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Impact of income inequality on renewable energy demand in south Asian economies

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A B S T R A C T

The demand for renewable energy is growing worldwide due to environmental degradation. However, in poor countries, the use of renewable energy may be impeded by the level of poverty and income inequality. Therefore, this paper studies the income inequality impact on renewable energy demand in seven South Asian economies by using the balanced panel data from 1996 to 2018. The study employs generalized methods of moments (GMM) estimation technique followed by other econometric approaches to check the robustness of findings. The renewable energy demand function includes economic growth, carbon emissions, and government effectiveness as control variables. The study has found the adverse effects of income inequality, economic growth, and carbon emissions on renewable energy demand. Government effectiveness also drives renewable energy use. The findings are robust and reliable concerning panel data methods used in the analysis. These findings bear important policies for a sustainable environment in South Asian economies.

1. Introduction

Climate change and income inequality are among the pressing challenges of developed and developing economies worldwide and they are closely associated. Failure to reduce income inequality is likely to exacerbate climate change within and between countries (Dell et al., 2012; Burke et al., 2015; Hallegatte and Rozenberg, 2017; Diffenbaugh and Burke, 2019) and income inequality within countries tends to slow down the implementation of climate policies (Chancel, 2020, 2022).

To properly understand the impact of income inequality on the implementation of climate change policies, the relationship between renewable energy demand and income inequality should also be realized. This is because economic complexity in terms of unequal income distribution has environmental implications (Payne et al., 2023; Chu et al., 2023; Ghosh et al., 2022; Doğan et al., 2022a, 2022b). This issue is yet to be explored extensively in the field of resources and development economics. This remains unexplored due to the lack of sound and timely data on income inequality. Researchers and policymakers struggle to bring basic insight into mitigating climate change though efforts are made (Wang et al., 2022). Since data on the bottom 50%, top 10%, and 1% of the income distribution are available, one can also establish the basic facts about which groups of the population sitting in the ladder of income distribution contribute to growth of renewable energy demand or effective climate change mitigation.

The primary purpose of the study is to understand the role of ineffective income distribution (i.e. income inequality) on renewable energy demand in seven South Asian economies namely, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. This purpose is further motivated because income inequality is a part of both social and economic boundaries. Reducing income inequality is a primary motive of an economy. In this line the recent study by Mahalik et al. (2018) argues that greater income inequality damages environmental quality in emerging economies. In a nutshell, our study contributes to the climate change mitigation domain by incorporating income disparity as a factor of renewable energy demand. Further, the income inequality aspect of green energy demand is examined in the presence of environmental, economic, and institutional factors. This helps in propounding instrumental contribution in terms of holistic conclusions and policy

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prescriptions to counter climate emergency in South Asian economies.

However, our study is different from the existing studies mentioned above in many aspects. The variables and their specifications, suitable estimation techniques with specific econometric features, larger observations with seven South Asian countries and 23 years in our paper are distinct where a comprehensive empirical analysis is carried out. The comprehensive-analysis on the determinants of renewable energy demand is best suited for climate action needed in South Asian economies and other developing countries in socio, economic, environmental, and institutional fronts. Compared with previous work on the determinants of renewable energy demand in developed and developing economies (Andrich et al., 2013; Rahman and Velayutham, 2020; Bai et al., 2020; Uzar, 2020a,b; Asongu and Odhiambo, 2021; Churchill et al., 2021; Rahman and Sultana, 2022), this study presents four major developments in terms of data, method, and scope.

First, the paper, for the first time, uses the bottom 50% to the top 10% of the income distribution as a proxy for income inequality data sourced from the World Income Inequality Database. Second, panel data methods deployed in the estimated model allow capturing the effects of autocorrelation and cross-sectional dependence, making it further possible to better understand the drivers of renewable energy demand in South Asian economies. Third, the paper uses the income inequality data over the 1996–2018 period for seven South Asian Countries, collected before the eve of the Covid-19 pandemic. For almost three decades, critical shifts in the distribution of South Asian economic growth are seen, which have not been systematically studied from the viewpoint of understanding its role in renewable energy demand. Fourth, the paper includes economic growth, carbon emissions, and government effectiveness in renewable energy consumption function as control variables. The inclusion of these control variables along with income inequality in renewable energy demand function has theoretical implications. Income inequality through both economic and political channels can impact the renewable energy consumption (Uzar, 2020a,b). Economic growth is not a *free lunch* as far as its environmental impact is concerned. For decoupling economic growth and environmental degradation, economic growth in developing economies must promote the use of green energy keeping the environmental quality in mind. Similarly, higher environmental degradation in terms of rising carbon emissions should motivate the governments of developing economies to sensitize both consumers and producers for deployment of clean energy in consumption and production activities.

However, previous papers recognize economic growth as an important driver of renewable energy demand (Alam and Murad, 2020; Wang et al., 2021). It is true because increasing economic growth can increase the income level of the people if the growth trickle-down effect occurs. As a result, people with an increased income level can increase their renewable energy consumption if they give utmost importance to the comfort of living in a thriving natural environment.

