Cite this Article: Khan, R. M., & Farooq, S. (2024). Energy Dependency of South Asian Economies: A Comparative Analysis. *JHEDS*, *4*(1), 90-103. https://doi.org/10.59219/jheds.04.01.48

JHEDS
JOURNAL OF HIGHER EDUCATION AND DEVELOPMENT STUDIES

Energy Dependency of South Asian Economies: A Comparative Analysis

Raza Muhammad Khan [1] Sohail Farooq [2]

Volume 4, Issue 1 (Winter 2024) | ISSN (Online): 2959-300X | ISSN (Print): 2959-3174 | Pages: 90–103

Corresponding Author: Raza Muhammad Khan. ✉ razamkhan11@gmail.com

Abstract: The main purpose of this research study is to assess and compare energy dependency (ED) performance scores by focusing on South Asian economies within the Data Envelopment Analysis (DEA) framework. Data is utilized for the period 2003 to 2021. The results indicate that the energy sectors of Pakistan and India exhibited inefficient performance within the South Asian region. Both countries faced challenges in effectively using and producing energy from their primary energy resources, leading to a remarkable growth rate in ED. Considering these findings, it is crucial for Pakistan and India to critically review their existing energy policies based on scientific principles. The primary objective should be to develop and implement an appropriate energy policy that effectively reduces their dependency on energy imports and addresses the inefficiencies within their energy systems.

Keywords: South Asian Economies, Data Envelopment Analysis, Energy Efficiency, Energy Dependency

Introduction

Since the dawn of the industrial age, the living conditions of billions of people have been completely transformed by energy usage, as it provides remarkable comfort in all human activities to perform increasingly productive tasks. Energy is a foundation stone of the modern industrial economy. Energy is, therefore, used as a powerful engine for the socioeconomic development of a country (Akinsemolu, 2018). The excessive utilization of fossil fuels gives rise to significant economic and environmental challenges, such as a rise in the cost of living and the emission of greenhouse gases. These problems have directly contributed to the worsening of poverty and the intensification of global warming (Jochem, Rothengatter, & Schade, 2016). (Ibrahim, Dincer, & Acar, 2018) further emphasize the harmful consequences of extensive fossil fuel consumption, including resource depletion, heightened CO_2 levels, and worsened climate change, projecting a continued surge in energy demand over the next three decades.

South Asia is a region with a population of approximately 21.4% of the world's population, India leads with a population of 1428.63 million (See Table-1).

[1] PhD Scholar, Department of Economics, Hazara University Mansehra, Khyber Pakhtunkhwa, Pakistan.
Email: razamkhan11@gmail.com
[2] Assistant Professor, Department of Economics, Hazara University Mansehra, Khyber Pakhtunkhwa, Pakistan.
Email: thesohailfarooq@hotmail.com

Table 1
South Asian economy's GDP and population

	GDP			Population	
Economies	**Total Billion US$**	**Annual Growth**	**Per Capita**	**Total Millions**	**Annual Growth (%)**
Afghanistan	14.27	-6.2	408	42.24	2.68
Bangladesh	460	7.3	1785	172.95	1.01
Bhutan	2.77	5.2	2992	0.79	0.63
Maldives	6.17	2	11036	0.52	-0.6
Pakistan	375	-0.17	1696	240.49	1.96
Sri Lanka	74.4	1.6	3988	21.89	0.25
India	3417	7.6	2090	1428.63	0.92
Nepal	40.83	1.9	1083	30.90	1.11

Data Source: Population (World Population Review-2022), GDP Trading Economics -2021).

Meanwhile, Pakistan ranks second with 240.49 million people. Bangladesh holds the eighth position globally and third in South Asia, with 172.95 million people (World Population Review, 2022). Prior to the COVID-19 pandemic, SAEs, s experienced robust average annual GDP growth rates exceeding 6%. However, they experienced a 7.7% decline in regional growth in 2020. Despite this, these eight SAEs contributed 4.3% to the global GDP in 2023, amounting to USD 101326 billion (Trading Economics, 2021).

Primary Energy Consumption (PEC) and Production (PEP) in SAEs

The concept of primary energy refers to energy contained within natural resources before undergoing human-induced conversion. This includes the energy required by end users, along with inefficiencies and energy losses during the transformation of raw materials such as oil, gas, coal, uranium, hydro, and wind into usable forms like electricity (J, Cleveland, & Morris, 2015). Data from Table 2 shows the PEC and PEP of SAE.

Table 2
PEC and PEP in SAEs by fuel

		PEC				PEP			
Exajoules		**Bang.**	**India**	**Pak.**	**Sri Lanka**	**Bang.**	**India**	**Pak.**	**Sri Lanka**
Natural Gas	2021	1.10	2.24	1.62	-	0.85	1.03	1.18	-
(EJ)	2022	1.05	2.09	1.38	-	0.84	1.07	1.03	-
Coal	2021	0.15	19.30	0.72	0.07	-	13.38	0.19	-
(EJ)	2022	0.18	20.09	0.64	0.06	-	15.02	0.19	-
Oil	2021	0.46	9.25	1.02	0.23	0.01	1.4	0.18	-
(EJ)	2022	0.55	10.05	0.99	0.20	0.01	1.3	0.16	-
Nuclear	2021	-	0.40	0.14	-	-	0.16	0.06	-
(EJ)	2022	-	0.42	0.20	-	-	0.17	0.08	-

Hydro (EJ)	2021	0.01	1.51	0.35	0.07	0.003	0.58	0.14	0.03
	2022	0.01	1.64	0.33	0.07	0.003	0.63	0.13	0.03
Renewable	2021	0.04	1.82	0.05	0.01	0.002	1.71	0.02	0.005
	2022	0.01	2.15	0.06	0.02	0.002	2.02	0.06	0.006
Total PEC and PEP	2021	1.76	34.52	3.90	0.38	0.87	18.26	1.77	0.04
	2022	1.8	36.44	3.60	0.35	0.86	20.21	1.65	0.04

Author's own calculations based on BP-Statistical Review 2023.

