Journal of Innovative Technology, Vol. 6, No. 1, pp. 1-12, March 2024
http://doi.org/10.29424/JIT.202403_6(1).0001

Energy insecurity: An obstacle on the way of South Asian technological innovation and economic growth

Farwah Ali Syed [1,2], Kwo-Ting Fang [3], Jabbar Ul-Haq [4], Hubert Visas [5], Adiqa Kausar Kiani [6*]

ABSTRACT

Consequences of energy insecurity for the economy have recently received significant attention deterring the gross domestic growth of an economy in a number of countries. This paper offers a cutting-edge analysis of the relationship that exists between energy insecurity and economic growth in the SAARC states during 1995-2018, with the employment of a novel and comprehensive approach, two proxies of energy insecurity have been constructed to address both the supply and demand sides of the energy insecurity, the data is presented in a unified measuring unit for optimal accuracy. An extended "Cob-Douglas production" function is employed for the empirical analysis. The feasible generalized least squares method is used to deal with heterogeneous data, cross-section correlations, and auto-correlation, that produce robust results. The study emphasized that energy insecurity is one of the hurdles in the way of economic growth, implying that the growing disparity between energy supply and demand poses a risk to the South Asian region's ability to experience sustained economic growth and technological innovation. The results are insensitive and robust to diverse econometric practices applied and findings are extremely pertinent to decision-makers and stakeholders in the energy industry because they make a strong argument for taking action to solve the growing issue of energy insecurity in the SAARC region.

Keywords: Energy Insecurity, Gross Domestic Product growth, SAARC, Feasible generalized least squares method.

1. INTRODUCTION

Energy is indispensable to the economic operation of any modern economy. It drives economic productivity and industrial development, which leads to a prosperous economy (Alshami & Sabah, 2020; Asif & Muneer, 2007; Lorde, Waithe, & Francis, 2010; Omer, 2008). Since the 1973 global energy crisis, the number of studies that model gasoline demand has increased. Initially, studies focused on concerns about the availability of limited resources, and national security concerns raised by the 1970s oil supply shocks (Brons, Nijkamp, Pels, & Rietveld, 2008; Hamilton, 2011; Kilian, 2008). Ensuring that everyone has access to affordable, sustainable, reliable, and contemporary energy is also referred to as sustainable development goals (SDGs) (UN-SDGs-7 (2021)). Interrelated SDGs address the world's most pressing glitches; energy insecurity is also indirectly associated with the root cause of other problems. Population growth also affects this, as it is directly related to demand and supply (J. Liu et al., 2018; Van Zanten & Van Tulder, 2020; Yu, Kubiczek, Ding, Jahanzeb, & Iqbal, 2022). To encounter the rising energy consumption in emerging economies, the energy supply must be sufficient to stimulate growth while also addressing threats of energy insecurity energy (Chu et al., 2023; Rasul, 2016; Rehman & Deyuan, 2018). Energy is one of the important components in the process of growth of a country (Stern, 2011). Nevertheless, for economic growth to be sustained, energy must always be available in sufficient quantities and at all times (Oyedepo, 2012, 2014; Sandaka & Kumar, 2023; WB, 2020a). Four possible hypotheses in the literature about the association of energy use and growth have been offered (Kahia, Aïssa, & Lanouar, 2017; Le, 2016; Ozturk, 2010; Squalli, 2007). According to the growth hypothesis, increased use of energy leads to economic growth, indicating that consumption of energy significantly impacts growth. According to the conservation hypothesis, rising income levels result in increased energy consumption. For this theory to be valid, growth and energy use must have a unidirectional relationship. In addition, a conservative energy policy has no effect on economic expansion. According to the feedback hypothesis, the causal relationship between energy consumption and Gross Domestic Product (GDP) is bidirectional. Yet, the neutrality hypothesis proposes no causal affiliation between economic growth and energy consumption (Le, 2016).

Additionally, essential input for both consumption/use and production/supply is energy, making it the basis for economic progress (Akinlo, 2008; Aqeel & Butt, 2001). If rising energy demand exceeds supply, developing economies could be harmed.

Manuscript received October 11, 2023; revised November 23, 2023; accepted November 26, 2023.

[1] Ph.D. Scholar, Department of Information Management, National Yunlin University of Science and Technology, Taiwan, R.O.C.
[2] Research Fellow, School of Economics, Quaid-i-Azam University, Islamabad, Pakistan.
[3] Professor, Department of Information Management, National Yunlin University of Science and Technology, Taiwan, R.O.C.
[4] Professor, Department of Economics, University of Sargodha, Sargodha, Pakistan.
[5] Professor, School of International Trade & Economics, University of International Business and Economics, Beijing 100029, China.
[6] Professor (corresponding author), Future Technology Research Center, National Yunlin University of Science and Technology, Taiwan, R.O.C. (email: adiqa@yuntech.edu.tw)

These escalating supply-and-demand imbalances may inhibit long-term economic growth (Li et al., 2021). Energy security can be achieved when the energy sources are available systematically at a suitable rate (IEA, 2019a). Making speedy investments to deliver energy in response to a fluctuating economy and environment is the main concern of long-term energy security. Contrarily, the ability of the energy system to react swiftly to unanticipated changes in supply-demand stability is what is concerned with short-term energy security. This implies that energy insecurity occurs when a country's energy supplies are interrupted or when it cannot afford to provide energy, resulting in economic, social, and environmental issues (Asif & Muneer, 2007). When countries are forced to import large quantities of fuel to meet their energy needs, energy insecurity has significant economic repercussions, causing them to spend significantly more than other countries (Jansen & Seebregts, 2010). Energy security's definition and dimensions appear to be fluid, evolving as circumstances change over time (Ang, Choong, & Ng, 2015). It is metaphorical and multi-dimensional (Chester, 2010; Vivoda, 2010). In existing empirical studies, various energy consumption proxies and energy security are utilized (Asghar, 2008; Imran & Siddiqui, 2010; Le & Nguyen, 2019; Mahmood & Ayaz, 2018; Shittu, Adedoyin, Shah, & Musibau, 2021; Stern, 1993). The terms "energy insecurity" and "energy security" are mutually complementary (Xu, Yu, Zhang, & Ji, 2021). This shows that there exists reasonable flexibility in the construction of energy insecurity measures as different proxies of energy security can be cast-off to address the energy crisis situation of a specific country (Le & Nguyen, 2019). When energy cost and availability become an issue, increased global energy consumption may contribute to energy insecurity in developing economies. It is anticipated that the energy demands of developing nations, particularly in South Asia[1], will rise by 33% by 2040 (IEA, 2015).

The global energy insecurity situation has dramatically changed during the last decades, especially in Asia, which has experienced rapid economic expansion (Sarker, Hossain, & Islam, 2020). "Coping with Shocks: Migration and the Road to Resilience", the most recent South Asia Economic Focus, projects that regional GDP would average 5.8% this year, which is a 1 percentage point revision down than the prediction published in June. This was followed by the 7.8% growth in 2021, when most economies were recovering from the pandemic down turn. Furthermore, Conferring to the World Bank's regional wise assessment, Southern Asia has already unequal and vulnerable growth that will be slower than predicted growth due to effects of the conflict in Ukraine and ongoing economic hardships including energy crises (WB, 2022). These countries are experiencing a widening difference between their demand and domestic supply of energy (i.e., energy insecurity), which has resulted in a greater reliance on imports (Sarker et al., 2020; Singh, 2013). Furthermore, the energy crises situation seems to be worsening as South Asia continues to lack conceptual and practicable action frameworks for improving long-term energy security at the regional levels (Sarker et al., 2020), hence it is not favorable for sustainable economic growth. Rising energy demand could have a detrimental influence on developing economies if it outstrips supply (Mahmood & Ayaz, 2018; Newbery, 2006). These growing demand and supply imbalances could stymie long-term economic growth (Li et al., 2021). Growing economies, particularly those that import industrial raw materials and energy inputs to meet production requirements, are attractive case studies for further research into this relationship in the current context.