Carbon emissions can be another factor in increasing renewable energy consumption. It shows that the natural environment comes under the threat of climate change and global warming if greenhouse gases increase due to rising carbon emissions. This is a sign of a climate emergency that calls for massive production and use of alternative energy (i.e. renewable). Thus, one can infer that a higher amount of carbon emissions can drive renewable energy for the sake of a better natural environment (Alola et al., 2019; Belaïd and Zrelli, 2019).

Finally, government effectiveness (i.e. institutional quality) can stimulate the use of renewable energy (Rahman and Sultana (2022); Cadoret and Padovano, 2016; Rahman and Sultana (2022); Huang et al., 2022). Government intervention is vital if pollution level increases. This is because rising pollution shows a greater sign of market failure that can cause loss of social welfare of people if they suffer a lot health-wise. Similarly, rising pollution indicates that market players do not account for the loss created to the natural environment. Given this, we can see that strict government intervention can better check the market failure. Perhaps, it is possible if market players can use renewable or clean energy in consumption and production activities for the benefit of the natural environment. Therefore, one can hypothesize that government effectiveness can enhance the use of renewable energy (J. Wang et al., 2022; Uzar, 2020a,b).

South Asia is one of the climate-sensitive regions of the world along with the African countries. Poverty and income inequality are also severe. The estimated catastrophic effects of climate change can have larger intensity in South Asia region because of poverty and lower level of economic development (Tol, 2009). This climate induced poverty and resource constraint have adverse effects on renewable energy production and consumption. Because it is established that poverty and financial constraint can impede the provision of renewable energy (Thomas, 2016). This adverse scenario is seeming to be more aggravating given the expected fragile and uneven economic growth in South Asia in the wake of geopolitical conflicts (Russia-Ukraine war) and the volatile international energy market. In addition to this backdrop as seen in Fig. 1, the demand for renewable energy is declining over the period 1990–2015 and carbon dioxide emissions are increasing significantly during the same period. However, during the same period, the renewable energy consumption as a percentage of total energy consumption remains approximately same at global level which is depicted in Fig. 2. Given these duo characteristics of environmental fragility and the declining renewable energy consumption share in South Asia, it is imperative to explore the possible determinants of renewable energy consumption. With keeping this background in mind, this study aims to explore the impact of income inequality on renewable energy demand along with the effects of economic growth, carbon emissions, and government effectiveness in seven South Asian countries.

However, the seven South Asian countries are selected on the basis of data availability for the empirical analysis. Given the adverse environmental impact of skewed income distribution (Mahalik et al., 2018), this study bears importance of clean energy demand for South Asia countries both in theoretical and policy settings. This study has also brought the importance of social construct (i.e. role of skewed income distribution among rich and poor) to fight the climate change and global warming. Maintaining social parity in terms of equal distribution of the income level among the citizens not only raises social harmony but also can contribute to the promotion of eco-friendly energy use (Doğan et al., 2021). The study finds the adverse effects of income inequality, economic growth, and carbon emissions on renewable energy demand. Government effectiveness drives renewable energy use. These findings are crucial for the policymakers when they engage in promoting the use of renewable energy in economic activities of South Asian economies.

The structure of the paper is follows as: Section 2 documents the extant relevant literature. In section 3, the theoretical model is specified along with data descriptions and methodologies used for the empirical analysis. Section 4 discusses the findings. Finally, conclusions and related policy proposals are presented in section 5.

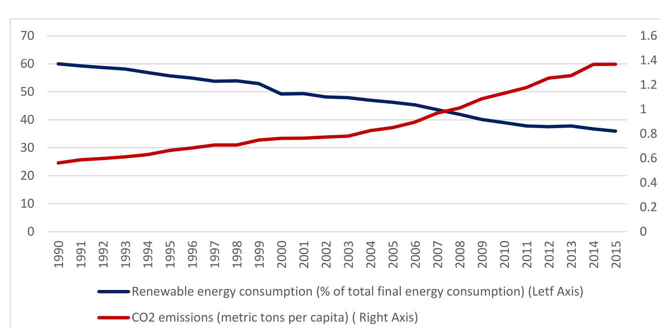

Fig. 1. Trend of renewable energy consumption and carbon dioxide emissions in South Asia.
Source: Word Development Indicators, The World Bank

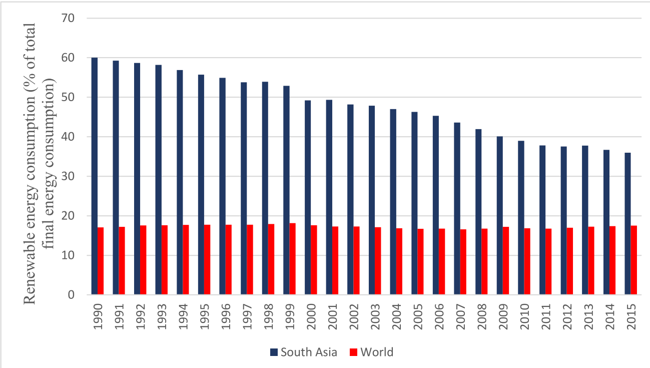

Fig. 2. Trend of renewable energy consumption in South Asia vs World.
Source: Word Development Indicators, The World Bank