From 2021 to 2022, the PEC of Bangladesh and India increased, while it decreased in the case of Pakistan and Sri Lanka. Natural gas is the primary source in the case of Bangladesh and Pakistan, Coal in India, and Oil in Sri Lanka. These figures underscore the notable energy consumption and production trends in these countries. SAE has witnessed a significant increase in energy demand over the past two decades, driven by population and industrial growth. This annual increase is projected to double by 2050, but 67% of energy is imported, making it susceptible to oil and gas price fluctuations (Chen, 2022).

Table 3 illustrates that except for Bangladesh, in the case of the rest of the sample countries, the Energy Deficiency had declined in 2022 as compared to the levels of 2021. SAEs, are heavily relied on imported fossil fuels, exposing them to energy efficiency issues and frequent oil shocks (Krishnan, 2009). The reliance on imported fossil fuels to fulfill rising energy needs is proving to be ineffective and costly for SAEs. The Covid-19 pandemic and Russia-Ukraine conflict have led to a volatile global fossil fuel market. India and Pakistan are particularly affected by the surge in coal prices, threatening the financial sustainability of their coal power plants and exacerbating circular debt issues in Pakistan's power sector (Das, 2022).

Table 3
Primary energy deficiency in SAEs

Exajoules	**Bangladesh**		**India**		**Pakistan**		**Sri Lanka**	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Nat. Gas	-0.25	-0.21	-1.21	-1.02	-0.44	-0.35	0	0
Coal	-0.15	-0.18	-5.92	-5.1	-0.53	-0.45	-0.07	-0.06
Oil	-0.45	-0.54	-7.85	-8.75	-0.84	-0.83	-0.23	-0.2
Nuclear	-	-	-0.24	-0.25	-0.08	-0.12	0	0
Hydro	-0.01	-0.01	-0.93	-1.01	-0.21	-0.2	-0.04	-0.04
Renewable	-0.04	-0.01	-0.11	-0.13	-0.03	-0.001	-0.01	-0.014
Total	-0.89	-0.94	-16.26	-16.23	-2.13	-1.95	-0.34	-0.31

Authors' own calculations based on BP-Statistical Review 2023.

India's expenditure on crude oil imports surged to USD 119.2 billion in fiscal year 2021-22, reflecting its status as the globe's third-largest oil consumer and importer, with projections indicating a potential surpassing of USD 260 billion in energy imports in FY2023 (India Economic Survey, 2021-22). Similarly, Pakistan saw a doubling of its import bill in FY22, reaching USD 23.32 billion, driven by surges in global oil prices (Pakistan Economic Survey, 2021-22). Bangladesh faces challenges managing its energy import expenses, with petroleum product imports reaching a record high of USD 1.54 billion in FY22, straining the country's foreign currency reserves (Bangladesh Bank, 2022). Sri Lanka's reliance on imported energy sources exacerbates its economic challenges, with fuel imports reaching USD 3.7 billion in 2021 (Seneviratne, 2022).

The increase in energy import bills highlights energy security concerns in SAE, emphasizing the need for reliable and affordable energy access. To address these concerns, SAEs are diversifying energy sources, investing in renewables, and improving infrastructure and efficiency (Toman, 2002). This shift aims to reduce dependency on imported fossil fuels, mitigate supply risks, and support economic growth through sustainable energy solutions.

Energy Dependency (ED) level of SAEs

SAE, s faces a severe energy crisis despite its remarkable economic growth, driven by a population exceeding 1.7 billion people and a GDP growth averaging 5.2% over the past two decades, with projections indicating a potential increase to approximately 6.6% by 2022 (Blackman & Anne, 2022). A striking characteristic of these economies is their heavy reliance on a single energy source for over half of their total electric power generation, showcasing a diverse energy mix across the region. To meet their escalating energy demands, SAEs heavily rely on energy imports, particularly oil and natural gas. Despite efforts to enhance EE and invest in renewable energy sources, several SAEs still have renewable energy accounting for less than 5% of their total energy consumption. ED represents the share of a country's total energy requirements that are fulfilled through imports from other nations. It is calculated as:

$$\text{ED} = \text{Net imports/GAE (Gross Available Energy)}$$

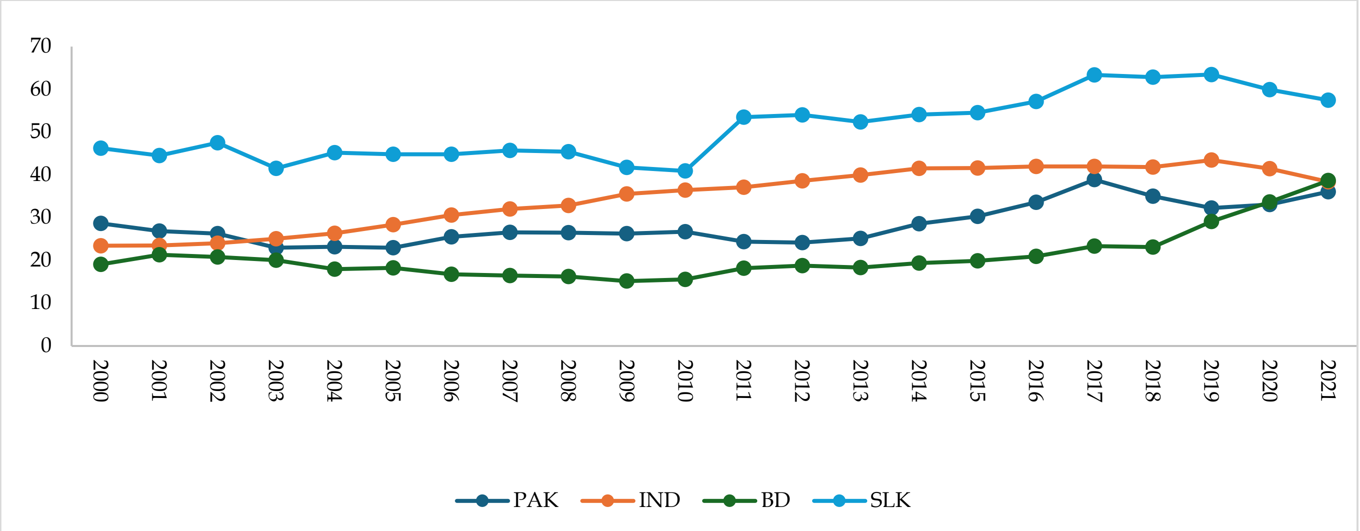
$$\text{Net imports} = \text{Total Imports} - \text{Total Exports}$$

$$\text{GAE} = \text{Prim. Prodn.} + \text{Recovered \& recycled products} + \text{Imp.} - \text{Exp.} + \text{Stock changes}$$

