continent. Similarly, this problem cannot be addressed individually; hence, joint efforts are indeed required to cater these inevitable changes in climate (Jebli et al. 2016). Globally, various institutions and bodies[1] were formed to address this issue effectively. These institutes did a lot of work and conducted several conventions and meetings repeatedly at different levels every year in different countries. In this regard, the most recent meeting, named as United Nations Climate Change Conference (COP24), was held in 2018 in Poland. The COP24 emphasizes the successful implementation of Paris agreement (COP15), as most of the countries fail to comply with the understandings of COP15. The COP24 enforced the participants to reduce the carbon emission level below the Kyoto protocol agreement[2] (Nicholas Apergis and Danuletiu 2014).

There is a substantial evidence available on the relationship between renewable energy consumption, agriculture value-added, economic growth, and CO_2 emission in various localities of the world for different time periods (Alam et al. 2015; Azad et al. 2015; Saidi and Mbarek 2016; Kais and Sami 2016; Jebli and Youssef 2015, 2017; Mohsin et al. 2019b; Mohsin et al. 2018; Sun et al. 2019a, b). However, the statistical evidence for progressive policy measures remains questionable and unsatisfactory, specifically in the case of SAARC countries. Therefore, the current study analyzes the influence of economic growth, agriculture, and renewable energy on CO_2 by considering SAARC[3] states. The SAARC countries' investigation case is appealing because these nations are resource-intensive and keep high potential in the field of agriculture, renewable energy, and financials. Furthermore, this relationship is critical to examine because 21% of the world population lived in SAARC nations. Hence, the life of 1.7 billion humans is at stake due to CO_2 emission's dangerous effects.

Turning to the regional climate change, approximately 60% of the world's population lives in the Asian region, and most of the people still fulfill their energy needs by burning fossil fuels and other non-renewable sources that discharge massive CO_2 emissions. This emission represents a rise from 2.002 billion metric tons to 5.158 billion metric tons in the previous two decades (IEA 2019). More specifically, in South Asia, SAARC[4] countries already experiencing intensified effects of higher temperatures, more rainfall, extreme weather events, and rising sea levels, which has a strong impression on the financial performances of these countries and millions of poor people's life (Hanif et al. 2019). According to the World Health Organization (WHO 2019), around 2.4 million individuals die every year in South Asia owing to air pollution. Similarly, the agriculture sector emitting a handsome amount of CO_2 emission in SAARC countries, which has doubled in the last 50 years and expected to rise as much as 30 percent in the coming years (FAOSTAT 2019). The harmful impact of increasing CO_2 from agriculture sector challenging all the countries irrespective of economy volume and populace.

In contrast, some of these counties have limited their dependence on non-renewable energy sources to attain strong, sustainable growth, and in this respect, almost 18 percent of the energy has come from renewables. On a regional basis, renewable energy proportion in the total energy use is about 6.30% in

[1] International Panel on Climate Change (IPCC), UN Climate Action Summit, United Nations Framework Convention on Climate Change (UNFCCC), United Nations Environment Programe (UNEP).

[2] Under the Kyoto protocol agreement, it was decided that CO2 emission must be less than 8%.

[3] There are total eight-member countries of SAARC including Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka.

[4] South Asian Association for Regional Cooperation.

West Asia, 41.44% in South Asia, 20.75% in Central Asia, 6.28% in East Asia, and 37.73% in Southeast Asia (IEA 2019). In addition, SAARC countries have taken many steps in this course, and these nations have restated the need to reinforce regional alliance to maintain, safeguard and handle the region's vulnerable ecosystems, including the need to tackle the problems of the climatic zone and ecological disasters since 1987. However, fossil fuels demand continuously rises, which credited the performance of economic activities with its significant contributions (IEA 2019).