2. Literature review

Research in the renewable energy field is attracting studies on determinants of renewable energy consumption from diverse domains like environment and economy. However, the socioeconomic dimensions of renewable energy consumption are a newly explored issue that incorporates urbanization, income inequality, trade openness, economic growth, etc. Uzar (2020a,b) is one of the first among the researchers to dig out the role of income inequality in affecting the provision and consumption of renewable energy by providing both theoretical and empirical basis for it. He presented economic and political channels through which income inequality affects renewable consumption in an economy. In economic terms, income inequality in a country impacts social norms by widening the gap between the rich and the poor through the unequal distribution of national income. This gives rise to consumerism, individualism, and short-termism in society. This affects the production pattern of the economy and changes the composition of factors of production, and the pattern of consumption also. This also includes the choice between the use of fossil fuels and renewable sources of energy. On the other hand, income inequality has also a role to play in renewable energy policy formulation through the institutions. Institutional quality and political demand are very often determined by the way income and wealth are distributed in a society. The quality of the institutions and popular political demand influence the environmental and energy policy of the governments. Apart from this theoretical underpinning, he carried out an empirical analysis of 43 developed and developing countries over the period 2000–2015. The analysis manifests that a reduction in income inequality increases the consumption of renewable energy. Asongu and Odhiambo (2021) also find a similar result for 39 Sub-Saharan African (SSA) countries. By taking a panel data setup stretching from 2004 to 2014 and employing generalized methods of moments and quantile regression they found that rising income inequality is an obstacle to renewable energy consumption. Shahbaz et al. (2022), Andrich et al. (2013), and Tan and Uprasen (2021) also find inhibiting effects of income inequality on renewable energy consumption. In this line, Bai et al. (2020) studied the effect of income inequality on the impact of renewable energy technological innovation on carbon dioxide emissions across Chinese provinces during 2000–2015. They find that rising income inequality weakens the abatement effect of renewable energy technological innovation on carbon dioxide emissions. On a different note, Churchill et al. (2021) employ a panel of 17 countries over the period from 1990 to 2016 in a time-varying non-parametric framework to gauge the effect of income inequality on the consumption of renewable energy and how the association changed over time. Their results indicate a negative relationship between 1995 and 2002, and a positive relationship from 2010. Overly, most of the existing studies propound that income parity societies promote renewable energy consumption.

Economic growth is also a prominent factor in the literature that affects renewable energy consumption. The basis for the effect of economic growth on renewable often called green energy can be traced from the environmental Kuznets Curve analysis (Grossman and Krueger, 1991) which states that after a certain level of income, the demand for environmentally sound goods in a society increases with successive economic growth, though it hampers the environment initially (Rahman, 2017; Rahman et al., 2021). In line with this Alam and Murad (2020) find a positive impact of economic growth on renewable energy consumption in 23 Organization for Economic Cooperation and Development (OECD) countries. Their panel data analysis over the period 1970–2012 and application of ARDL, PMG, MG, and dynamic fixed effects models postulate that economic growth encourages the use of renewable energy significantly. Wang et al. (2021) have also had similar results. Apart from this, most of the studies have focused on the causal relationship between economic growth and renewable energy consumption. Apergis and Payne (2010a,b) for 13 countries with Eurasia during 1992–2007, Apergis and Payne (2010) for 20 OECD countries during 1985–2005 and Lin and Moubarak for China during 1977–2011, found bidirectional causality between economic growth and renewable energy consumption. However, Wang et al. (2021) for China over the period 1997–2017, Ocal and Aslan (2013) for Turkey over the period 1990–2010, and Rahman and Sultana (2022) for 19 emerging countries during 2002–2019, found unidirectional causality running from economic growth to renewable energy consumption.

The existing literature signifies the ecological factors in the provision of renewable energy consumption. Assi et al. (2021) presented an empirical analysis of the relationship between environmental degradation and renewable energy consumption in the Association of South-East Asian, ASEAN +3 countries over the period 1998–2018. The results obtained from the panel-autoregressive distributed lag (P-ARDL) model show that environmental degradation significantly reduces the consumption of renewable energy. Huang et al. (2022) for 5 ASEAN countries also find an inhibitory effect of environmental degradation on renewable energy consumption during the period 1980–2018. However, Alola et al. (2019) find a contrasting result. Their study on Coastline Mediterranean Countries (CMCs) over the period 1999–2014 postulates that higher environmental degradation in terms of increased carbon dioxide emissions increases the consumption of renewable energy. As far as the causality between environmental degradation and renewable energy consumption is concerned, Belaïd and Zrelli (2019) for 9 Mediterranean countries from 1980 to 2014, Rahman et al. (2022) for 22 well-developed countries over the period 1990–2018, Rahman and Vu (2020) for Australia and Canada during 1960–2015 and Sharif et al. (2020) for top 10 polluted countries over 1990–2017 found bidirectional causality between both the variables.