Following the EUROSTAT methodology (Eurostat, 2020), we analyzed the ED levels of SAEs using data from the International Energy Dataset. As illustrated in Figure 3, among the SAEs, Sri Lanka recorded the highest ED level at 57.5% in 2021, peaking at 63.5% in 2019, and lowest at 40.9% in 2010. India had 38.4% in 2021, with a peak at 43.5% in 2019 and a minimum of 23.4% in 2000. Pakistan reached 36.1% in 2021, with its highest at 38.9% in 2017 and lowest at 22.97% in 2005. At the same time, Bangladesh peaked at 38.7 in 2021. This heavy reliance of SAEs on imported energy is critically affecting its socio-economic and political landscape. Making it critical to scientifically investigate the inefficiencies of basic energy indicators and enable policymakers to reduce the ED by adjusting these indicators effectively.

Figure 1

ED of South Asian Economies (in %).



Source: Figure depicts the ED level in SAE, calculated by the author and based on IEA data set

Literature Review

A brief review of the literature reveals that substantial studies – (Khalil & Zaidi, 2014), (Komal & Abbas, 2015), (Nadeem & Munir, 2016), (Rafique & Rehman, 2017), (Rehman & Deyuan, 2018), (khan, Farooq, & Gilal, 2020), (Selvanathan et al., 2020), (Amin, Khan, & Rahman, 2022), and (Sumaira & Siddique, 2022), had made attempts to land in the discipline of Energy economics mainly addressing the overall consumption and, in some cases, sectoral usage of the energy in the South Asian region collectively and at country level. Some of these studies - (Qazi, Ahmed, & Mudassar, 2012), (Shahbaz & Feridun, 2012), (Hussain, Javaid, & Drake, 2012), (Mahmood & Kanwal, 2017), (Aklin, Bayer, Harish, & Urpelainen, 2017), (Baz, Xu, Ampofo, Ali, & Khan, 2019), and (Latief & Lefen, 2019)- even had tried to enquire the associations between energy usage and the economic variables.

Numerous studies have been conducted to investigate energy efficiency (EE) in relation to SAE. For instance, a study conducted by (Danish, Zhang, Wang, & Wang, 2017) examined Pakistan's EE from 1970 to 2012. With the application of sensitivity analysis, they arrived at the conclusion that the renewable energy scenario was the most suitable for the country. In a comprehensive study conducted by (Rafique & Rehman, 2017), the future energy scenario of Pakistan was assessed. They utilized a simulation model incorporating three-dimensional indicators and a combined total of 11 indicators under various scenarios. The study aimed to reduce energy imports from 2005 to 2050. The researchers provided a detailed analysis of the security concerns surrounding the electrical energy supply in Pakistan. Additionally, they thoroughly deliberated on the inequality /gap between energy demand and supply, the exhaustion of energy reserves, energy security concerns, and the mounting energy costs within the context of Pakistan.

(Islam, et al., 2014) Carried out an extensive study centred around the concept of energy security in Bangladesh. Where they tried to cover various aspects, including availability, status, policies, achievements, and future prospects of energy alternatives in Bangladesh, they concluded that there is a need for diverse energy options to improve energy efficiency in Bangladesh. Another research work conducted by (Zaman & Brudermann, 2018) assessed energy services security in relation to energy governance frameworks and potential conflicts arising from current EE policies in achieving the desired environmental standards targets. They have developed a new framework for energy governance to assess the energy service security of Bangladesh's electricity system to ensure reliable and secure energy services within the country. The study emphasizes the need to merge energy governance and energy security perspectives to address the challenges associated with energy transition, especially in Bangladesh.

A research work (Pode, 2010) focused on India's energy security and strategies to reduce its dependence on foreign energy sources. In his research enquiry, he explored various dimensions of India's energy sector, giving particular emphasis to the diverse array of energy sources and the composition that constitutes India's overall energy mix. By scrutinizing these components, he tried to bring to light the possible paths of EE that lie ahead for India.

The overall SES index for the supply subsystem was determined to be approximately 0.75, indicating a shortfall from the desired ideal value of 1.0. From the results, they concluded that this approach offers an efficient method for monitoring the performance of the energy supply sub-system and thereby recommended the utilization of this approach in the formulation of policy interventions aimed at enhancing the overall SES index in the Indian context.

Although these studies offered novelty, they failed to take into account the ED level and its performance scores on the basis of basic energy indicators in the context of South Asia. Hence, there is a need for a more comprehensive study that considers a wider range of indicators and employs DEA to accurately measure the ED performance score on the basis of basic energy indicators within the context of South Asia. Certainly (Sözen, Alp, & Iskender, 2014) and (Ozturk, 2014) were among the pioneers who highlighted the issue of Energy Dependency in their respective studies. (Sözen, Alp, & Iskender, 2014), Evaluated the ED of 25 European Union member states. They evaluated the ED performance score based on energy indicators for the period from 1998 to 2006. The analysis was done using a non-parametric DEA approach. They concluded that Turkey was not performing, and other EU countries were not performing either. They suggested that Turkey should reduce its reliance on imported energy and use its available indigenous resources more efficiently. Hence, the available literature lacks assessments of ED performance scores for SAEs, highlighting a research gap. Therefore, this study seeks to fill this research gap by utilizing the DEA methodology to assess the ED efficiency score in SAEs. It will provide crucial insights for formulating energy policies and promoting efficient ED practices within the region.