The most recent study of Waqih et al. (2019) assesses CO_2 relationship with FDI, energy consumption, and economic growth in selected[5] SAARC countries by applied panel ARDL, EKC, and FMOLS from 1986 to 2014. Our study is distinct from Waqih et al. (2019) and contributes mainly in two ways. Firstly, we consider the latest available panel data set for SAARC nations from 2000 to 2017 to represent the scenario of the whole region and not the selected countries. Our core objective to include all eight SAARC nations is because earlier studies neglected to include some of them, which may conceive more effect in near future if no precautionary measures are taken. Secondly, we employed two-step system GMM proposed by Arellano and Bover (1995) and Blundell and Bond (1998), as this method controls the inconsistency and biasness of the country effect results. The system GMM in regression analysis is considered as more proficient, systematic and consistent with providing robust results. Moreover, instruments are structured by busing level and first difference equations in system GMM, which offer comprehensive information regarding sample size and also enlarge the number of instruments. A two-step approach of GMM allows performance to be insightful and acceptable in the early stages, even in the existence of endogenous regressors. This study (by including agriculture) is a pioneering effort that consists of all SAARC nations and applied system GMM for their analysis, to the best author's knowledge.

The structure of the paper is categorized into five main sections. After the introduction, existing literature related to economic growth, renewable energy consumption, agriculture, and carbon emissions were reported. In third section details the description of variables, specification of the model with techniques for analysis. The empirical results and discussions were dedicated to section four. Lastly, conclusions and practical implications are specified in the fifth section.

Literature and background

In recent years, human beings face severe threats in the shape of climate variation. These issues cannot be addressed individually, so they have to put collective efforts to solve and minimize the climatic change. Therefore, in the South Asian region, SAARC countries work and take various measures to protect, preserve, and balance the ecological changes as a whole. Since 1987, SAARC countries affirmed to strengthen, support and provide all required needs to settle these troubles (Akhmat et al. 2014a). Table 1 reports the average key indicators of all SAARC countries.

Furthermore, there are three research categories in the literature on the relationship between CO_2 emission, REC, GDP, and AG. The first category emphases on the nexus between CO_2 emission and GDP. Al Mamun et al. (2014) measured the link between CO_2 and GDP by utilizing an EKC from 1980 to 2009 and confirmed a positive and substantial association among GDP per capita to CO_2 emission. Similarly, Magazzino (2016) applied panel 3-variable VAR technique to scrutinize the link among GDP, CO_2, and energy use from 1971 to 2007 in six ASEAN countries. The results revealed a unidirectional relation between the selected variables. A similar association was estimated by Khan et al. (2013) from 1975 to 2011 for Pakistan and revealed that energy consumption plays an essential part in the expansion of CO_2 emission. As an overview of the literature on renewable energy consumption, agriculture, economic growth, and CO_2 emission, the summary is provided in Table 2.

The second kind of study investigates the nexus among CO_2 and REC. Kais and Mounir (2017) examined the link between environmental degradation, GDP, and REC on CO_2 emission for selected countries[6] for the period of 1990 to 2013. The results

[5] Bangladesh, India, Pakistan and Sri-Lanka.

[6] Canada, Japan, Spain, Switzerland, France, UK, Netherlands, USA and Sweden.

Table 1 Average variables key data

Countries	Carbon emission (kt)	% Renewable energy	Agriculture	GDP per capita
Afghanistan	10,014.58	18.42	20.47	520.90
Bangladesh	33,269.56	34.75	13.07	1698.26
Bhutan	362.89	1.00	17.37	3360.27
India	1,086,547	36.02	14.46	2015.59
Maldives	501.67	1.01	5.63	10,223.64
Nepal	2780.57	85.26	24.97	1025.80
Pakistan	108,569	46.48	22.57	1472.89
Sri-Lanka	9189.51	52.88	7.87	4102.48

Source: Based on World Bank data (2000–2017) [Some of the countries have up to date data until 2019 for all measured variables, while others don't have. Therefore, we consider data until 2017 for accurate assessment and intact future strategy for the region]

indicate the existence of a relationship between CO_2 and GDP, whereas no relation was found between REC and environmental degradation. Likewise, Ben Jebli and Ben Youssef (2017) shown a significant negative relationship between REC to CO_2 in Tunisia.

The third sort of researches attempted to evaluate the associations between agriculture and CO_2. Parajuli et al. (2019) used EKC from 1990 to 2014 for 86 different countries, and panel data results specified that agriculture sector is the major contributor to the CO_2 emission. In the same way, Tyner (2012), and Jebli and Youssef (2017) assessed the REC, agriculture and CO_2 link by applied Granger causality and VECM procedures. Their results confirmed a bi-directional relationship from agriculture production to carbon emission. Zaman et al. (2012) confirmed the unidirectional causality between agriculture machinery to CO_2 and also identified that agricultural technologies have a close link with CO_2 and economic growth.