The existing studies are unanimous on the role of governance and institutional factors in the provisioning of renewable energy consumption. Cadoret and Padovano (2016) trace the effect of government quality on renewable energy deployment. They postulate that maintaining government quality increases the deployment of renewable energy and lobbying in the manufacturing industries negatively affects the same. Huang et al. (2022) for selected ASEAN countries over the period 1980–2018 also find that the quality of the government increases the consumption of renewable energy. The effect of institutional quality on renewable energy consumption in a recent study by Rahman and Sultana (2022) for 19 emerging countries from 2002 to 2019, Wang et al. (2022) for 32 OECD countries during 1997–2019, and Uzar (2020a,b) for 38 countries during 1990–2015 find a positive impact of institutional quality on renewable energy consumption. Chang et al. (2018), also noted that a higher level of government effectiveness is helpful for energy efficiency.

The domain of understanding renewable energy dynamics needs an alternative measure of income inequality, which is missing in the existing literature. The impact of income distribution on renewable energy dynamics is yet to be studied in South Asian countries within a panel data setup. Further, the gap in terms of a comprehensive empirical framework by taking income distribution along ecological, economic, and institutional factors still exists. Our study intends to fill this research gap.

3. Methodology and data

3.1. Model specification

In this study, we examine the impacts of income inequality, economic growth, environmental degradation, and government effectiveness on renewable energy consumption. The econometric model for the study is developed from the review of the existing literature. Following Rahman and Sultana (2022), Huang et al. (2022), and Churchill et al. (2021), the following model is specified for our empirical investigation:

$$REC_{it} = \propto_0 + \propto_1 INQ_{it} + \propto_2 GDP_{it} + \propto_3 CO2_{it} + \propto_4 GEF_{it} + \varepsilon_{it} \tag{1}$$

In the above equation, REC refers to renewable energy consumption measured as a percentage of total final energy consumption; INQ is income inequality; GDP denotes real per capita gross domestic product; CO_2 denotes carbon dioxide emissions, and GEF denotes government effectiveness. ε indicates the error term in the model, i denotes the cross-section (country) index, and t is the time series index (year). $\propto_0$, $\propto_1$, $\propto_2$, $\propto_3$, and $\propto_4$ are the parameters of the interest of the study and are to be estimated with appropriate econometric tools. These parameters give both the directions and strengths of the relationship of the dependent variable with the independent variables. For example, a negative and statistically significant parameter indicates an inverse and strong association between the variables under consideration.

3.2. Data

To estimate the model presented in equation (1) we employ a panel data framework. We use data ranging from 1996 to 2018 for seven South Asian Countries (SACs). Data on the dependent variable in the model, renewable energy consumption is quantified as a percentage of renewable energy consumption out of total final energy consumption. It is sourced from World Development Indicator (WDI), The World Bank. The prime explanatory variable is income inequality. The data used for inequality are drawn from their calculation of the income share of the people of a country. Data on the income share of the top 10% of rich people and the bottom 50% of poor people are taken from the World Inequality Database. The income share of the top 10% of rich people is divided by the income share of the bottom 50% of poor people to get the measure of income inequality in the country. The higher the value of the ratio larger the income inequality between the rich and the poor. The control variables incorporated in the model are economic growth, environmental degradation, and government effectiveness. The real per capita GDP (constant US$ 2015) obtained from the World Development Indicator (WDI) is a proxy for economic growth. Carbon dioxide emissions are used as a proxy for environmental degradation. Because the higher concentration of carbon dioxide is hazardous to the natural environment. It is measured as carbon dioxide emissions per capita in metric tons and derived from the World Development Indicator (WDI), The World Bank. Government effectiveness in our study refers to the quality of public services and civil services; and how much they are independent of political pressures. Also, it indicates the commitment of the government towards quality policy formulation and implementation while maintaining credibility. The data on government effectiveness is obtained from the Worldwide Governance Indicators, 2021. The estimate of government effectiveness ranges from −2.5 (weak governance performance) to 2.5 (strong governance performance). The regression analysis is done by taking the natural log of real GDP per capita and the value of income inequality to smoothen their distributions.

3.3. Estimation procedure

The study employs descriptive statistics and econometric techniques to examine the relationships of renewable energy consumption with income inequality, economic growth, environmental degradation, and government effectiveness. Descriptive statistics represent the characteristic behavior of the variables under consideration and the econometric tools provide the inferences. Starting with the cross-sectional dependence test we use the appropriate panel unit root test to check the stationarity of the variables. The successive procedures involve the analyses of the direction and magnitude of the long-run associations of the dependent variable with the regressors and their robustness.