This study examines the situation of SAARC regions excluding Afghanistan (due to unavailability of data) that rely on imported energy to meet their energy requirements. Despite significant economic progress, the region's energy security remains an enormous obstacle. The SAARC nations are categorized as emerging nations with substantial energy deficits due to limited energy supply and rising energy demand (Sááez, 2007). The member states are unable to meet their needs for energy supply. As a result, energy disparities are used in this study as a proxy for energy insecurity; hence, more investigation about the growth of GDP and energy gap relationship is needed. As mentioned in Blogs-WB (2022), over prior dual decades, Southern Asia energy demand increased by over 50% since 2000. Population growth and manufacturing industry expansion are two factors that have involved in the increase of demand. Demand of electricity has steadily increased previously, averaging over 5% annually in South part of Asia, and is projected to increase than quadruple till 2050. However, two-thirds of South Asia's energy consumption is met through imports approximately. As a result, the volatility in the prices of gas and oil has significant impact on countries that rely heavily on imported fuel for power generation. Consequently, the need for power cost recovery increases. Additionally, more must be done to convert the region's electricity generation to more sustainable and environmentally friendly technologies. Over 80% of region's primary energy output is still derived through fossil fuels, making them a significant source of dependence. In comparison to emissions from other sectors, South Asia has the highest rate of glasshouse gas (GHG) emissions (68%) of any region. Similar to other developed markets, South Asia is currently experiencing energy market disruptions due to conflict, mounting domestic gas demand, and inadequate supply, which are negatively impacting fuel imports and increased burden on administrations to ensure the energy supply security (Blogs-WB, 2022). As a consequence of the current worldwide energy crisis, the tension between committing to energy transition policies that are long-term better for the planet and ensuring energy security is growing. To secure access to these resources, this tension necessitates both a shift from independence to interdependence and a broader range of energy sources.

This research looks into the influence of energy insecurity on SAARC countries' economic growth, Rather than adopting a single measure of energy insecurity, our study employs two proxies of the energy gap (for reference, Table 2), which is a more accurate metric than earlier studies For example, Asghar (2008) considered several types of energy consumption independently without aggregating different sources of consumption (i.e., coal, oil, electricity, natural gas, and total energy consumption) and each country's time series analysis was done separately. Mahmood and Ayaz (2018) aggregated the four sources of energy, and converted the data in a single measure of unit for energy insecurity (the imbalance between aggregate demand and aggregate supply) for Pakistan alone. Similarly, Nepal and Paija (2019) analyzed the situation of energy security based on electricity consumption for Nepal. However, panel study has an advantage over time-series approach (Fitrianto & Musakkal, 2016; C. Hsiao, 2014; F. S. Hsiao & Hsiao, 2006; Ranjan & Agrawal, 2011). To the best of our knowledge, our study differs from previous studies in the following ways: first, we used a panel of all seven SAARC countries including Nepal, Bhutan, and the Maldives, which have not been considered in most studies (Alam et al., 2015; Asghar, 2008; Imran & Siddiqui, 2010; Le & Nguyen, 2019; Shukla, Sudhakar, & Baredar, 2017).Second, our study performs unit conversion quadrillion British thermal unit

[1] South Asia and SAARC have been interchangeably used

(quad Btu), develops and uses new energy insecurity measures. Finally, we extended the "Cobb-Douglas production function" for our empirical analysis, because univariate models may produce inefficient results as they are less comprehensive than multivariate models (Y. Chen and Fang (2018); Fang and Chang (2016); Kahia et al. (2017); Le and Nguyen (2019); Nepal and Paija (2019); Oh and Lee (2004a), 2004b); Tang, Tan, and Ozturk (2016)), In the real world, there are frequently multiple factors at play and a univariate model is unable to account for these, due to its intrinsic constraints (La Tour, Moreau, Jas, & Gramfort, 2018).

This study includes five sections. A review of literature on energy insecurity and growth linkage is presented in the second section. The technique and panel diagnostics are discussed in detail in the third section of the paper. The fourth section, discussed results of the models. Conclusion and policy recommendations are presented in the last section.

2. LITERATURE REVIEW

Energy insecurity ramifications is being a burning research subject in recent years, receiving a lot of attention. Most countries are dealing with energy insecurity, which substantially impedes economic development (Li et al., 2021; Shah & Solangi, 2019). Despite its critical role, the relationship between energy security and economic growth has received little attention in the literature, particularly from quantitative approaches. Gasparatos and Gadda (2009) examined how Japanese society consumed resources between 1979 and 2003 and how that affect the environment and the country's economy. The emergy synthesis[2] concept was used to quantify resource appropriation, consumption and, supply trends. The study institute that the amount of energy essential to produce one dollar's worth of output been steadily declining, indicating a rise in the effectiveness of converting capital into economic yield. Balitskiy, Bilan, and Strielkowski (2014) investigated the rapport between energy security and growth in the 26 Europeon Union states from 1997 to 2011, using natural gas demanding as energy security proxy. The findings revealed that the variables had a relationship in long-term and had causality feedback in the short run. Mahmood and Ayaz (2018) employed the energy demand and supply gap as proxy variables for energy security. Data used from several energy resources (i.e., oil, coal, domestic gas, and electricity) from 1980 to 2012, were converted into BTU and then aggregated to produce demand and supply variables. The analysis revealed that in both the short and long runs, unidirectional causation exists between growth and energy gap, and the link was negative and statistically significant for Pakistan. Nepal and Paija (2019) examined the interrelationships among energy security proxied as electricity consumption and economic growth for Nepal between 1975 and, 2014 using a multivariate context. The conclusions drawn by the study that in the long-term, a 1% increment in population results in a 4.2% increase in electricity consumption. There has been no long-term correlation established between energy use and economic output in Nepal, and is uncommon in South Asia.

Le and Nguyen (2019) used ten proxies to capture the five energy security dimensions for a global sample of seventy-four nations, from 2002 to 2013. The study found that energy security boosts growth of GDP in each of the nations in the sample and subsamples. Energy insecurity measured by energy-carbon intensity had a negative influence on growth. Alekhina (2021) investigated the rapport between energy security 4A's framework[3] and the growth of 20 Asian regions between 1995 and 2015. The findings showed that energy security improves electricity access, and that increasing electricity consumption per capita is linked positively to the real income growth per capita, while a higher proportion of energy imports and higher energy strength inhibit economic growth. While including Climate security in the context of energy security; the results suggested that a rise in carbon emissions harms the growth of the economy. Xu et al. (2021) employed a panel of "31" countries from 1996 to 2015 to corroborate the damaging impact of energy insecurity evaluated by energy reliance, the share of renewable energy, and the effects of prices on economic development. The findings demonstrated that energy insecurity effects the growth negatively. Nepal and Musibau (2021) used the energy security index from 1980 to 2018 as a proxy variable for ASEAN, which explained the 28 percent variation in growth in the long run, while the feedback hypothesis existed among the variables in the short run. Investigating whether growth contributes to energy insecurity, Le and Park (2021) used five proxies of energy security that captured three aspects of energy insecurity[4] for a sample of 139 countries from 1996 to 2016 to check if growth adds to energy security. The results showed that growth contributes to energy security for the global sample.

The majority of studies on the proxies of energy security are qualitatively discussed (e.g., Alam et al., 2015; Ang et al., 2015; Auerswald, 2006; Azzuni & Breyer, 2018; Cherp & Jewell, 2014; Chester, 2010; Jansen & Seebregts, 2010; McGowan, 2011; Sááez, 2007; Vivoda, 2010; Yao, Shi, & Andrews-Speed, 2018). To the best of our knowledge, only Alekhina (2021); Balitskiy et al. (2014); Gasparatos and Gadda (2009); Le and Nguyen (2019); Le and Park (2021); Mahmood and Ayaz (2018); Nepal and Musibau (2021); Nepal and Paija (2019); Xu et al. (2021) have initiated the quantitative analysis based on the relationship between energy security and growth of economy. The present study has been motivated by the several gaps in existing literature. First, there is a need for more quantitative research on energy insecurity and economic growth linkage, as this important topic has received little attention. Secondly, the need to construct an energy insecurity indicator that covers both supply as well as demand features of energy becomes necessarily important for South Asia (Alam et al., 2015; Alekhina, 2021; Allison, 2021; Asif & Muneer, 2007; C. Hsiao, 2014; Jha, 2014; Li et al., 2021; Nandy, 2019; Nepal & Paija, 2019; Sáález, 2007; Sarker et al., 2020; Singh, 2013). Our study formulates the two indicators (i.e., EI1 and EI2) that consider the main sources of energy and will be able to give a broader and exact view of the situation prevailing in the region regarding the energy security risks for South Asia, that has been ignored by earlier studies (Alekhina (2021); Balitskiy et al. (2014); Nepal and Paija (2019); Xu et al. (2021)). In addition, its applicability is not limited to a single country; it can be used as a measure of energy insecurity for any country or group of countries. The indicators are flexible

---

[2] Synthesis of emergy is a framework for stock changes of natural assets that aggregate and quantify all of a system's inputs and outputs. Similar to how traditional economic analysis employs a common denominator (common currency) to compute these disparate inputs/outputs, the solar emjoule as its common currency is employed by emergy synthesis (Odum, 1988, 1996).