Global warming (CO_2 emission) is still a burning issue in the entire world, even though several steps were taken to minimize their harmful effects. According to the different international reports (IEA, WHO, and EPA), the South Asian region is reported as the most affected areas. A WHO report stated that about 2.4 million people died every year in South Asia because of air pollution. Furthermore, swift urbanization, rapid growth in population, industrialization, and increase in transportation need further raised the regions' pollution. Therefore, current study chooses eight (SAARC) countries from the stated area for the analysis because more than 21% of the world's total population lives there. In addition to existing literature, our study also considers agriculture along with renewable energy consumption and economic growth, because people of the SAARC nations are attached mainly to this sector. It is also critical to see the influence of agriculture, as it adds more than 15% to the total global greenhouse gas emissions (IPCC 2007). Several kinds of previous researches overlook to include all SAARC countries in the analysis, and used Granger causality, Johansen's co-integration and FMOLS tests Akhmat et al. (2014b). In contrast, the present study used a fixed-effect test, Hausman test, and system two-step GMM estimator, as these are more effective and consistent techniques, which also checks the robustness of the variables.

Methodological framework

Data

This study aims to find out the link between agriculture, economic growth, renewable energy consumption, and carbon emission in SAARC countries. We used annual cross-sectional data for all SAARC countries, including Bangladesh, Pakistan, India, Nepal, Afghanistan, Bhutan, Maldives, and Sri-Lanka from 2000 to 2017.[7] The panel data of variables, as mentioned earlier, were derived from WDI, IEA, and

[7] Some countries don't have up to date database (until 2019), therefore, we consider most recent available data from all countries.

Table 2 An overview of the previous studies on CO_2 emission

Authors	Methodology	Period	Countries	Results
Bhattacharya et al. (2017)	FMOLS, GMM model	1991–2012	85 developing and developed economies	CO_2 emission and economic productivity positively and negatively influenced by renewable energy consumption.
Menyah and Wolde-Rufael (2010)	Toda-Yamamoto causality	1960–2007	USA	Y → REC; CO_2 → REC
Tiwari (2011)	SVAR methodology	1960–2009	India	REC affects economic growth and reduces CO_2.
Kocak and Sarkgunesi (2018)	Quadratic Equation Model	1974–2013	Turkey	FDI impacts CO_2
Muhammad Mohsin et al. (2019a)	Hybrid error correction model, Platykurtic distribution, cointegration test	1975–2015	Pakistan	Economic growth, energy consumption, and urbanization raised the environmental degration
Ito (2017)	PMG/GMM	2002–2011	42 developing countries	REC has a substantial environmental and positive economic impact
Lin and Moubarak (2014)	GC-VECM	1977–2011	China	Short-run: RE …Y and RE… CO_2 Long run: CO_2 → RE and RE↔Y
Akhmat et al. (2014a)	VECM	1975–2011	Bangladesh, Nepal, Sir-Lanka, Pakistan, India	Electricity consumption raises average precipitation in India, methane in Bangladesh, Sri-Lanka, and Pakistan, and CO_2 in Nepal and Bangladesh
Jaforullah and King (2015)	GC and VECM	1965–2012	USA	REC is a useful source to diminish CO_2
Chin et al. (2018)	ARDL	1997–2014	Malaysia	FDI is a significant element of CO_2 emission
M. T. I. Khan et al. (2018)	GMM Granger causality Toda and Yamamoto	1990–2015	24 countries from Asia, Europe, Africa, and America	REC ↔ AVA; REC ↔ GHG
Moutinho and Robaina (2016)	VECM-GC/IAA	1991–2010	20 European countries	RE ↔ CO_2; RE ↔ Y
Waheed et al. (2018)	ARDL	1990–2014	Pakistan	An increase in forest area and REC will decrease the CO_2, while agriculture significantly contributes to CO_2 emission
Long et al. (2015)	Cointegration, Static and dynamic regression, GC, and Impulse response function analysis	1952–2012	China	The effect of REC on economic growth and CO_2 is both positive and negative. REC → CO_2; Y → RE
Mallick Mallick and Tandi (2015)	FMOLS, GMM	1972–2010	5 SAARC countries	The hypothesis of EKC is rejected for SAARC nations
N Apergis and Payne (2015)	VECM, GC, FMOLS	1980–2010	South America	RE ↔ CO_2; RE ↔ Y