Methodology

DEA, a non-parametric method, is used to assess the efficiency of decision-making units (DMUs) by utilizing multiple inputs and outputs. DEA is also useful for analyzing ED, offering insights into the efficiency of different economies regarding their energy consumption usage and production. Hence, it helps policymakers identify and address inefficiencies in energy consumption and production at the country level. A DMU Efficiency for a single input-output is calculated as Output/Input, whereas for multiple inputs and outputs, its ratio of the weighted sum of outputs and the weighted sum of inputs (Charnes, Cooper, & Rhodes, 1978). The assignment of weights, crucial for fair comparisons, follows a linear programming approach to optimize the input weights, ensuring all DMUs' efficiency does not exceed one (Banker & Thrall, 1992). This method not only simplifies computation but also supports the sharing of best practices among countries to improve energy efficiency and reduce ED (Thanassoulis, 2001).

Results

Descriptive Statistics

Table 5 provides a detailed analysis of ED levels in SAEs. As per data, Sri Lanka has the highest average ED rate at 50.97%; however, it has high fluctuations, indicating a significant reliance on imported energy. With rising unemployment and poverty, Sri Lanka's dependence has led to severe economic and political instability, especially evident since April 2022. In comparison, India, Pakistan, and Bangladesh have lower average ED rates of 34.83%, 28.37%, and 20.97%, respectively, with Pakistan experiencing the least variability. Regionally, the average ED growth rate is 33.78%, ranging from a high of 63.48% to a low of 15.15%, with a standard deviation of 12.75%, reflecting the impact of limited energy reserves across SAEs.

Table 4

Descriptive statistics of ED level in South Asia

Economy	Minimum	Maximum	Mean	Std. Deviation
Pakistan	22.97	38.88	28.37	4.58
India	23.44	43.46	34.83	7.03
Bangladesh	15.16468	38.65472	20.96536	5.849375
Sri-Lanka	40.92284	63.48294	50.96695	7.466102
South Asian Region	15.16468	63.48294	33.78337	12.75169

Source: Author's own calculation on IEA energy balances data set.

ED Performance Scores (on the basis of CCR and BCC) of the Model

Analysis of energy system efficiency in SAEs, detailed in Table 6, shows varying performances. Initially, in 2003, Pakistan and India displayed DRS with Pakistan achieving efficiency scores of 44% on CRS, 59% on VRS, and 75% on SE. India reported slightly higher scores of 59% on CRS, 69% on VRS, and 85% on SE. Both countries indicated the potential for significant input savings through operational improvements and optimal sizing. In contrast, Bangladesh and Sri Lanka exhibited optimal efficiency in 2003, scoring 100% across CRS, VRS, and SE. This high level of efficiency persisted through 2021, reflecting effective management and operation based on economies of scale. By 2021, Pakistan and India showed marked improvements, moving to IRS, with Pakistan recording 77% on CRS, 85% on VRS, and 80% on SE, and India matching closely with 77% on CRS, 84% on VRS, and 80% on SE. This progression suggests continued opportunities for input reduction and efficiency gains.

Despite regional advances, with average efficiency scores reaching 85% on CRS and 91% on VRS by 2021, SAE, s still lags in achieving global efficiency standards, highlighting the need for further investment in modern technology and improved energy management practices. The consistently high performance of Bangladesh and Sri Lanka emphasizes their sustained operational excellence, while the improvements in Pakistan and India point to ongoing efforts to optimize energy management in the face of initial inefficiencies.

Table 5

ED performance scores on the basis of CCR and BCC of the Model

Year	CRS				VRS				SE				Returns to Scale			
	Pak	Ind.	B. D	S.L.	Pak	Ind.	B. D	S.L.	Pak	Ind.	B. D	S.L.	Pak.	Ind.	B.D.	S.L.
2003	0.44	0.59	1	1	0.59	0.69	1	1	0.75	0.85	1	1	DRS	DRS	CRS	CRS
2004	0.48	0.66	1	1	0.67	0.75	1	1	0.71	0.89	1	1	DRS	DRS	CRS	CRS
2005	0.47	0.7	1	1	0.64	0.82	1	1	0.74	0.85	1	1	DRS	DRS	CRS	CRS
2006	0.59	0.82	1	1	0.83	0.9	1	1	0.71	0.91	1	1	DRS	DRS	CRS	CRS
2007	0.63	0.86	1	1	0.86	0.9	1	1	0.73	0.95	1	1	DRS	DRS	CRS	CRS
2008	0.71	0.87	1	1	0.85	0.87	1	1	0.83	0.99	1	1	DRS	IRS	CRS	CRS
2009	0.76	0.98	1	1	0.9	0.98	1	1	0.84	0.99	1	1	DRS	IRS	CRS	CRS
2010	0.83	1	1	1	0.95	1	1	1	0.88	1	1	1	DRS	CRS	CRS	CRS
2011	0.72	0.77	1	1	0.75	0.78	1	1	0.97	0.98	1	1	DRS	IRS	CRS	CRS
2012	0.75	0.78	1	1	0.75	0.79	1	1	0.99	0.99	1	1	IRS	IRS	CRS	CRS
2013	0.76	0.78	1	1	0.77	0.8	1	1	0.99	0.98	1	1	IRS	IRS	CRS	CRS
2014	0.81	0.77	1	1	0.82	0.78	1	1	0.99	0.99	1	1	IRS	IRS	CRS	CRS
2015	0.86	0.78	1	1	0.87	0.79	1	1	0.99	0.99	1	1	DRS	IRS	CRS	CRS
2016	0.94	0.79	1	1	1	0.8	1	1	0.94	0.99	1	1	DRS	IRS	CRS	CRS
2017	1	0.68	1	1	1	0.69	1	1	1	0.99	1	1	CRS	IRS	CRS	CRS
2018	1	0.67	1	1	1	0.67	1	1	1	1	1	1	CRS	CRS	CRS	CRS
2019	0.92	0.65	1	1	1	0.66	1	1	0.92	0.99	1	1	DRS	DRS	CRS	CRS
2020	0.78	0.66	1	1	0.83	0.74	1	1	0.94	0.9	1	1	IRS	IRS	CRS	CRS
2021	0.77	0.64	1	1	0.84	0.8	1	1	0.92	0.8	1	1	IRS	IRS	CRS	CRS

B.D. (Bangladesh), Ind. (India), Pak. (Pakistan), S.L. (Sri Lanka).