[3] Security of energy was formulated by Alekhina (2021) which includes the dimensions of availability, applicability, affordability, and acceptance of energy.

[4] Availability, developability, and acceptability aspects of energy security.

in that additional energy sources (such as biofuels, hydrocarbons, etc.) can be added to the construction of the EI measures, which was not possible in previous studies (Alekhina, 2021; Balitskiy et al., 2014; Gasparatos & Gadda, 2009; Le & Nguyen, 2019; Mahmood & Ayaz, 2018; Nepal & Paija, 2019; Xu et al., 2021). Thirdly, converting different units of measurement into a unified measuring unit is not only necessary but also essential to achieve accuracy and avoid measurement confusion (Bara & McLemore, 2020; Ehmke, Lusk, & Tyner, 2008; Klamik, 2006; Le, Chang, Taghizadeh-Hesary, & Yoshino, 2019). Multiply dissimilar units to get other quantities, will give really strange and unusable units as Alekhina (2021); Xu et al. (2021) ignored the importance of this conversion. For consistently correct answers. Our study converts all the sources of energy to quad Btu then, separate variables for demand and supply are generated. Fourthly, panel data gives a broader picture of the analysis than time series analysis (Fitrianto & Musakkal, 2016; C. Hsiao, 2014; F. S. Hsiao & Hsiao, 2006; Xu et al., 2021).

3. DATA & METHODOLOGY

3.1 Empirical Model

To determine whether there is a significant affiliation among GDP growth and energy insecurity in the South Asian region, we employed a commonly used empirical model in the existing literature for our empirical analysis: an extended growth model (Abbasi, Jiao, Shahbaz, & Khan, 2020; Le, 2016; Le & Nguyen, 2019; Shahbaz, Khan, & Tahir, 2013; Shahbaz, Zakaria, Shahzad, & Mahalik, 2018). This protracted Cobb Douglas production function is as given below:

$$Y = AK^{\alpha} L^{\beta} \mathrm{E}^{\gamma} e^{\mu} \quad (1)$$

Where Y represents actual domestic output, K represents capital, L represents labor, E represents the energy variable, 'A' represents an innovation element, and 'e' represents the error (N ~0,1). The elasticity of output related to labor, capital, and energy insecurity are denoted by α, β, and γ respectively. For this extended growth function, returns to scale is constant (α + β + γ →1). Following Le and Nguyen (2019), capital and labor divided by the total population to obtain the variables in per capita form and the impact of labor is kept constant. Capital per capita is in log form while energy inputs are in its original form, the models can be written as follows:

$$Grth_{it} = c_{it} + \alpha Cap_{it} + \gamma EC_{it} + \varepsilon_{it} \quad (2)$$

$$Grth_{it} = c_{it} + \alpha Cap_{it} + \gamma EI_{it} + \varepsilon_{it} \quad (3)$$

Each of the SAARC countries is represented by i=1 ...n, and each year from 1995 to 2018 is represented by t=1 ...T in eq.2 and 3. The growth per capita is represented by Grth, Cap is the natural log of Capital per capita, and EC represents the energy consumption and EI represents energy insecurity variable. Except for EC and EI which has relatively small and negative values, all the variables are transformed by taking natural logarithms (shown in Table 1). The empirical study uses a panel dataset of 7 SAARC countries including Pakistan, Sri Lanka, Bangladesh, India, Bhutan, Nepal, and the Maldives. Data were accessed from the WDI (World Bank), GGDC (Groningen Growth and Development Centre), and International Energy Statistics (EIA-IES) sources. Afghanistan is not included in the model estimation, due to the lack of its capital and labor data. This study considers a duration of 24 years (T →1995 to 2018) and only a few cross-sections (i.e., 7 countries) giving a total of 168-panel observations. Despite the importance of energy and its contribution to economic growth, the disparity between energy demand and supply has a negative effect on the growth process (Allison, 2021). To examine the significance of energy in the manufacturing process and confirm its contribution to economic growth, we will use two proxies of energy consumption: total primary consumption and aggregate consumption of a variety of energy sources, including electricity, gas, oil, and coal. In order to investigate the situation of energy insecurity and its relationship to SAARC economic growth as the primary objective of the study, two measures of energy insecurity are developed. The imbalance between the demand and supply of crude oil, natural gas, electricity, and coal is used. Energy Information Administration (EIA) maintains disaggregated data for a variety of energy sources and units of measurement. The figures in different units were converted to quad Btu for the purpose of comparison and accurate estimation. The proposed EIA unit conversion factor from 2021 is used for this purpose. Electricity, oil, and natural gas data are in different units, but coal and natural gas data are already in Btu, so no conversion was necessary.

Table 1 Variable descriptions, calculations, data sources, and summary statistics for SAARC countries.

Variables	Calculations	Sources	Obs	Mean	Std. Dev.	Min	Max
GDP growth per capita (Grth)	Annual %	WDI	168	3.8329	3.4994	-15.3957	23.0751
Log of Capital per capita (Cap)	Log of Capital/population	GGDC, WDI	168	0.0225	0.0224	0.0042	0.1056
Energy Consumption (*EC1*)	Total primary energy consumption	EIA-IES	168	3.1654	6.8795	0.0042	31.3283
Energy Consumption (*EC2*)	Aggregation of four sources of energy consumption.	EIA-IES	168	3.2550	7.1681	0.0029	33.1273
Energy Supply (ES1)	Total primary energy supply	EIA-IES	168	2.0155	4.2107	0.0001	17.1894
Energy Supply (ES2)	Aggregation of four sources of energy supply.	EIA-IES	168	3.4119	7.871	0.0002	35.251
Energy Insecurity (*EI1*)	Total Primary Energy Consumption / Aggregate Energy Supply (TPEC/AggES)	EIA-IES	168	4.9572	5.9410	0.8468	29.2365

Energy Insecurity (*EI2*)	Aggregate Energy Demand / Aggregate Energy Supply (AggED/ AggES)	EIA-IES	168	4.1982	6.3360	0.8808	30.3623

Note: Electricity, crude oil, natural gas and coal are the four main sources of energy.

3.2 Construction of energy insecurity variable:

The data on energy sources which are labeled in Table 2 are used to generate two diverse measures of energy insecurity (EI1 and EI2). EI1 is the imbalance between total primary energy consumption and aggregate supply, both of which are derived from the EIA-IES. It measures the ratio between supply and demand of energy, with the idea that a larger gap indicates that a country's energy supply (production) is less than its energy demand (consumption), implying greater energy insecurity. EI2 is the ratio between aggregate demand and aggregate supply, both of which are first aggregated to obtain energy demand and supply and then energy demand is divided by energy supply.