3.3.1. Cross-sectional dependence test

In traditional econometric analysis, there is an assumption that error terms in panel data structures are cross-sectionally independent. However, very often cross-sectional dependence is present in panel regression analyses. Ignoring cross-sectional dependence in estimation can have serious repercussions. Therefore, we use four tests for cross-section dependence: Breusch-Pagan (1980) LM, Pesaran (2004) scaled LM, Baltagi et al. (2012) bias-corrected scaled and Pesaran (2004) CD.

3.3.2. Panel unit root test

Confirmation of the presence of cross-sectional dependence gives rise to the case for using the second-generation panel unit root test. We employ the cross-sectional augmented I'm Pesaran-Shin (CIPS) unit test developed by Pesaran (2007). It gives more consistent results than the first-generation unit root test. CIPS test statistic is obtained from Cross-sectional Augmented Dickey-Fuller (CADF) test statistic. The CADF test statistic can be expressed as:

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \delta_i \bar{y}_{t-1} + \sum\nolimits_{j=0}^{\rho} \theta_{ij} \Delta \bar{y}_{t-j} + \sum_{j=1}^{\rho} \mu_{ij} \Delta y_{i,t-j} + \varepsilon_{it} \tag{2}$$

Where y_t is the cross-section average. Now CIPS statistic can be presented as:

$$\text{CIPS} = \frac{1}{N} \sum_{t=1}^{n} CADF_i \tag{3}$$

3.3.3. Panel cointegration tests

Cointegration test is common in panel data regression when the variables are integrated order of 1. Pedroni (1999, 2004) redeveloped the Engle and Granger (1987) test for the presence of cointegration in a panel system. The Pedroni test is reliable in the case of cross-sectional dependence and gives estimates for cointegration by allowing heterogeneous intercepts and trend coefficients across the cross-section. The null hypothesis; H_0 of no cointegration is tested. Under the null hypothesis testing, if the critical value exceeds the value of the test statistic, the null hypothesis (H_1) will be accepted against H_0, which suggests cointegration among the variables under consideration.

3.3.4. Benchmark regression analysis

To estimate the coefficients in equation (1) the study employs generalized methods of moments (GMM). In estimating the renewable energy demand function, there may be a possibility of bidirectional causality between renewable energy demand and income inequality (Topcu and Tugcu, 2020). This may give rise to the issue of endogeneity while modelling the renewable energy demand function for South Asian economies. In such scenario, Arellano and Bond (1991) suggest to use transformation of the instrumental variables. As this technique is useful in the estimation of instrumental variables, it solves the endogeneity issue by considering instruments as first differences. Similar approach is employed by Hu et al. (2022) and Ozturk and Ullah (2022) in their recent panel studies. It has, further, advantages over the initial technique for instrumental variable regression like the 2-stage least squares.

The conventional instrumental variable estimation gives unreliable results in the presence of heteroskedasticity. The advantage of GMM is it uses the orthogonality condition to overcome the problem of heteroskedasticity. Our empirical investigation employs GMM-based Arellano-Bond linear dynamic panel estimation (Holtz-Eakin et al., 1990; Arellano and Bond, 1991; Arellano and Bover, 1995), also known as difference GMM estimator. Arellano-Bond GMM estimation considers the first-difference form of the equation;

$$y_{it} - y_{it-1} = \mu_1(y_{it-1} - y_{it-2}) + \mu_2(I_{it} - I_{it-1}) + \mu_3(x_{it} - x_{it-1}) + (\varepsilon_{it} - \varepsilon_{it-1}) \quad (4)$$

Transformation of the GMM equation into the first difference form rules out the possibility of the biasedness from the omitted variables and country-specific effects. For example, some countries are technologically more advanced and developed than others in the production and consumption of renewable energy. This may also have different impacts on our explanatory variables like economic growth, and carbon emission. Which in turn can ruin our results.

3.3.5. *Tests for the robustness of the findings*

The study applies the Panel Correlated Standard Error (PCSEs) method familiarised by Bailey and Katz (2011) to capture the cross-sectional dependence in our panel setting. It is not prone to the issue of outliers and the serial correlation among the variables. The method gives reliable standard error estimates with both time-series and cross-sectional data (Reed and Webb, 2010; Millo, 2014; Ikpesu et al., 2019). We also employ Feasible Generalized Least Squares (FGLS) given by Hansen (2007) which also gives reliable estimates in the presence of cross-sectional dependency and heteroskedasticity. Additionally, we use the estimates of pooled ordinary least-squares regression with Driscoll and Kraay standard errors (Driscoll and Kraay, 1998), which are well-calibrated in the case of cross-sectional dependency (Hoechle, 2007). Further Newey–West standard errors are also carried out. The rationale for obtaining Newey-West standard errors is that it is robust and consistent in presence of possible heteroscedasticity and autocorrelation (Hoechle, 2007).