Source: Author's own calculation by using DEAP 2.1 version., and the data has been collected from IEA energy balances data set.

Analysis of Slack and Setting Targets for Efficiency Improvement

In Data Envelopment Analysis, slacks indicate inefficiency, occurring only in inefficient DMUs. Analyzing these slacks—excess inputs or insufficient outputs—helps pinpoint areas for operational improvement. For instance, the input-oriented CRS model highlights inefficiencies in Pakistan's energy sector, and our results from 2003 onwards, presented in Table 7, shows that certain inputs could be reduced by 55.8% to 65.2% to maintain the same ED level, signalling substantial overuse. Similar analyses for subsequent years up to 2021 demonstrate consistent opportunities for reducing input use, with reductions required between 39.9% and 56.5% to optimize efficiency. This Slack analysis provides a targeted approach to enhancing efficiency in the sector over time.

In the case of India, significant inefficiencies have been recorded. In 2003, six of the seven input variables required reductions to improve efficiency, with necessary cuts ranging from 49.1% to 96.2%. This pattern of inefficiency, requiring both radial and slack adjustments, persisted into 2021, where inputs such as 2 and 3 needed reductions of approximately 36.5%, while others also underwent adjustments.

Conversely, Bangladesh and Sri Lanka maintained consistent efficiency across the same period, achieving 100% in Overall Technical Efficiency and SE each year. Their consistent performance, with no required reductions in inputs, highlights effective energy sector management under CRS conditions.

Table 7

Slacks and Radial Movement are based on CCR criteria.

Original values						**Radial movements**					**Slack movements**					**Projected values**				
Var	**2003**	**2008**	**2013**	**2018**	**2021**	**2003**	**2008**	**2013**	**2018**	**2021**	**2003**	**2008**	**2013**	**2018**	**2021**	**2003**	**2008**	**2013**	**2018**	**2021**
Results for Pakistan as DMU																				
ED	22.99	26.53	25.18	35.02	36.09	0	0	0	0	0	0	0	0	0	0	22.99	26.53	25.18	35.02	36.09
PPE	33.18	34.11	33.55	33.37	33.76	-18.47	-10.07	-7.90	0	-7.69	0	-2.43	-6.55	0	-9.80	14.71	21.60	19.09	33.37	16.27
NIG	0	0	0	3.85	4.59	0	0	0	0	-1.05	0	0	0	0	-0.98	0	0	0	3.85	2.54
NIPE	9.86	12.31	11.29	17.68	19.28	-5.49	-3.64	-2.66	0	-4.39	-0.37	-0.83	0	0	-3.34	4.0	7.84	8.63	17.68	11.54
NICP	8.76	10.66	10.29	9.11	9	-4.87	-3.15	-2.42	0	-2.05	-0.17	0	-0.27	0	0	3.71	7.51	7.59	9.11	6.95
GEG	48.44	49.27	50.69	58.50	67.34	-26.96	-14.55	-11.94	0	-15.34	-4.66	0	0	0	0	16.81	34.72	38.74	58.50	52.00
FEC	34.21	36.80	35.91	41.28	43.71	-19.04	-10.87	-8.46	0	-9.95	0	-2.95	-6.93	0	-14.73	15.17	22.98	20.52	41.28	19.02
GIPEC	42.89	46.50	44.90	50.5	53.44	-23.88	-13.73	-10.58	0	-12.17	-0.18	-3.10	-6.08	0	-12.71	18.83	29.67	28.25	50.5	28.56
Results for India as DMU																				
ED	25.06	32.87	39.94	41.85	38.38	0	0	0	0	0	0	0	0	0	0	25.06	32.87	39.94	41.85	38.38
PPE	31.65	34.87	38.43	42.12	43.26	-12.92	-4.65	-8.33	-13.75	-15.76	-2.63	-10.77	-12.75	-8.09	-11.74	16.10	19.46	17.36	20.28	15.77
NIG	0.03	0.80	1.20	1.87	1.94	-0.01	-0.11	-0.26	-0.61	-0.71	-0.02	-0.70	-0.94	-1.26	0	0	0	0	0	1.23
NIPE	10.45	17.07	25.70	30.55	27.73	-4.27	-2.28	-5.57	-9.97	-10.10	-2.15	-0.55	-0.44	-0.54	0	4.03	14.24	19.69	20.04	17.63
NICP	10.41	16.18	21.82	24.09	23.25	-4.25	-2.16	-4.73	-7.87	-8.47	-2.45	0	-0.26	0	-2.30	3.71	14.03	16.83	16.23	12.48
GEG	57.18	70.02	91.66	117.58	116.17	-23.34	-9.34	-19.85	-38.39	-42.31	-15.78	-23.88	-28.43	-20.1	-21.71	18.07	36.81	43.38	59.09	52.16
FEC	27.41	32.73	38.55	44.96	44.94	-11.19	-4.36	-8.35	-14.68	-16.37	0	0	0	0	-3.33	16.22	28.37	30.20	30.28	25.24
GIPEC	43.19	55.43	70.06	77.99	77.35	-17.63	-7.39	-15.18	-25.46	-28.17	-5.38	-13.67	-16.16	-10.62	-13.64	20.18	34.38	38.73	41.90	35.53
Results for Bangladesh as DMU																				
ED	20.03	16.21	18.35	23.12	38.66	0	0	0	0	0	0	0	0	0	0	20.03	16.21	18.35	23.12	38.66
PPE	12.87	15.97	18.49	19.76	17.76	0	0	0	0	0	0	0	0	0	0	12.87	15.97	18.49	19.76	17.76
NIG	0	0	0	0	3.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.072
NIPE	3.22	3.08	4.16	5.94	11.19	0	0	0	0	0	0	0	0	0	0	3.22	3.08	4.16	5.94	11.19
NICP	2.97	2.80	3.83	4.99	6.33	0	0	0	0	0	0	0	0	0	0	2.97	2.80	3.83	4.99	6.33
GEG	14.44	23.57	34.64	48.35	56.38	0	0	0	0	0	0	0	0	0	0	14.44	23.57	34.64	48.35	56.38
FEC	12.97	14.08	15.78	18.79	19.27	0	0	0	0	0	0	0	0	0	0	12.97	14.08	15.78	18.79	19.27
GIPEC	16.13	19.03	22.74	26.03	29.46	0	0	0	0	0	0	0	0	0	0	16.13	19.03	22.74	26.03	29.46
Results for Sri Lanka as DMU																				
ED	41.50	45.46	52.39	62.84	57.48	0	0	0	0	0	0	0	0	0	0	41.50	45.46	52.39	62.84	57.48
PPE	24.12	25.01	22.78	20.96	21.71	0	0	0	0	0	0	0	0	0	0	24.12	25.01	22.78	20.96	21.71
NIG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NIPE	19.17	20.89	25.83	35.77	33.03	0	0	0	0	0	0	0	0	0	0	19.17	20.89	25.83	35.77	33.03
NICP	18.82	20.64	22.08	28.77	24.99	0	0	0	0	0	0	0	0	0	0	18.82	20.64	22.08	28.77	24.99
GEG	39.97	49.28	56.90	71.30	74.23	0	0	0	0	0	0	0	0	0	0	39.97	49.28	56.90	71.30	74.23
FEC	38.79	39.21	39.61	43.17	44	0	0	0	0	0	0	0	0	0	0	38.79	39.21	39.61	43.17	44
GIPEC	46.79	46.92	50.80	59.72	59.61	0	0	0	0	0	0	0	0	0	0	46.79	46.92	50.80	59.72	59.61
Pakistan as DMU						**India as DMU**					**Bangladesh as DMU**					**Sri Lanka as DMU**				
TE	0.44	0.71	0.76	1	0.77	0.59	0.87	0.78	0.67	0.64	1	1	1	1	1	1	1	1	1	1
Peer/LW																				