Following the IEA (2004) formula, the energy supply function is constructed as:

$$ES = EP + (EImp - Eexp) \quad (4)$$

Here ES=Energy Supply, EP=Energy Production, EImp = Energy Import, and Eexp= Energy exports. Using the above-stated supply function, we generated four distinct supply functions for electricity, coal, crude oil, and gas. Using these supports, the following aggregated supply energy function is generated:

$$AggES = NGS + CS + ElecS + OS \quad (5)$$

Where AggES stands for Aggregate energy supply, NGS=-Natural gas supply, CS=Coal supply, ElecS=Electricity supply and, OS=Oil supply

Energy Consumption is the proxy for energy demand (Alam et al., 2015; Farhani & Solarin, 2017; Liu, Zhou, Huang, & Hao, 2018; Wolde-Rufael, 2005). This study employs total primary energy consumption and aggregate energy consumption which is the aggregation of the individual consumption of four sources of energy, as energy demand variable.

$$AggED = NGC + ElecC + CC + OC \quad (6)$$

AggED=Aggregate Energy Demand of four sources of energy, NGC= Consumption of Gas, ElecC= Electricity Consumption, CC= Consumption of Coal, and OC= Consumption of Oil. The energy gap is used as a proxy for energy insecurity. When the demand and supply of energy imbalance widens, the security of energy deteriorates, suggesting a rise in energy insecurity. The following equation represents energy insecurity (EI):

$$EI = \frac{ED}{ES} \quad (7)$$

Here EI=Energy Insecurity, ED= Energy Demand, and ES-=Energy Supply

Table 2 Energy Insecurity proxies' construction.

Energy Insecurity proxies	Formula	Description
EI1	$EI1 = \frac{TPEC}{AggES}$	The first proxy used for the energy insecurity variable is formulated by dividing primary energy consumption by aggregate supply.
EI2	$EI2 = \frac{AggED}{AggES}$	The second proxy for energy insecurity is equal to the ratio between aggregate demand and aggregate supply.

Source: Author's calculations.

3.3 Methodological Framework

The panel Feasible Generalized Least Square (FGLS) model, incorporates cross sections differences (unnoticed heteroscedasticity) utilizing variations in the estimations' standard errors (Davidson & MacKinnon, 1993), utilized in the current examination for model estimation presented in Equations. 2 and 3. FGLS performs better at regulating heteroscedasticity than other contending models like the fixed effect panel (FE) model and random effect panel (RE), which simply account for cross-sectional differences by modifying intercept (Hassan, Bukhari, & Arshed, 2020). Additionally, by changing the cross-sectional specific standard errors, FGLS models can be made more resistant to cross-sectional dependency, serial autocorrelation, and heteroscedasticity (Davidson & MacKinnon, 1993; Maddala & Lahiri, 2006). The presentation of the FGLS robust model is given below mathematically as:

$$\begin{aligned} B_{GLS} &= (\chi\Omega^{-1}\chi)^{-1}\chi\Omega^{-1}y \\ Var(B_{GLS}) &= (\chi\Omega^{-1}\chi)^{-1} \\ \Omega &= \sum\nolimits_{t^*t} \Theta I_{\Gamma_i{}^*\Gamma_i} \end{aligned} \quad (8)$$

The **Ω** identity matrix here, is adapted to account for heteroscedasticity and auto-correlation, and the coefficients and standard errors are computed. According to Beck and Katz (1995), the robust FE model and PCSE are both inferior to the GLS model in terms of efficiency (Hanif, Arshed, & Aziz, 2020). As the number of observations is far bigger than the number of cross-sections (i.e., 7 countries), the cross-sectional dependence test proposed by M. Pesaran (2004); M. H. Pesaran (2015) as well as the Breusch and Pagan (1980) Lagrange multiplier (BPLM) test, were used to test for the presence of cross-sectional dependence in the data. Furthermore, the "Modified Wald" test for heteroscedasticity and the Wooldridge test for serial correlation are used in this study to detect heteroscedasticity and the presence of auto-correlation in the data. The results of the panel diagnostic tests as reported in Tables 3.1, 3.2, 3.3 and 3.4, suggest that our data suffer from the mentioned problems. In this context, to estimate our empirical model and to address these problems, we employed the "Feasible

Generalized Least Square" (FGLS) because when T = 24 & N = 7, FGLS is a better choice as suggested by the "Parks-Kmenta" method (Kmenta, 1971; Parks, 1967). The "Panel Corrected standard errors" (PCSEs) approach can be used to solve the problem of heteroscedasticity and autocorrelation (Beck & Katz, 1995). When data has cross-sectional dependence and the cross-sections exceed the period dimensions of the panel data, the "Discroll and Kraay standard errors" (DKSEs) approach is utilized (Driscoll & Kraay, 1998). Estimated model of the present study is given below:

$$Grth_{it} = c_{it} + \alpha Cap_{it} + \gamma E_{it} + \varepsilon_{it} \quad (9)$$

Here "E" represents the energy inputs of energy consumption and energy insecurity respectively.

4. EMPIRICAL RESULTS

4.1 Results of the Energy and Economic Growth Relationship

In general, the model must be identified before it can be estimated and statistically analyzed. In panel data, auto-correlation, the issue of heteroscedasticity, and the cross-sectional dependency problem must all be tested. Results of the panel diagnostic tests are reported in Tables 3.1 and 3.2 respectively and FGLS estimation for the data is shown in table 4:

Table 3.1 Panel Diagnostics tests results for Model 2

Test	Description	Test stat (1)	Test stat (2)
Modified Wald (χ2)	Heteroscedasticity	1903.82***	1916.95***
Wooldridge Test	Serial correlation	0.001	0.001
Pesaran(2015)	CSD	1.679*	1.693*
Bruesh Pagan LM	CSD	25.591	25.702

Note: Significance level, *show 0.1, **show 0.05, ***show 0.01. In the FE (fixed effect) regression model, the Wald test is used to determine group-wise heteroscedasticity. For all 'i' H0=σi2 = σ2: There is no concern with heteroscedasticity. The null hypothesis for serial correlation, H0: There is no auto-correlation in the data. In column 1, EC1 is used and in column 2, EC2 is used as the proxy for energy consumption.

Table 3.2 Pesaran CD Test (2004) For model 2

Variables	CD-test stat (1)	CD-test stat (2)
Grth	2.41 **	2.41**
Cap	19.02***	19.02***
EC2	20.96***	
EC1		21.29***

Point to be noted: CD ~ N (0, 1) is the null hypothesis of cross-section independence. At a 1% significance level, *** denotes null hypothesis rejection. EC1and EC2 represents the proxies for energy consumption in column 1 and 2 respectively.

Table 4 Results of the relationship between energy use and GDP growth (FGLS)

	FGLS	
Variables	(1)	(2)
Cap	0.8212**	0.8137 **
	(0.2902)	(0.2894)
EC1	0.0822***	
	(0.0159)	
EC2		0.0802***
		(0.0152)
Constant	7.1942***	7.1615***
	(1.3512)	(1.3481)
Wald stat.	40.72***	41.71***
P-values	0.0000	0.0000

Note: Growth per capita is the dependent variable in all models. EC1,EC2 and Cap are the explanatory variables in both models (EC stands for energy consumption) Parentheses present S.E. ***, **, *indicates prob<1 %, prob<5 %, prob<10 %.

The valuation results revealed a positive association between the variables. Coefficients of energy consumption used in the analysis of this panel of SAARC countries from 1995 to 2018 are EC1 (0.0822) and EC2 (0.0802), both are positive and also significant at the 1% significance level. For the selected SAARC countries, an increase in EC1 and EC2 result in an increase in per capita growth, demonstrating that energy plays a significant role in a nation's economic development, thus supporting the growth hypothesis (Bozkurt & Destek, 2015; Solarin & Ozturk, 2015). As predicted by theory, capital per head is positive and also significant at the 0.01 percent level. The Wald statistic and its corresponding probability value show the model's overall significance at the 1% level, showing that the explanatory variables' ability to forecast GDP growth is reliable. The estimation results revealed that energy is the primary driver of growth per capita due to the rising global demand for goods and services. Energy consumption, which can be compared to the oxygen available to all nations, is closely related to economic growth. Therefore, the use of nonrenewable energy is strongly correlated with economic growth, which degrades environmental quality. Economic growth requires the availability of nonrenewable energy in this context (Sahir & Qureshi, 2007; Shahbaz, Khan, Ali, & Bhattacharya, 2017). Industrial and agricultural productions are dependent on energy, which leads to an increase in emissions of nitrous oxide, carbon, and methane. In 2015, 82% of the world's energy came from fossil fuels, maintaining their position as the dominant energy source globally. According to the IEA, this ratio has remained relatively constant over the past four decades (Khan, Saleem, Shabbir, & Huobao, 2022). Alternatives to nonrenewable energy sources, such as renewable energy, may be helpful in resolving these issues from the standpoint of policy implications (Stern, 2004).