4. Empirical results

4.1. *Preliminary results*

Table 1 presents the descriptive statistics and correlation matrix. The panel data set has 23-time series units and seven south Asian countries. So, the study has a reliable number of observations, i.e. 161. It is quite noticeable from the results that all the variables are widely dispersed around their respective means. In renewable energy consumption, the disparity among south Asian countries is huge. The maximum and minimum values suggest that some are extensively using renewable sources of energy in line with the climate change mitigation policy and others' excessive dependence on fossil fuels is worrisome. Similarly, regional income inequality in the south Asian region is also very high. This inequality can be seen both across the countries (dispersed real GDP per capita among countries) and within the countries (dispersed income inequality variable for individual country). However, all the south Asian countries lack the effectiveness of governance (a maximum value of 0.9 is way below the highest estimate). From the matrix of correlations, it can be noticed that all the explanatory variables, income inequality, economic growth, environmental degradation, and government effectiveness are negatively correlated with renewable energy consumption. Although the correlation only with government effectiveness is not statistically significant. A more consistent and reliable inference is to be drawn from the successive regression analysis.

The preliminary test results for cross-sectional dependency are presented in Table 2. For all four test statistics, the null hypothesis of cross-sectional independence is rejected at a minimum level of significance, which indicates that there exist effects of some unobserved common elements, present in all the countries under consideration and impacting each of them. After the confirmation of the presence of cross-sectional dependence, the panel unit root test is done using the CIPS method. The results of the unit root test are given in Table 3. The null hypothesis of unit root for all the variables is rejected at the first difference in all three specifications, without constant and trend, with constant, and with the trend. So, all the variables are integrated order of 1 and non-stationary at the level.

When all the variables have an integrating property of order 1, as in our case, it is necessary to check whether the variables are correlated in the long-run. Without the presence of long-run association, the regression results will be spurious and can be attributed to their co-movements. Table 4 presents the results of the cointegration test propounded by Pedroni. The cointegration is done over the model from

Table 2
Cross-sectional dependence test.

Variables	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
REC	326.33***	47.11***	46.95***	17.92***
INQ	231.93***	32.55***	32.39***	5.05***
GDP	452.01***	66.51***	66.35***	21.25***
CO2	370.41***	53.92***	53.76***	19.19***
GEF	83.56***	9.65***	9.49***	2.60***
After Fixed Effect				4.489***
After Random Effect				4.458***

Table 1
Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Renewable energy consumption (% of total final energy consumption)	161	53.95	28.197	1.118	93.456
GDP per capita (constant 2015 US$)	161	2358.878	2471.82	507.853	9822.54
Log of GDP per capita	161	7.379	.817	6.23	9.192
CO2 emissions (metric tons per capita)	161	.919	.778	.089	3.704
Government Effectiveness	161	−.248	.484	−1.054	.901
Inequality (Top 10 to Bottom 50)	161	3.194	.731	2.044	5.129
Inequality (Top 1 to Bottom 50)	161	1.289	.517	.712	3.153

Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Renewable energy consumption	1.000					
(2) GDP per capita	−0.715***	1.000				
(3) CO2 emissions	−0.714***	0.868***	1.000			
(4) Government Effectiveness	−0.018	0.311***	0.331***	1.000		
(5) Inequality T10/B50	−0.217***	0.329***	0.212***	0.679***	1.000	
(6) Inequality T1/B50	−0.423***	0.449***	0.267***	0.595***	0.920***	1.000

Note: ***$p < .01$.

Table 3
Panel unit root test (CIPS both at level and first differences).

Variable Name		Without Constant and Trend	With Constant but no Trend	With constant and trend	Remarks
Renewable energy consumption	At Level	−0.943	−0.967	−2.634	I(1)
	1st difference	−4.205***	−4.486***	−4.646***	
Log of GDP per capita	At Level	−0.151	−1.895	−1.640	I(1)
	1st difference	−3.289***	−3.418***	−3.899***	
CO2	At Level	−0.703	−1.106	−1.453	I(1)
	1st difference	−4.190***	−4.445***	−4.843***	
Government Effectiveness	At Level	−1.496	−2.254	−2.518	I(1)
	1st difference	−4.369***	−4.452***	−4.389***	
Inequality T10/B50	At Level	−1.451	−1.426	−1.275	I(1)
	1st difference	−2.002***	−2.299*	−2.281	
Critical values					
10%		−1.570	−2.210	−2.73	
5%		−1.720	−2.330	−2.86	
1%		−1.980	−2.570	−3.1	

Note: ***$p < .01$, *$p < .1$.

Table 4
Pedroni test for cointegration.

	Statistic	p-value
Modified Phillips–Perron t	1.8476**	0.0323
Phillips–Perron t	−3.3058***	0.0005
Augmented Dickey–Fuller t	−3.6039***	0.0002

Note: ***$p < .01$, **$p < .05$.

equation (1). All three test statistics of the cointegration test confirm the presence of long-run relationships among the variables in the model. This calls for regression analysis based on the discussed model.