1				1																
2																				
3	1.10	0.10	0.77		0.84	1.25	0.20		0.53	0.40	1	1	1	1	1					
4	0.02	0.23	0.21		0.07		0.65	0.76	0.47	0.40						1	1	1	1	1

Note: TE -(CCR score), LW= Lambda Weights at respective Peers.

Source: Autor's own calculation by using DEAP 2.1 version, and the data has been collected from IEA energy balances data set.

Benchmarking

Below we highlight the significance of benchmarking as a tool for organizations, industries, and economies aiming to improve performance and competitiveness. It involves evaluating performance against established best practices or industry standards to identify areas for improvement and enhance overall performance. Benchmarking provides insights into efficiency by comparing entities to efficient DMUs, serving as references. It can be viewed from two perspectives: efficient economies serving as benchmarks for inefficient ones and inefficient economies referencing efficient ones to gauge their own efficiency levels.

Table 8

Benchmarking on the basis of CCR and BCC Criterion

Year	CRS						VRS					
	DMUs		Peers weight				DMUs		Peers weight			
	Pak	Ind.	Pak.		Ind.		Pak.	Ind.	Pak.		Ind.	
			λ3	λ4	λ3	λ4			λ3	λ4	λ3	λ4
2003	0.44	0.59	1.1	0.02	λ3=1.25		0.59	0.85	0.86	0.14	0.77	0.23
2004	0.48	0.66	1.12	0.07	λ3=1.47		0.67	0.89	0.81	0.19	0.69	0.31
2005	0.47	0.7	1.1	0.07	λ3=1.55		0.64	0.85	0.82	0.18	0.62	0.38
2006	0.59	0.82	1.15	0.14	λ3=1.83		0.83	0.91	0.69	0.31	0.51	0.49
2007	0.63	0.86	1.16	0.16	1.88	0.02	0.86	0.95	0.67	0.34	0.47	0.53
2008	0,71	0.87	0.99	0.23	0.17	0.65	0.85	0.99	0.65	0.35	0.43	0.57
2009	0.76	0.98	0.94	0.29	λ4=0.85		0.9	0.99	0.58	0.42	0.23	0.77
2010	0.83	1	0.83	0.34	λ2=1		0.95	1	0.56	0.44	λ2=1	
2011	0.72	0.77	0.87	0.16	0.2	0.62	0.75	0.98	0.83	0.18	0.46	0.54
2012	0.75	0.78	0.83	0.16	0.22	0.64	0.75	0.99	0.85	0.15	0.44	0.56
2013	0.76	0.78	0.77	0.21	λ4=0.76		0.77	0.98	0.8	0.2	0.37	0.63
2014	0.81	0.77	0.71	0.27	0.19	0.7	0.82	0.99	0.74	0.27	0.36	0.64
2015	0.86	0.78	0.73	0.29	0.14	0.71	0.87	0.99	0.7	0.3	0.37	0.63
2016	0.94	0.79	0.81	0.29	0.33	0.61	1	0.99	λ1=1		0.42	0.58
2017	1	0.68	λ1=1		0.48	0.49	1	0.99	λ1=1		0.53	0.47
2018	1	0.67	λ1=1		0.53	0.47	1	1	λ1=1		0.53	0.47
2019	0.92	0.65	0.99	0.05	0.84	0.3	1	0.99	λ1=1		0.58	0.42
2020	0.78	0.66	0.84	0.08	0.48	0.42	0.83	0.9	0.97	0.03	0.53	0.47
2021	0.77	0.64	0.84	0.07	0.4	0.4	0.84	0.8	λ3=1		0.5	0.5

For both CRS and VRS, Bangladesh and Sri Lanka had been confirmed as peer countries for Pakistan, with peers' weights of λ3= 1.00 (Bangladesh) and λ4= 1.00 (Sri Lanka).