4.2 Results of the Energy insecurity and Economic growth relationship

In panel data, auto-correlation, the issue of heteroscedasticity, and the cross-sectional dependency problem must all be tested. Results of the panel diagnostic tests for the data are informed below:

Tabl 5.1 Results of Panel Diagnostics for Model 3

Test	Description	Test stat. (1)	Test stat. (2)
Modified Wald (χ2)	Heteroscedasticity	12990.33***	2703.97***
Wooldridge Test	Serial correlation	1.776	1.338
Pesaran(2015)	CSD	1.963*	1.927*
Bruesh Pagan LM	CSD	26.440	26.411

Note: *show 0.1, **show 0.05, ***show 0.01 level of significance. In the FE (fixed effect) regression model, the Wald test is used to determine group-wise heteroscedasticity. For all 'i' H0=σi2 = σ2: There is no concern with heteroscedasticity. The null hypothesis for serial correlation, H0: There is no auto-correlation in the data. EI1, EI2 represented as the proxies of energy insecurity in column 1 and 2.

Table 5.2 Pesaran CD Test (2004) results for Model 3

Variables	CD-test stat. (1)	CD-test stat. (2)
Grth	2.41**	2.41 **
Cap	19.02***	19.02 ***
EI1	3.05***	
EI2		2.70***

Point to be noted: CD ~ N (0, 1) is the null hypothesis of cross-section independence. At a 1% significance level, *** denotes null hypothesis rejection.EI1 and EI2 used as the proxy of energy insecurity in column1 and column 2.

As shown in Tables 5.1and 5.2 the probability for all Panel Diagnostics tests is less than the 0.10 level of significance, indicating that the sample data used for the analysis exhibits heteroskedastic and cross-sectional dependence issues. To address these issues, the DKSEs, FGLS, and PCSEs are used for estimation, which correct for heterogeneity, autocorrelation, and cross-sectional dependence while producing robust standard errors. The estimated results are displayed in Tables 6, 7, and 8 as shown in Tables 6, 7, and 8 below.

Table 6 Economic Growth and Energy Insecurity in SAARC (FGLS)

	FGLS	
Variables	(1)	(2)
Cap	1.5830***	1.4665**
	(0.2596)	(0.2497)
EI1	-0.1686**	
	(0.0635)	
EI2		-0.1914**
		(0.0724)
Constant	11.6729***	11.0992***
	(1.2547)	(1.1869)
Wald stat.	38.05***	37.65***
P-values	0.0000	0.0000
countries	7	7
Observation	168	168

Note: GDP per capita growth is the dependent variable in all models. EI1, EI2 and Cap are the explanatory variables in all of the models (EI stands for energy insecurity) Parentheses present S.E. ***, **, *indicates prob<1 %, prob<5 %, prob<10 %.

In Table 6 the empirical results based on the impact of energy insecurity on economic growth for a model of seven SAARC countries during 1995-2018 time period. Using the FGLS method, the results revealed that both of the proxies used to measure energy insecurity have a significant negative influence on growth of an economy (as expected and according to the literature Le et al., 2019). The coefficient of capital per head for models 1 and 2 is positive/statistically significant, suggesting that it has a progressive effect on the growth of GDP at the 0.01 significance level. The findings indicate that energy security is essential for these countries to ensure that their economies run smoothly and that their populations have access to sufficient, stable, and cost-effective supplies of modern, clean energy. Additionally, improved energy production to meet improved energy consumption has substantial positive effects on economic growth (Le & Nguyen, 2019). In South Asia, nearly two-thirds of the energy consumed is imported. Consequently, nations that rely heavily on imported fuel for power generation are disproportionately affected by the volatility of oil and gas prices. As a result, energy cost recovery requirements have increased. Since the majority of South Asian regions have limited domestic energy resources and rely heavily on imported energy (mainly crude lubricant) from other counties, the primary objective of energy security for SAARC countries should be to reduce their reliance on imported energy sources for rapid economic growth. Furthermore, the energy issue can be resolved by fully exploiting fossil fuels, preventing energy loss, and increasing the region's reliance on non-conventional energy sources (Blogs-WB, 2022).

Table 7 Energy Insecurity & Economic Growth in SAARC (PCSEs)

	PCSEs	
Variables	(1)	(2)
Cap	0.4608	0.4565
	(0.4232)	(0.4238)
EI1	-0.5957***	
	(0.1484)	
EI2		-0.7911***
		(0.2018)
Constant	5.6129**	5.6179**
	(1.9824)	(1.9813)
Wald stat.	27.62***	25.90***
P-values	0.0000	0.0000
Observation	168	168
Countries	7	7

Note: Grth is the dependent variable in all models. EI1, EI2 and capital are the explanatory variables in all of the models (EI stands for energy insecurity) Parentheses present S.E. ***, **, *indicates p-val < 0.01, p-val < 0.05, p-val < 0.1.

According to Table-7, the energy insecurity variables used in the two models (EI1 and EI2) are all negatively associated with GDP growth (the target variable) and are significant at the 1% level statistically, indicating that a one-unit rise in explanatory variables is expected to result in a decrease in GDP growth when estimating the model with EI1 and EI2 respectively. As stated previously, the log of capital per capita in each model has a positive relationship with the variable measuring the growth of per capita GDP, but the impact is insignificant statistically, as demonstrated by the PCSE estimation results. Energy is required for GDP growth, but conventional oil and gas supplies are probable to decline, constraining the energy supply in near future. The findings of the study conducted by L. Chen (2021) show that increased use of renewable energy indicates an economy's commitment to green investment, production, and growth. Moreover, the findings indicate that the SAARC region requires a long-term renewable energy policy. The renewable energy use has positive possessions on environmental sustainability and sustainable development in the county, from the perspective of energy policy.

Table 8 Eco-Growth and Energy Insecurity in SAARC (DKSEs)

	DKSEs	
Variables	(1)	(2)
Cap	0.4608	0.9344**
	(0.3725)	(0.3677)
EI1	-0.5957***	
	(0.1189)	
EI2		-0.1184*
		(0.0583)
Constant	5.6129***	8.2374***
	(1.7022)	(1.6784)
Wald- stat.	14.90***	4.80**
P-values	0.0001	0.0181
Observation	168	168
Countries	7	7

Note: GDP per capita growth is the dependent variable in all models. EI1, EI2 and capital are the explanatory variables in all of the two models (EI stands for energy insecurity) Parentheses present S.E. ***, **, *indicates P-Val less than 0.01, P-Val less than 0.05, P-Val less than 0.1.

Results of the DSKEs in table 8 report a statistically significant negative association between the two measures of energy insecurity and GDP growth at the 1% and the 5% significant levels, respectively. The coefficient of capital shows that it has a optimistic influence on GDP growth, and the findings are significant statistically in each of the two models at the 1 percent level of significance. Capital formation is essential to economic growth (Le & Nguyen, 2019), and results for this variable support this claim. The results for all of the explanatory factors, including capital per capita, and our most concerned variables (i.e., the two indicators of energy insecurity), are consistent in FGLS, PCSEs, and DSKEs estimations, indicating that the model is consistent. A sustainable future requires efficient resource management to ensure that sufficient energy resources are accessible/available for present as well as future generations (IEA, 2019b). Nonrenewable, scarce, or life-sustaining resources should be given special consideration. Energy conservation is essential, especially when the energy source is nonrenewable. The preservation of global resources, as well as the health of the economy and environment, are dependent on the prudent use of resources (IEA, 2019a; UN-News, 2022). The effective use of resources, particularly energy derived from scarce resources (fossil fuels), is essential to minimize energy insecurity.