4.2. Benchmark results and discussions

Table 5 presents the results obtained from the panel dynamic GMM. The main finding of the analysis is that renewable energy consumption has an inverse relationship with income inequality in the selected south Asian countries. It implies that a rise in income inequality in a country discourages the demand for renewable energy. So, it can be said that rising income inequality between the rich and the poor is detrimental not only to the social framework and standard of living of the people but also to the provisioning of clean and green energy in the south Asian region. In a more general sense, it can be said that income inequality harms climate change mitigation programs and poses a serious challenge concerning to it. The grounds for such a finding are multi-faceted. Income inequality can have economic, social, and political repercussions on renewable energy consumption.

In an economically unequal society, the people at the bottom of the income level face double disadvantages of high cost and low awareness concerning the provision of renewable and non-conventional sources of energy. Due to lower income, they are not able to access the facility coming out from the green energy technology. Initially, the installation cost for production, storage, transmission, and consumption capacities is huge for a country to bear where the lion's share of the income is kept by very few. Further, the concentrated income among the rich has a negligible tendency to trickle down to the poor in case of higher income inequality in a country. This leaves a minimal opportunity for an economically unequal society to opt for renewable energy consumption. In social terms, income inequality between the rich and the poor creates a social imbalance with groupings and the division of society. This gives rise to the feudal tendency in the operation of economic activities. Where the goods are bestowed with the upper rich and bads are vested with the lower poor. So, any advanced and improved technologies and products are regarded as the cup of tea of the few rich only and the poor remain deprived. This argument can also be extended to the distribution of renewable energy and its consumption. Thereby, income inequality limits the consumption of renewable and clean energy. Further, due to the information and knowledge gap that arose out of the income inequality between rich and poor, there exists a higher possibility of corruption at different levels of governance. A corrupt and ununiformed society is less likely to have the underlying political gill for the use of renewable energy. In such cases, an unequal society will seek an economic cost and benefits approach only and will not consider the ecological context of human life. So, higher income inequality can reduce the consumption of renewable energy also through the channel of corruption. Our finding is consistent with the findings of Uzar (2020a, b) who conducted for a sample for 43 selected developed and developing countries. The similar analysis by Asongu and Odhiambo (2021) on 39 Sub-Saharan African countries also supports our finding.

From the GMM estimation result, it can also be noticed that economic growth reduces renewable energy consumption. This finding is unexpected and interesting. As per the EKC hypothesis, the demand for a clean and quality environment initially decreases and then increases with the increase in income level. Regarding this, the south Asian economies are said to be operating in the initial phase of the EKC hypothesis. For most of the countries in the region, rapid and consistent economic growth is still a priority to counter their fundamental economic problems like poverty and unemployment. So, the choice for production technique is made on economic grounds rather than an environmental one. Fossil fuels for these countries are a readymade option for them to accelerate their production and growth which is

Table 5
Panel dynamic GMM: Linear dynamic panel-data estimation.

REC	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
INQ	−2.225***	.189	−11.77	0	−2.595	−1.854
GDP	−16.553***	.392	−42.23	0	−17.321	−15.785
CO2	−1.573***	.353	−4.45	0	−2.265	−.88
GEF	−.742	.485	−1.53	.126	−1.692	.208
Constant	184.461***	2.637	69.94	0	179.292	189.63
Mean dependent var	53.950	SD dependent var				28.197
Number of obs	161.000	Chi-square				3831.689***

Note: ***$p < .01$.

easily available and cost-effective. So there remains a thin scope for using renewable energy with the growth of the economies in the South Asian region. However, this result is not consistent with the results of existing recent studies (i.e. Alam and Murad, 2020 for 23 OECD countries and Wang et al., 2021 for China).

Environmental degradation is found to have a significant and negative relationship with renewable energy consumption. This refers to a situation where a polluted society has a lesser tendency to use energy from renewable sources. This can be attributed to the lax implementation of the policies concerning the protection of the natural environment in the south Asian region. The same argument is extended by Assi et al. (2021) for ASEAN +3 countries where excessive environmental pollution reduces renewable energy demand. Another finding consistent with our result is obtained by Huang et al. (2022) for the selected ASEAN countries. However, our finding is contrast to the finding of Alola et al. (2019) for Coastline Mediterranean Countries. Government effectiveness has a negative relationship with renewable energy consumption. This finding is not statistically significant and calls for further robustness check.

4.3. Robustness of the results

The results obtained from the GMM are compared with the results from the other estimation techniques to check its robustness. It can be seen from Table 6 that income inequality, economic growth, and environmental degradation have inhibitory impacts on renewable energy consumption across the estimates of PCSEs, FGLS, Regression with Newey–West standard errors, and Regression with Driscoll-Kraay standard errors. So, the results and discussions presented in the above subsection are robust. However, the estimates of these four tests for government effectiveness are not consistent with the estimate of GMM for the same variables. In the robustness check, we found that government effectiveness is positively related to renewable energy consumption. This is attributed to the commitment of the governments in these selected south Asian countries towards the introduction and implementation of quality policy for the provision of renewable energy. With the rising concern over the climate calamities, the call for climate change mitigation initiatives is getting prominence. These endeavours are now reflected in many multilateral and international forums (Doğan et al., 2020). In addition to this, the countries are individually setting their goals for mitigating climate change (for example India's carbon neutrality goal set to be achieved by 2070). To achieve these targets, effective and committed governance are coming out to be implemented and execute environmental quality enhancing energy policies. This may be the reason we get contributory effects of governance effectiveness on renewable energy demand. This finding is consistent with the findings of Huang et al. (2022) for selected ASEAN countries and Cadoret and Padovano (2016). The R^2 of the tests depicts that more than 65% of changes in renewable energy demand are explained by income inequality, economic growth, environmental degradation, and government effectiveness and the rest 35% variation of the renewable energy demand is also contributed by the factors embodied in the residual term. Overall, it shows the important role of renewable energy demand determinants in our study.