Table 2 continued

Authors	Methodology	Period	Countries	Results
Bento and Moutinho (2016)	Toda-Yamamoto, ARDL	1960–2011	Italy	REC decreases CO_2 in the short as well as long run Y → RE
Ahmed et al. (2017)	FMOLS, GMM	1971–2013	Pakistan, India, Bangladesh,	The hypothesis of EKC is rejected
Chunark et al. (2017)	AIM and CGE	2015's Development plan (2015–2036)	Thailand	REC upsurges the growth and minimizes CO_2
Al-Mulali et al. (2015)	VECM GC/Cointegration test	1980–2010	Latin America and Caribbean countries	RE ↔ CO_2; RE ↔ Y
Belaid and Youssef (2017)	VECM, GC, ARDL	1980–2012	Algeria	(Long-run) RE → Y and RE → CO_2
Zhang et al. (2017)	DOLS, FMOLS, ARDL, GC, VECM	1970–2012	Pakistan	REC plays a pivotal part in limiting CO_2.
Sadorsky (2009)	DOLS and FMOLS	1980–2005	G7 countries	CO_2 → RE; Y → RE
Sun et al. (2019a, b)	Panel autoregressive lag distribution (ARDL), Panel causality test	1996–2017	SAARC countries	Long-run: Capital, FDI and EG increase CO_2 emissions Short-run: trade inflow, capital and FDI redueces CO_2 emissions
Ahmed and Long (2013)	Cubic ARDL	1971–2008	Pakistan	EKC does not confirmed in the short-run but supported in the long-run
Silva et al. (2012)	SVAR	1960–2004	Denmark, Portugal, the USA, Spain	REC has a negative impact on GDP per capita and also reducing CO_2 emission, apart from the USA
Shahbaz et al. (2014)	UECM, ARDL	1975–2010	Bangladesh	EKC exists between energy consumption and industrial development
Nicholas Apergis and Danuletiu (2014)	Regime-wise Granger-causality/FMOLS	1980–2010	7 Central American countries	RE ↔ Y; RE ↔ CO_2
S. Alam et al. (2007)	VAR	1971–2005	Pakistan	EKC exist
Boluk and Mert (2014)	Panel fixed effect model	1990–2008	16 EU countries	REC substantially lower the CO_2

↔, →, and … signify bidirectional causality, unidirectional causality, and no causality relationships, respectively

SAARCSTAT databases. The econometric techniques used were; descriptive statistics, fixed and random tests along with Hausman and Generalized Method of Moments (GMM) analysis. All the results were found by using software of Microsoft Excel, STATA 12 and Eview's 9. Moreover, the variables description, sources, and measurement units were detailed in Table 3.

The current study firstly used the Hausman test to choose between fixed and random effect tests. The outcomes of Hausman test (Table 5) allow us to use fixed effect test, as the value of Chi square is less than 5%. The rule for the selection between these two tests is; if Chi square value is less than 5% then the model used will be panel fixed effect. In contrast, we will employ panel random effect regression if the value of

Table 3 Variables description and sources

Variables	Symbol	Measure	Data source
Carbon emission	CO_2	Per capita metric tons	(WDI)
Renewable energy consumption	RE	% of total energy consumption	(IEA)
Real GDP (economic growth)	GDP	Per capita US$	(SAARCSTAT)
Agriculture value-added	AG	% of GDP	(WDI)

All variables were in logarithmic form

Chi square is insignificant. Both random and fixed effect regression was utilized to fascinate the shocks related to specific country and time variations specification provided in the model.

Furthermore, the fixed effect test is applied to assess the potential influence of variables in interest that are changing over time. It further manages the impact of time-invariant attributes, which takes the net effect from explicatory variables on the resulted variable. Moreover, in random effect test, it is supposed that deviation throughout panel countries should be stochastic and uncorrelated with explanatory variables of the specified model. These processes of regression also assist in simplifying the propositions beyond sample used within the model.