4.3 Robustness of the results:

The Tables-6, 7, and 8 present empirical indication on the influence of energy insecurity on GDP growth in seven countries from 1995 to 2018. The estimation results reveal that capital in per capita form have positive effects on GDP per capita growth for the full data sample when different econometric methods are used to estimate the two suggested models, as projected in related theories. Because capital input is an indispensable for an economic output, rise in the gross capital formulation increases production capacity, resulting in economic growth benefits. Despite the observed results appearing to be comparatively vigorous to these assessment methods, the results for EI1 and EI2 are consistent across PCSE, FGLS, and DSKE estimations; EI1and EI2 all significantly negatively influence economic growth. The study's main focus is on the impact of energy insecurity on growth GDP. According to the significant and negative coefficients of EI1 and EI2, energy insecurity hurts economic growth. Our findings are in line with the study of Le and Nguyen (2019), who calculated the energy security index by dividing primary energy production by primary energy consumption, implying that a higher supply relative to demand is virtuous for the economy and is a positive measure of energy security. EI1 is the ratio of primary energy consumption and aggregate supply and is a negative measure of energy security in this study (i.e., energy insecurity). The negative effect of energy insecurity measures indicates that energy demand exceeds energy supply (i.e., higher energy insecurity) and that a higher energy supply capacity is required to meet energy demand if it must benefit economic development. This affirms the critical responsibility of guaranteeing long-term global energy supply capacity and resource equality in promoting economic growth (Ozturk & Acaravci, 2013). Energy endowments and exploration capacity are critical elements in determining a stable and maintainable energy supply, which is a critical input in economic activity; otherwise, growing energy insecurity poses a risk to economic growth. Empirical findings highlight the need of looking at the energy-economic growth relationship from both the production and consumption sides. This is supported by the findings of this study, which show that higher levels of energy insecurity correspond to worsening economic growth in SAARC countries. As the estimation results reveal, the risk of energy insecurity hurts economic development. This is especially true in emerging nations like those of SAARC, where the market forces disparity cause energy vulnerability to rise (Le et al., 2019).

5. CONCLUSION AND POLICY IMPLICATIONS

Energy security is well-defined as an adequate, reliable energy supply at a predetermined price. This refers to the constant energy supply required to meet the demand of energy. Energy security is essential to a nation's economic development, whereas energy insecurity retards economic development and jeopardizes economic growth. The relationship between energy insecurity and economic growth has been studied and conceptually analyzed in the literature. In this study, we empirically examined the relationship between energy insecurity and economic growth. The study examines separately the energy demand and supply of SAARC region. We used total primary energy consumption and the sum of four energy sources (coal, oil, gas, and electricity) as two proxy variables for energy demand and derived a supply function (Output + imports - exports) for energy supply. We obtained all energy data from the EIA website in different units, converted the data to the same unit of Btu to maintain the accuracy of the data, and then created a function of supply for each source and aggregated the supply from all sources to calculate the total energy supply for all seven SAARC countries. Similarly, we aggregated all energy consumption sources into the energy demand function. Additionally, total primary energy was employed as energy demand.

After obtaining the necessary demand and supply variables, it was necessary to develop indicators of energy insecurity. Using the ratio between energy demands and energy supply, we developed two distinct energy insecurity indicators. Using panel diagnostics, non-homoscedasticity (error variance), serial correlation, and cross-sectional dependence were identified in the panel data. As suggested in the literature and theory, the FGLS, DSKEs, and PCSEs procedures were utilized to address these obstacles and attain reliable and robust results. This study found that energy insecurity hinders SAARC's economic growth. As the energy demand exceeds the energy supply, this growing disparity calls attention to the demand-side management in each country.

To achieve the proposed goals to reduce the energy vulnerability of SAARC nations, the focus must be shifted from energy supply to energy demand. By addressing the issue of demand, the gap between energy supply and demand would decrease, thereby improving the energy security of South Asian nations. According to this, an energy surplus over demand is required to support economic expansion as a whole. In order to increase the level of energy security needed for growth, it is crucial to comprehend the means by which energy supply and demand gaps can be reduced. To address the issue of energy insecurity, the governments of the SAARC countries should prioritize supply and demand management. Governments in the SAARC region should implement appropriate energy policies to promote economic growth, as energy disparities may limit the impact of global development. Impacts of COVID-19 and recent geopolitical crises have provided additional evidence of the sector's potential for volatility. These economies must apply the lessons learned from recent crises and become more adept at preparing for future challenges, many of which may have lengthy and historic consequences. This action will facilitate a successful and lasting recovery. The present study has certain limitations because it only analyses data from 1995 to 2018 and does not account for the pandemic condition that occurred in 2019. Since 2019 and onward, the majority of the data contains missing values. In light of the current COVID-19 situation, policymakers, government officials, and energy-related executives must conduct additional research to determine the economic growth and energy insecurity linkages. This assessment of pandemic disruption will aid in coping with the economy and can be modified to assist with the current economic crisis.

REFERENCES

Abbasi, K., Jiao, Z., Shahbaz, M., & Khan, A. (2020). "Asymmetric impact of renewable and non-renewable energy on economic growth in Pakistan: New evidence from a nonlinear analysis. " *Energy Exploration & Exploitation,* **38**(5), 1946-1967.

Akinlo, A. E. (2008). "Energy consumption and economic growth: Evidence from 11 Sub-Sahara African countries." *Energy economics,* **30**(5), 2391-2400.

Alam, A., Malik, I. A., Abdullah, A. B., Hassan, A., Awan, U., Ali, G., & Naseem, I. (2015). "Does financial development contribute to SAARC′ S energy demand? From energy crisis to energy reforms." *Renewable and sustainable energy reviews,* **41**, 818-829.

Alekhina, V. (2021). "The Role Of Energy Security In Economic Growth In Asia: Quantitative Analysis And Policy Options." *The Singapore Economic Review*, **66**(02), 545-567.

Allison, J. E. (2021). "Energy Cooperation in South Asia: Utilising Natural Resources for Peace and Sustainable Development by Mirza Sadaqat Huda." *Global Environmental Politics,* **21**(2), 165-166.

Alshami, M. A., & Sabah, A. (2020). "The Strategic Importance of Energy Consumption to Economic Growth: Evidence from the UAE." *International Journal of Energy Economics and Policy,* **10**(1), 114.

Ang, B. W., Choong, W. L., & Ng, T. S. (2015). "Energy security: Definitions, dimensions and indexes." *Renewable and sustainable energy reviews,* **42**, 1077-1093.

Aqeel, A., & Butt, M. S. (2001). "The relationship between energy consumption and economic growth in Pakistan." *Asia-Pacific Development Journal,* **8**(2), 101-110.

Asghar, Z. (2008). "Energy-GDP relationship: a causal analysis for the five countries of South" *Asia. Applied Econometrics and International Development,* **8**(1).

Asif, M., & Muneer, T. (2007). "Energy supply, its demand and security issues for developed and emerging economies." *Renewable and sustainable energy reviews,* **11**(7), 1388-1413.

Auerswald, P. E. (2006). "The myth of energy insecurity." *Issues in Science and Technology,* **22**(4), 65-70.

Azzuni, A., & Breyer, C. (2018). "Definitions and dimensions of energy security: a literature review." *Wiley Interdisciplinary Reviews: Energy and Environment,* **7**(1), e268.

Balitskiy, S., Bilan, Y., & Strielkowski, W. (2014). "Energy security and economic growth in the European Union." *Journal of Security & Sustainability Issues,* **4**(2).

Bara, J. E., & McLemore, J. P. (2020). "Unit Conversions in the 21st Century: Insights into a Routine yet Critical Scientific and Engineering Task as Measured through User Interactions with a Mobile App." *Chemical Engineering Education,* **54**(3), 112-120.

Beck, N., & Katz, J. N. (1995). "What to do (and not to do) with time-series cross-section data." *American political science review,* **89**(3), 634-647.

Blogs-WB. (2022). "Blogs- World Bank(WB),An integrated electricity market in South Asia is key to energy security., from https://blogs.worldbank.org/endpovertyinsouthasia/integrated-electricity-market-south-asia-key-energy-security

Bozkurt, C., & Destek, M. A. (2015). "Renewable energy and sustainable development nexus in selected OECD countries." *International Journal of Energy Economics and Policy,* **5**(2), 507-514.