5. Conclusion and policy implications

This study explores the determinants of renewable energy demand in seven South Asian economies. We constructed a theoretical framework based on the associations of renewable energy demand with income inequality, economic growth, carbon dioxide emissions, and government effectiveness. The panel data analysis for the period 1996–2023 uses GMM, FGLS, PCSEs, and robust standard errors techniques. The findings are robust and reliable with respect to panel methods used in the analysis. We find the adverse effects of income inequality, economic growth, and carbon dioxide emissions on renewable energy demand. Government effectiveness drives renewable energy use. These findings bear important policies for a sustainable environment in South Asian economies. In these economies between 1996 and 2018, the income inequality has contributed the reduction in the renewable energy demand. Economic growth reduces renewable energy demand, which is an indication of fossils-driven output. Therefore, the South Asian countries are reluctant in using renewable energy in economic activities. The carbon dioxide emissions reduce renewable energy use. It shows that rising pollution level does not encourage the usage of renewable energy in South Asia. However, effective government practices significantly promote the renewable energy demand.

The above findings bear crucial policy implications for the development of renewable energy sector in South Asia. The development of clean energy sector could also help countries in South Asia to have green growth and sustainable development in long-run. Therefore, it is essential for us to discuss the policy insights of our findings. We find that greater income inequality reduces renewable energy demand. It suggests that policymakers and governments in South Asia need to reduce the income gap between wealthy and poor groups so that it becomes possible to increase renewable energy demand. Bridging the income gap in the society can strengthen the economic and political channels that may help in raising renewable energy demand. In this regard, direct benefit transfer, transfer payment, and effective economic income distribution schemes (tax, allowance) can also serve the purpose. Increasing economic growth reduces renewable energy demand. It shows that inclusive economic growth does not take place; therefore, the bottom population could not consume renewable energy due to lesser income level at their disposal. Hence, the governments in South Asia should try to include the bottom population in the economic growth process for the greater demand of renewable energy.

Similarly, the rising pollution level discourages renewable energy demand in South Asia. This is true because producers in South Asia do not use clean energy due to its being expensive. Therefore, rising pollution can arise due to the greater use of fossil fuels and lesser use of renewable sources. In such a situation, rising pollution can be controlled if renewable energy demand could be integrated into the consumption

Table 6
Results from the different robustness tests.

Variables	Regression with Newey–West standard errors	Regression with Driscoll-Kraay standard errors Pooled OLS	Panels corrected standard errors (PCSEs)	FGLS regression	Linear dynamic panel-data estimation
INQ	−13.515***	−13.515***	−13.515***	−13.515***	−2.225***
GDP	−5.418	−5.418*	−5.418**	−5.418*	−16.553***
CO2	−24.666***	−24.666***	−24.666***	−24.666***	−1.573***
GEF	29.984***	29.984***	29.984***	29.984***	−.742***
Constant	167.194***	167.194***	167.194***	167.194***	184.461***
	F(4, 156) = 74.75***	F(4, 22) = 898.88***	Wald chi2(4) = 421.15***	Wald chi2(4) = 305.40***	Wald chi2(4) = 3831.689***
		R-squared = 0.6548	R-squared = 0.6548	Log likelihood = −679.9372	

Note: ***p < .01, **p < .05, *p < .1.

and production activities at a greater scale. Finally, government effectiveness increases renewable energy demand. We suggest that effective government intervention should continue both at micro and macro levels to protect the natural environment via enhancing renewable energy usage in economic activities.

However, our study is limited to seven countries only. Its finding cannot be generalized to other developing economies given their heterogeneous socio-economic and political characteristics. So in line with our study, there exists a scope for future research. Other robust measures of income inequality can be employed for the future study in a larger panel framework for further generalization of the results across developing economies. Along with this, new determinants of renewable energy demand can be explored with the incorporation of possible socio-economic attributes.

CRediT authorship contribution statement

Mantu Kumar Mahalik: Supervision, Writing – original draft, & Refined Revised Draft. **Gupteswar Patel:** Data Collection &, Data curation, Formal analysis, Writing – original draft, & Refined Revised Draft. **Bimal Kishore Sahoo:** Formal analysis, Writing – original draft, & Refined Revised Draft. **Mohammad Mafizur Rahman:** Writing – original draft, & Refined Revised Draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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