Model specification

Different researches are conducted to evaluate the causes of CO_2 emission by adopting a linear model, however, current study by following the studies of Berk et al. (2018), Destek et al. (2016), Shahbaz and Lean (2012), Hanif and Gago-de-Santos (2017) and Hanif et al. (2019), form the following generalized functional model:

$$\mathrm{CO}_2 = f(\mathrm{REC},\ \mathrm{GDP},\ \mathrm{AG}, \phi) \tag{1}$$

where CO_2, REC, GDP, and AG specified total carbon emission, renewable energy consumption, economic growth, and agriculture value-added, respectively. Our GMM-based econometric model is presented as;

$$CO_{2it} = \beta_o + \beta_1 REC_{it} + \beta_2 GDP_{it} + \beta_3 AG_{it} + \beta_n \phi_{it} + e_{it} \tag{2}$$

where i indicates cross-sections (of all SAARC countries) whereas t represents time series; however, the slope of the variables is signified with the sign of β, ϕ_{it} represents a set of additional control variables and e_{it} denotes the estimation residual. It assumes that while other elements remain fixed, one unit rises in explanatory variable increases or decreases carbon emissions by β units. The extended arrangements of Eq. (2) to analyze the effect of renewable energy consumption, economic growth and agriculture value-added on carbon emission for SAARC countries are as follows:

$$lnCO_{2it} = \beta_o + \beta_1 lnREC_{it} + \beta_2 lnGDP_{it} + \beta_3 lnAG_{it} + ln\beta_n \phi_{it} + e_{it} \tag{3}$$

where ln shows natural logarithms of the variables and log alteration is used because GDP may don't have a linear relationship with CO_2; however, it may have an exponential link. Additionally, formulating logarithm forms enables to decrease the multicollinearity problem.

GMM (generalized method of moments)

To analyze the empirical relationship among selected variables, we used the two-step system GMM proposed by Arellano and Bover (1995) and Blundell and Bond (1998). First of all, the core objective behind the application of system GMM instead of ordinary least squares (OLS) is that the later models don't control the biasness and inconsistency which leads toward the occurrence of omission of unobserved time-invariant country effect (Blundell et al. 2001; Hoeffler 2002). Secondly, system GMM models in the regression are more consistent and efficient estimation techniques, which also check the robustness and realization of the errors that are correlated between past and present. Conclusively, Arellano and Blundell's GMM estimation are much more systematic and proficient as compared to other GMM estimation techniques.

In addition, to ensure the system GMM estimation's consistency, we employed four primary diagnostics. Firstly, we used Arellano and Bond (1991) test to confirm that the first differenced error term is without first and the second-order serial correlation. The null hypothesis of the p value reported by AR (2) is that the

first difference residuals have no serial correlation in second-order. Secondly, we applied Hansen (1982) test to identify constraints that report p values for null assumptions and make sure that the error term should not be correlated with instrument. The third one is to make sure the validity of the additional moment restrictions and for that, Difference in Hansen test was employed. The four and last condition is to avoid sample biasness caused by overfitting and to ensure the number of instruments which should be smaller than or equal to the number of groups in regression.

Empirical results

The results of the descriptive statistical analysis of the panel data variables are given in Table 4. The bottom of the table contains correlation statistics of the variables under investigation to determine the multi-collinearity intensity. The correlation results described that a negative correlation exists between CO_2 → REC and CO_2 → AG, which elaborates that renewable energy consumption and agriculture decrease CO_2 emission in the SAARC region. In contrast, a positive correlation exists between CO_2 and GDP, which determines positive long-term relationship between environmental quality and economic growth.

In Table 5, the results of Hausman test were reported with a probability value, which is less than 5% that helps us to conclude the application of the fixed-effect model confidently. Table 6 shows the fixed effect regression results and indicates that RE has a significant but negative relation with CO_2 emissions, which describes that a one percent increase in renewable energy will decrease the carbon emission by 0.95%. Our results endorsed the study of Bilgili et al. (2016), which also showed the same link from renewable energy consumption to CO_2. This result defined the importance of renewable energy as an alternative source and suggested that mitigation of CO_2 emission is possible through its use.