Breusch, T. S., & Pagan, A. R. (1980). "The Lagrange multiplier test and its applications to model specification in econometrics." *The review of economic studies,* **47**(1), 239-253.

Brons, M., Nijkamp, P., Pels, E., & Rietveld, P. (2008). "A meta-analysis of the price elasticity of gasoline demand. A SUR approach." *Energy economics,* **30**(5), 2105-2122.

Chen, L. (2021). "Environmental cost of sustainable development and climate change: can SAARC shift some liability with renewable energy and efficiency?" *Environmental Science and Pollution Research,* **28**(47), 67137-67149. doi: 10.1007/s11356-021-15209-2

Chen, Y., & Fang, Z. (2018). "Industrial electricity consumption, human capital investment and economic growth in Chinese cities." *Economic modelling,* **69**, 205-219.

Cherp, A., & Jewell, J. (2014). "The concept of energy security: Beyond the four As." *Energy Policy,* **75**, 415-421.

Chester, L. (2010). "Conceptualising energy security and making explicit its polysemic nature." *Energy Policy,* **38**(2), 887-895.

Chu, L. K., Ghosh, S., Doğan, B., Nguyen, N. H., & Shahbaz, M. (2023). "Energy security as new determinant of renewable energy: the role of economic complexity in top energy users." *Energy,* **263**, 125799.

Davidson, R., & MacKinnon, J. G. (1993). *Estimation and inference in econometrics* (Vol. 63): Oxford New York.

Driscoll, J. C., & Kraay, A. C. (1998). "Consistent covariance matrix estimation with spatially dependent panel data." *Review of economics and statistics,* **80**(4), 549-560.

Ehmke, M. D., Lusk, J. L., & Tyner, W. (2008). "Measuring the relative importance of preferences for country of origin in China, France, Niger, and the United States." *Agricultural Economics,* **38**(3), 277-285.

EIA. (2021). US-Energy Information Administration/energy-explained/units-and-calculators/energy-conversion-calculators., from https://www.eia.gov/energyexplained/units-and-calculators/energy-conversion-calculators.php

Fang, Z., & Chang, Y. (2016). "Energy, human capital and economic growth in Asia Pacific countries—Evidence from a panel cointegration and causality analysis." *Energy economics,* **56**, 177-184.

Farhani, S., & Solarin, S. A. (2017). "Financial development and energy demand in the United States: New evidence from combined cointegration and asymmetric causality tests." *Energy,* **134**, 1029-1037. doi: https://doi.org/10.1016/j.energy.2017.06.121

Fitrianto, A., & Musakkal, N. F. K. (2016). "Panel data analysis for Sabah construction industries: Choosing the best model." *Procedia Economics and Finance,* **35**, 241-248.

Gasparatos, A., & Gadda, T. (2009). "Environmental support, energy security and economic growth in Japan." *Energy Policy,* **37**(10), 4038-4048.

Hamilton, J. D. (2011). Historical oil shocks.

Hanif, N., Arshed, N., & Aziz, O. (2020). "On interaction of the energy: Human capital Kuznets curve? A case for technology innovation." *Environment, Development and Sustainability,* **22**(8), 7559-7586. doi: 10.1007/s10668-019-00536-9

Hassan, M. S., Bukhari, S., & Arshed, N. (2020). "Competitiveness, governance and globalization: What matters for poverty alleviation?" *Environment, Development and Sustainability,* **22**(4), 3491-3518.

Hsiao, C. (2014). *Analysis of panel data:* Cambridge university press.

Hsiao, F. S., & Hsiao, M.-C. W. (2006). "FDI, exports, and GDP in East and Southeast Asia—Panel data versus time-series causality analyses." *Journal of Asian Economics,* **17**(6), 1082-1106.

IEA. (2004). International Energy Agency (IEA), Energy Statistics Manual, IEA, Paris 2021, from https://www.iea.org/reports/energy-statistics-manual-2

IEA. (2015). International Energy Agency (IEA) (2015), World Energy Outlook 2015, IEA, Paris ,Energy. . from https://www.iea.org/reports/world-energy-outlook-2015,World

IEA. (2019a). International Energy Agency (IEA)-Areas-of-Work,Ensuring-Energy-Security. from https://www.iea.org/areas-of-work/ensuring-energy-security

IEA. (2019b). Multiple Benefits of Energy Efficiency, International Energy Agency (IEA), Paris. from https://www.iea.org/reports/multiple-benefits-of-energy-efficiency

Imran, K., & Siddiqui, M. M. (2010). "Energy consumption and economic growth: A case study of three SAARC countries." *European Journal of Social Sciences,* **16**(2), 206-213.

Jansen, J. C., & Seebregts, A. J. (2010). "Long-term energy services security: What is it and how can it be measured and valued?" *Energy Policy,* **38**(4), 1654-1664.

Jha, R. (2014). "Sustainable Development in South Asia: Need for Cooperation in Food-Water-Energy Security." *Jha, Ram Kumar and Akshat Mishra (March, 2014), "Sustainable Development in South Asia: Need for Cooperation in Food-Water-Energy Security", CUTS International, Jaipur, 302016.*

Kahia, M., Aïssa, M. S. B., & Lanouar, C. (2017). "Renewable and non-renewable energy use-economic growth nexus: The case of MENA Net Oil Importing Countries." *Renewable and sustainable energy reviews,* **71**, 127-140.

Khan, M. B., Saleem, H., Shabbir, M. S., & Huobao, X. (2022). "The effects of globalization, energy consumption and economic growth on carbon dioxide emissions in South Asian countries." *Energy & Environment,* **33**(1), 107-134.

Kilian, L. (2008). "Exogenous oil supply shocks: how big are they and how much do they matter for the US economy?" *The Review of Economics and Statistics,* **90**(2), 216-240.

Klamik, A. (2006). "From the Classroom: Converting Customary Units: Multiply or Divide?" *Teaching Children Mathematics,* **13**(3), 188-191.

Kmenta, J. (1971). Elements of econometrics.

La Tour, T. D., Moreau, T., Jas, M., & Gramfort, A. (2018). "Multivariate convolutional sparse coding for electromagnetic brain signals." *arXiv preprint arXiv:1805.09654*.

Le, T.-H. (2016). "Dynamics between energy, output, openness and financial development in sub-Saharan African countries." *Applied Economics,* **48**(10), 914-933.

Le, T.-H., Chang, Y., Taghizadeh-Hesary, F., & Yoshino, N. (2019). "Energy insecurity in Asia: A multi-dimensional analysis." *Economic modelling,* **83**, 84-95.

Le, T.-H., & Nguyen, C. P. (2019). "Is energy security a driver for economic growth? Evidence from a global sample." *Energy Policy,* **129**, 436-451.

Le, T.-H., & Park, D. (2021). "What drives energy insecurity across the world? A panel data analysis." *Energy Research & Social Science,* **77**, 102093.

Li, Q., Cherian, J., Shabbir, M. S., Sial, M. S., Li, J., Mester, I., & Badulescu, A. (2021). "Exploring the relationship between renewable energy sources and economic growth. The case of SAARC countries." *Energies,* **14**(3), 520.

Liu, J., Hull, V., Godfray, H. C. J., Tilman, D., Gleick, P., Hoff, H., . . . Sun, J. (2018). "Nexus approaches to global sustainable development." *Nature Sustainability,* **1**(9), 466-476.

Liu, L., Zhou, C., Huang, J., & Hao, Y. (2018). "The Impact of Financial Development on Energy Demand: Evidence from China." *Emerging Markets Finance and Trade,* **54**(2), 269-287. doi: 10.1080/1540496X.2017.1358609

Lorde, T., Waithe, K., & Francis, B. (2010). “The importance of electrical energy for economic growth in Barbados.” *Energy economics,* **32**(6), 1411-1420.

Maddala, G., & Lahiri, K. (2006). “Introduction to econometrics (Vol. 67): New York, NY: Wiley.”

Mahmood, T., & Ayaz, M. T. (2018). “Energy security and economic growth in Pakistan.” *Pakistan Journal of Applied Economics,* **28**(1), 47-64.