Source: Author's own calculation by using DEAP 2.1 version

The analysis of Table 8 indicates that Bangladesh and Sri Lanka were consistently used as benchmarks 20 times across the model based on CCR and BCC criteria. Throughout the study period (2003 to 2021), both Bangladesh and Sri Lanka emerged as the peer/reference countries for Pakistan and India, respectively. Despite being smaller economies, they showcased effective resource management and efficient energy utilization, leading Pakistan and India to utilize them as benchmarks across all three models in the study. In Table 8, Pakistan showed inefficiency for the model under consideration, except for 2017 and 2018 (CCR) and 2016-2019 (BCC). To become efficient in 2021, Pakistan needed to decrease energy indicators by 16% (CCR) with $\lambda 3=0.84$. However, under BCC, Pakistan remained inefficient with a score of 0.84, implying a 100% reduction with $\lambda 3=1.00$ following Bangladesh. Similarly, India was mostly inefficient except in 2010 (CCR) and 2010-2018 (BCC). In 2021, India needed a 60% reduction (CCR) with $\lambda 3=0.4$ or $\lambda 4=0.4$ (BCC) to match Bangladesh or Sri Lanka's efficiency, respectively. India's VRS score was 0.50, necessitating a 50% reduction with $\lambda 3=0.50$ to match Bangladesh's efficiency.

Conclusion

This research work emphasizes the significance of enabling SAEs to reconsider their ED status relative to peers and to align political strategies for energy dependency reduction. It introduces a distinct model, illustrating the impact of primary energy indicators on ED (see Table 4). The model employs different inputs for effective examination. The technological efficiency of the model is assessed using input-oriented CCR or CRS and BCC or VRS models. The study also identifies input redundancies and output shortfalls by comparing the inefficiencies of reference countries from 2003 to 2021. Furthermore, benchmarking analysis is also conducted through the DEA measurement Windows program (DEAP version 2.1). The Model results indicate that Bangladesh and Sri Lanka consistently achieved 100% scores for both BCC and CCR criteria from 2003 to 2021, operating within the MPSS. Conversely, Pakistan attained 100% CCR scores only in 2017 and 2018, failing to maintain desired efficiency levels from 2003 to 2016 and from 2019 to 2021. Moreover, the economy has witnessed a 100% BCC score for only four years, i.e., from 2016 to 2019, and it remained inefficient in the remaining years of the study. The results of the model further reveal that India experienced both the 100% CCR and BCC score in the year 2010 and remained inefficient in the remaining eighteen years. Based on the basic energy indicators (input variables of the Model), it can be concluded that both India and Pakistan are identified as inefficient economies in terms of decreasing ED scores. Pakistan and India faced challenges with inefficiencies, emphasizing the importance of serious efforts to improve the efficiency of their respective energy management systems. By improving energy system operations and adjusting to optimal size could lead to significant input savings for both these SAEs. In order to promote sustainable economic growth, it is therefore recommended that SAEs, particularly India and Pakistan, prioritize renewable energy, reduce external energy reliance, diversify their energy mix, and promote regional cooperation.

References

Akinsemolu, A. A. (2018). The role of microorganisms in achieving the sustainable development goals. *Journal of Cleaner Production*, *182*, 139–155. https://doi.org/10.1016/j.jclepro.2018.02.081

Aklin, M., Bayer, P., Harish, S. P., & Urpelainen, J. (2017). Does basic energy access generate socioeconomic benefits? A field experiment with off-grid solar power in India. *Science Advances*, *3*(5), e1602153. https://doi.org/10.1126/sciadv.1602153

Amin, S. B., Khan, F., & Rahman, M. A. (2022). The relationship between financial development and renewable energy consumption in South Asian countries. *Environmental Science and Pollution Research*, *29*, 58022–58036. https://doi.org/10.1007/s11356-022-19596-y

Bangladesh Bank. (2022). *Major Commodity-wise Import Payments under (Cash+Buyer's Credit+IDB/ITFC Loan+ Loans & Grants).* Central Bank of Bangladesh.

Banker, R. D., & Thrall, R. M. (1992). Estimation of returns to scale using data envelopment analysis. *European Journal of Operational Research*, *62*(1), 74–84. https://doi.org/10.1016/0377-2217(92)90178-c

Baz, K., Xu, D., Ampofo, G. M. K., Ali, I., Khan, I., Cheng, J., & Ali, H. (2019). Energy consumption and economic growth nexus: New evidence from Pakistan using asymmetric analysis. *Energy*, 116254. https://doi.org/10.1016/j.energy.2019.116254

Blackman, M., & Anne, V. (2022). Reshaping Norms: A New Way Forward. *South Asia conomic Focus.* Tokyo: World Bank.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, *2*(6), 429–444. https://doi.org/10.1016/0377-2217(78)90138-8

Chen, G. (2022). *An Integrated Electricity Market in South Asia is Key to Energy Security*. World Bank Blogs.

Cleveland, J, C., & Morris, C. G. (2015). *Dictionary of Energy* (2nd ed.). Elsevier.

Danish, Zhang, B., Wang, B., & Wang, Z. (2017). Role of renewable energy and non-renewable energy consumption on EKC: Evidence from Pakistan. *Journal of Cleaner Production*, *156*, 855–864. https://doi.org/10.1016/j.jclepro.2017.03.203

Das, N. (2022). *South Asia is paying a high price for its dependence on imported fossil energy*. The Climate Analytics Blogs.