In contrast, the relationship between GDP and CO_2 was positive and strongly significant. A one percent increase in economic growth will result in a 0.90% rise in CO_2 emission. The potential reason for this result is the excessive use of stained fuels like coal or wood to generate electricity for most of the population. Further, WB (2019) revealed that accessibility of the power is human's necessity, while many people don't have; therefore, to provide them instant energy-burning stained fuel increases, which caused to

Table 4 Descriptive statistics and correlation matrix

	CO_2	REC	AG	GDP
Mean	0.5347	3.4728	2.8798	4.2338
Median	0.4377	3.8504	2.9418	4.3316
Maximum	1.1847	4.5375	3.6454	4.6052
Minimum	3.2346	− 0.1019	1.7471	2.8470
SD	0.9905	1.3180	0.5164	0.3411
Skewness	0.5299	− 1.7960	− 0.7479	− 1.5616
Kurtosis	2.8626	4.9174	2.7361	5.8933
Jarque–Bera	4.188761	60.7903	8.4589	66.4608
Probability	0.123147	0.0000	0.0146	0.0000
Observation	88	88	88	88
Correlation matrix				
CO_2	1.00			
REC	− 0.5281	1.00		
AG	− 0.7287	0.6935	1.00	
GDP	0.8091	− 0.2787	− 0.5313	1.00

Table 5 Hausman test

Test summary	Chi square statistic	df	Prob.
Cross-section random	17.5985	3	0.0005

Table 6 Panel fixed effect regression

Variable	Coefficient	SD	t-statistic	Prob.
RE	− 0.9597*	0.0921	− 10.4237	0.0000
GDP	0.9066*	0.0863	10.5027	0.0000
AG	− 0.0019	0.1406	− 0.0132	0.9895
Constant	1.0348	0.7617	1.3585	0.1783
R^2	0.9875			
Adjusted R^2	0.9859			
F-stat	609.0738			

* and **significance level at 1% and 5% respectively

enhance CO_2 emission and also destroy human health at large. Moreover, CO_2 also produced at a mass level by inefficient technologies and utilization of solid fuel.

Additionally, the coefficient value of agriculture shows an insignificant link with carbon emission. Lastly, the value of R square (0.98) indicates that the 98% dependent variable might be described through independent variables. The result of fixed-effect regression concludes that the energy needs of the population must be met with the usage of renewable sources and enhanced economic growth by depending less on fossil fuels and other non-renewable resources.

Generalized method of moments (GMM)

The GMM estimator is testing the robustness of our variables, and all results are presented in Table 7. It is broadly acknowledged that two-step GMM results are more robust as compared to the one-step system GMM. Furthermore, instruments are structured by busing both level and first difference equations in system GMM. This kind of procedure offers comprehensive information regarding sample size and also enlarges the number of instruments. The efficiency of a two-step GMM approach allows for initial conditions to be insightful and acceptable even in the existence of endogenous regressors. In the end, Hansen J-test and second-order autocorrelation tests were utilized to examine the instrument quality based on level and difference equations and over-identification restriction validity, respectively.

Table 7 GMM estimations

Variable	Coefficient	Prob.
RE	− 0.1205**	0.0337
GDP	0.7311*	0.0000
AG	− 0.5401*	0.0018
Constant	6.9325*	0.0000
Observations	88	
Instruments	9	
R square	0.7684	
Adjusted R^2	0.7592	
Hansen J-statistic	0.631	
Wald Chi square	752.63	
Prob.	0.0000	
Difference in the Hansen test	0.294	
Arellano Bond AR (2)	0.175	

* and **significance level at 1% and 5% respectively

The results of the two-step system GMM show that REC has a significant negative relationship with CO_2, which highlights that renewable energy consumptions lead to a reduction in carbon emission in SAARC countries. More specifically, a one percent rise in renewable energy consumption reduces carbon emission by 0.12%, provided other elements are constant. The results put emphasizes on the practicality of renewable energy sources in the SAARC region and are aligned with the studies of Bhattacharya et al. (2017), Dogan and Seker (2016), and Hanif and Gago-de-Santos (2017). Moreover, People need to be aware of alternative sources, i.e., renewable sources and retrench fossil fuel consumption dangers that release carbon emissions.