Eurostat. (2020). *Energy dependency rate.* https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Energy_dependency_rate

Hussain, M., Irfan Javaid, M., & Drake, P. R. (2012). An econometric study of carbon dioxide (CO2) emissions, energy consumption, and economic growth of Pakistan. *International Journal of Energy Sector Management*, *6*(4), 518–533. https://doi.org/10.1108/17506221211282019

Ibrahim, D., & Acar, C. (2018). Potential Energy Solutions for Better Sustainability. In I. Dincer, C. O. Colpan, & O. Kizilkan, *Exergetic, Energetic and Environmental Dimensions* (pp. 3-37). Elsevier.

India Economic Survey. (2021-22). *Trade and payments.* Ministry of Finance, Department of Economic Affairs, New Delhi.

Islam, A., Chan, E.-S., Taufiq-Yap, Y. H., Mondal, Md. A. H., Moniruzzaman, M., & Mridha, M. (2014). Energy security in Bangladesh perspective—An assessment and implication. *Renewable and Sustainable Energy Reviews*, *32*, 154–171. https://doi.org/10.1016/j.rser.2014.01.021

Jochem, P., Rothengatter, W., & Schade, W. (2016). *Climate change and transport*. Mpra.ub.uni-Muenchen.de. https://mpra.ub.uni-muenchen.de/id/eprint/91601

Khalil, H. B., & Zaidi, S. J. H. (2014). Energy crisis and potential of solar energy in Pakistan. *Renewable and Sustainable Energy Reviews*, *31*, 194–201. https://doi.org/10.1016/j.rser.2013.11.023

khan, R. M., Farooq, S., & Gilal, M. A. (2020). Electricity Consumption and Economic Growth: A Time-Series Study on Pakistan. *I*, *V*(I), 24–37. https://doi.org/10.31703/ger.2020(v-i).03

Komal, R., & Abbas, F. (2015). Linking financial development, economic growth and energy consumption in Pakistan. *Renewable and Sustainable Energy Reviews*, *44*, 211–220. https://doi.org/10.1016/j.rser.2014.12.015

Krishnan, R. (2009). How Energy Secure is South Asia: Observations through an Environmental Lens. *Energy & Environment*, *20*(6), 967–972. https://doi.org/10.1260/095830509789625329

Latief, R., & Lefen, L. (2019). Foreign Direct Investment in the Power and Energy Sector, Energy Consumption, and Economic Growth: Empirical Evidence from Pakistan. *Sustainability*, *11*(1), 192. https://doi.org/10.3390/su11010192

Mahmood, T., & Kanwal, F. (2017). Long Run Relationship between Energy Efficiency and Economic Growth in Pakistan: Time Series Data Analysis. *Forman Journal of Economic Studies*, *13*, 105–120. https://doi.org/10.32368/fjes.20170005

Nadeem, S., & Munir, K. (2016). Energy Consumption and Economic Growth in Pakistan: A Sectoral Analysis. *MPRA*. https://mpra.ub.uni-muenchen.de/id/eprint/74569

Ozturk, I. (2014). Energy dependency and security: the role of efficiency and renewable energy sources. *International Growth Center (IGC)*.

Pakistan Economic Survey. (2021-22). *Trade and payments.* Islamabad: Ministry of Finance. https://www.finance.gov.pk/survey/chapter_22/PES08-TRADE.pdf

Pode, R. (2010). Addressing India's energy security and options for decreasing energy dependency. *Renewable and Sustainable Energy Reviews*, *14*(9), 3014–3022. https://doi.org/10.1016/j.rser.2010.07.007

Qazi, A. Q., Ahmed, K., & Mudassar, M. (2012). *Disaggregate Energy Consumption and Industrial Output in Pakistan: An Empirical Analysis.* Kiel Institute for the World Economy (IfW), Kiel.

Rafique, M. M., & Rehman, S. (2017). National energy scenario of Pakistan – Current status, future alternatives, and institutional infrastructure: An overview. *Renewable and Sustainable Energy Reviews*, *69*, 156–167. https://doi.org/10.1016/j.rser.2016.11.057

Rehman, A., & Deyuan, Z. (2018). Pakistan's energy scenario: a forecast of commercial energy consumption and supply from different sources through 2030. *Energy, Sustainability and Society*, *8*(1). https://doi.org/10.1186/s13705-018-0167-y

Selvanathan, E. A., Jayasinghe, M., & Selvanathan, S. (2020). Dynamic modelling of inter-relationship between tourism, energy consumption, CO 2 emissions and economic growth in South Asia. *International Journal of Tourism Research*, *23*(4), 597–610. https://doi.org/10.1002/jtr.2429

Seneviratne, B. (2022). *Global Oil Price Volatility: How Can Sri Lanka Cope?* Institute of Policy Studies of Sri Lanka.

Shahbaz, M., & Feridun, M. (2011). Electricity consumption and economic growth empirical evidence from Pakistan. *Quality & Quantity*, *46*(5), 1583–1599. https://doi.org/10.1007/s11135-011-9468-3

Sözen, A., Alp, İ., & İskender, Ü. (2013). An Evaluation of Turkey's Energy Dependency. *Energy Sources, Part B: Economics, Planning, and Policy*, *9*(4), 398–412. https://doi.org/10.1080/15567249.2010.509080

Sumaira, & Siddique, H. M. A. (2022). Industrialization, energy consumption, and environmental pollution: evidence from South Asia. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-022-22317-0

Thanassoulis, E. (2001). *Introduction to the Theory and Application of Data Envelopment Analysis* (1st ed.). Springer.

Toman, M. A. (2002). International Oil Security: Problems and Policies. *The Brookings Review*, *20*(2), 20. https://doi.org/10.2307/20081032

TRADING ECONOMICS. (2021). *GDP - Countries - List | Asia*. Tradingeconomics.com. https://tradingeconomics.com/country-list/gdp?continent=asia

World Population Review. (2022). *Asia Population 2020 (Demographics, Maps, Graphs)*. Worldpopulationreview.com. https://worldpopulationreview.com/continents/asia-population

Zaman, R., & Brudermann, T. (2018). Energy governance in the context of energy service security: A qualitative assessment of the electricity system in Bangladesh. *Applied Energy*, *223*, 443–456. https://doi.org/10.1016/j.apenergy.2018.04.081