Similarly, the results of AG have a significant negative influence on the CO_2, which elaborates that one percent increase in agriculture value-added will lower the carbon emission by 0.54%, while other factors remain constant. Furthermore, non-renewable energy like diesel fuel was used in agricultural sector for irrigation, which causes CO_2 discharge. Farmers utilize different chemical pesticides and fertilizers with high amount of nitrogen to protect and raise the level of their yields which also surge the CO_2. In addition, farmers must utilize modern techniques and types of machinery that can grow the level of agricultural production which leads towards enhanced economic growth and diminish CO_2 emission. Advanced techniques reduce GHG emissions and improve productivity (Panhwar 2004). In conclusion, outcomes of the two-step system GMM shows that usage of renewable energy along with modern agriculture methods have a leading role in diminishing the CO_2.

In contrast, the results of GDP highlights that economic growth contributes significantly to the CO_2 of SAARC nations. More specifically, an increase of one percent in real economic growth will raise carbon emission by 0.73%, which suggests that SAARC countries used fossil fuels, gases, and other non-renewable sources without considering its harmful impact on the atmosphere (Shukla et al. 2016). The results of GDP to CO_2 emission confirm the previous findings of Balli et al. (2019), who reported that CO_2 radiation rises due to increasing in sustainable

economic growth. However, this impact can be balanced by quitting current non-renewable resources and producing renewable energy to meet future demands. In addition to providing inexpensive renewable energy, it would reduce carbon emissions in the region as well (Waqih et al. 2019).

Conclusion

The current study analyzed the relationship between renewable energy consumption, economic growth, agriculture sector, and carbon emission in SAARC countries from 2000 to 2017. We applied a fixed effect test and two-step system Generalized Method of Moment's (GMM) technique to check the time-invariant differences on cross-sections and robustness of our results, respectively. Results of the fixed effect test signify that renewable energy consumption has a negative and significant relation with CO_2 emission, whereas economic growth has strong but positive relationships with CO_2 in a fixed-effect test. Furthermore, agriculture has no impact on CO_2 emission in the fixed-effect model. The fixed-effect regression results determine that population's power requirements should be encountered by the use of renewable resources. Economic activity has to be expanded through a minimul dependacne on the fossil fuels as well as other non-renewable resource consumptions.

In GMM analysis, renewable energy consumption and agriculture show adverse and significant effects on CO_2 emission, while the impact of economic growth is substantial and positive. The results suggest that a rise in the consumption of renewable sources in energy mix and low carbon emission steps will help to achieve sustainable development in SAARC region. The transition from fossil fuels to renewable energy is essential to promote an eco-friendly environment, and these resources could be used to meet the Kyoto Protocol targets. Moreover, excessive usage of fossil fuels to encounter energy needs domestically, and expansion in the economic growth at the same time are found to be difficult to overwhelming carbon emission-related issues. In addition, the rapid increase in population and the deterioration of natural resources in this part of the world have a negative impact in the shape of rising in carbon emissions. However, the pace of economic growth can be maintained or enhanced with the added consumption of renewable energy sources. Hence, this study concludes that agriculture and renewable energy consumption are the most significant absorbers of CO_2. Moreover, agriculture production should increase to a maximum level with modern technologies and the use of hybrid seeds varieties.

Policy recommendations

The overall findings show a clear indications of ecological destruction in the region; therefore plans should be formulated at the regional level through co-operation and initiation of research and development fund for this goal. Governments of these countries should cut the subsidies on fossil fuels and invest these funds in clean and green sources. The SAARC countries should mutually coordinate, support and focus on policies that can boost renewable energy productions and regulates emissions at regional level. For prospective viewpoint, the impending studies could also be stretched to other parameters effecting the natural environment in order to attain broad agreement, because this will improve the existing results which might aid in backing the legislations in long run. In this way, the subcontinent will generate pure, dirt free, friendly and sustainable atmosphere. Lastly, the results were well concentrated and covered all defined goals of the study.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Research involving human participants and/or animals Our research does not involve any human Participants or Animals during the whole process.

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