McGowan, F. (2011). “Putting energy insecurity into historical context: European responses to the energy crises of the 1970s and 2000s.” *Geopolitics,* **16**(3), 486-511.

Nandy, D. (2019). “Energy security and economic growth in South Asia: An alternative policy option” *Handbook of Research on Economic and Political Implications of Green Trading and Energy Use* (pp. 393-408): IGI Global.

Nepal, R., & Musibau, H. O. (2021). “Energy security, renewable, non-renewable energy and economic growth in ASEAN economies: New insights.” *The Singapore Economic Review,* **66**(02), 457-488.

Nepal, R., & Paija, N. (2019). “Energy security, electricity, population and economic growth: The case of a developing South Asian resource-rich economy.” *Energy Policy,* **132**, 771-781.

Newbery, D. (2006). Power sector reform, private investment and regional co-operation.

Odum, H. T. (1988). “Self-organization, transformity, and information.” *Science,* **242**(4882), 1132-1139.

Odum, H. T. (1996). *Enviromental accounting: emergy and enviromental decision making:* New York, US: Wiley.

Oh, W., & Lee, K. (2004a). “Causal relationship between energy consumption and GDP revisited: the case of Korea 1970–1999.” *Energy economics,* **26**(1), 51-59.

Oh, W., & Lee, K. (2004b). “Energy consumption and economic growth in Korea: testing the causality relation.” *Journal of policy modeling,* **26**(8-9), 973-981.

Omer, A. M. (2008). “Energy, environment and sustainable development.” *Renewable and sustainable energy reviews,* **12**(9), 2265-2300.

Oyedepo, S. O. (2012). “Energy and sustainable development in Nigeria: the way forward.” *Energy, sustainability and society,* **2**(1), 1-17.

Oyedepo, S. O. (2014). “Towards achieving energy for sustainable development in Nigeria.” *Renewable and sustainable energy reviews,* **34**, 255-272.

Ozturk, I. (2010). “A literature survey on energy–growth nexus.” *Energy Policy,* **38**(1), 340-349.

Ozturk, I., & Acaravci, A. (2013). “The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey.” *Energy economics,* **36**, 262-267.

Parks, R. W. (1967). “Efficient estimation of a system of regression equations when disturbances are both serially and contemporaneously correlated.” *Journal of the American Statistical Association,* **62**(318), 500-509.

Pesaran, M. (2004). “General Diagnostic Tests for Cross Section Dependence in Panels.” Cambridge Working Papers in Economics 0435, Department of Applied Economics, University of Cambridge.”

Pesaran, M. H. (2015). “Testing weak cross-sectional dependence in large panels.” *Econometric reviews,* **34**(6-10), 1089-1117.

Ranjan, V., & Agrawal, G. (2011). “FDI inflow determinants in BRIC countries: A panel data analysis.” *International business research,* **4**(4), 255.

Rasul, G. (2016). “Managing the food, water, and energy nexus for achieving the Sustainable Development Goals in South Asia.” *Environmental Development,* **18**, 14-25.

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), 1-5.

Sááez, L. (2007). “US policy and energy security in South Asia: economic prospects and strategic implications.” *Asian Survey,* **47**(4), 657-678.

Sahir, M. H., & Qureshi, A. H. (2007). “Specific concerns of Pakistan in the context of energy security issues and geopolitics of the region.” *Energy Policy,* **35**(4), 2031-2037.

Sarker, T., Hossain, S., & Islam, K. N. (2020). “Role of regional cooperation and integration in improving energy insecurity in South Asia.”

Sandaka, B. P., & Kumar, J. (2023). “Alternative vehicular fuels for environmental decarbonization: A critical review of challenges in using electricity, hydrogen, and biofuels as a sustainable vehicular fuel.” *Chemical Engineering Journal Advances,* 100442.

Shah, S. A. A., & Solangi, Y. A. (2019). “A sustainable solution for electricity crisis in Pakistan: opportunities, barriers, and policy implications for 100% renewable energy.” *Environmental Science and Pollution Research,* **26**(29), 29687-29703.

Shahbaz, M., Khan, S., Ali, A., & Bhattacharya, M. (2017). “The impact of globalization on CO2 emissions in China.” *The Singapore Economic Review,* **62**(04), 929-957.

Shahbaz, M., Khan, S., & Tahir, M. I. (2013). “The dynamic links between energy consumption, economic growth, financial development and trade in China: fresh evidence from multivariate framework analysis.” *Energy economics,* **40**, 8-21.

Shahbaz, M., Zakaria, M., Shahzad, S. J. H., & Mahalik, M. K. (2018). “The energy consumption and economic growth nexus in top ten energy-consuming countries: Fresh evidence from using the quantile-on-quantile approach.” *Energy economics,* **71**, 282-301.

Shittu, W., Adedoyin, F. F., Shah, M. I., & Musibau, H. O. (2021). “An investigation of the nexus between natural resources, environmental performance, energy security and environmental degradation: Evidence from Asia.” *Resources Policy,* **73**, 102227.

Shukla, A. K., Sudhakar, K., & Baredar, P. (2017). “Renewable energy resources in South Asian countries: Challenges, policy and recommendations.” *Resource-Efficient Technologies,* **3**(3), 342-346.

Singh, B. K. (2013). “South Asia energy security: Challenges and opportunities.” *Energy Policy,* **63**, 458-468.

Solarin, S. A., & Ozturk, I. (2015). “On the causal dynamics between hydroelectricity consumption and economic growth in Latin America countries.” *Renewable and sustainable energy reviews,* **52**, 1857-1868.

Squalli, J. (2007). "Electricity consumption and economic growth: Bounds and causality analyses of OPEC members." *Energy economics,* **29**(6), 1192-1205.

Stern, D. I. (1993). "Energy and economic growth in the USA: a multivariate approach." *Energy economics,* **15**(2), 137-150.

Stern, D. I. (2004). "The rise and fall of the environmental Kuznets curve." *World development,* **32**(8), 1419-1439.

Stern, D. I. (2011). "The role of energy in economic growth." *Annals of the New York Academy of Sciences,* **1219**(1), 26-51.

Tang, C. F., Tan, B. W., & Ozturk, I. (2016). "Energy consumption and economic growth in Vietnam." *Renewable and sustainable energy reviews,* **54**, 1506-1514.

UN-News. (2022). United Nations News (UN_News)global perspective human stories,UN meets to help reverse 'precipitous drop' in tourism., from https://news.un.org/en/story/2022/05/1117552

UN-SDGs-7. (2021). United Nation Sustainable Development Goal-Number-7 (UN SDGs-7),UN-STAT-report-2021., from https://sdgs.un.org/goals/goal7

Van Zanten, J. A., & Van Tulder, R. (2020). "Beyond COVID-19: Applying "SDG logics" for resilient transformations." *Journal of International Business Policy,* **3**(4), 451-464.

Vivoda, V. (2010). "Evaluating energy security in the Asia-Pacific region: A novel methodological approach." *Energy Policy,* **38**(9), 5258-5263.

WB. (2020a). World Bank-Understanding Poverty- Energy Overview., from https://www.worldbank.org/en/topic/energy/overview#1

WB. (2020b). World Bank (WB) 2020,Maldives-building-back-better-through-clean-energy. from https://www.worldbank.org/en/news/feature/2020/12/11/maldives-building-back-better-through-clean-energy

WB. (2022). World Bank (WB), 2022 /Where we work/Region/South Asia/Overview., from https://www.worldbank.org/en/region/sar/overview

Wolde-Rufael, Y. (2005). "Energy demand and economic growth: the African experience." *Journal of policy modeling,* **27**(8), 891-903.

Xu, X., Yu, J., Zhang, D., & Ji, Q. (2021). "Energy insecurity, economic growth, and the role of renewable energy: a cross-country panel analysis." *The Singapore Economic Review,* **66**(02), 323-343.

Yao, L., Shi, X., & Andrews-Speed, P. (2018). "Conceptualization of energy security in resource-poor economies: The role of the nature of economy." *Energy Policy,* **114**, 394-402.

Yu, M., Kubiczek, J., Ding, K., Jahanzeb, A., & Iqbal, N. (2022). "Revisiting SDG-7 under energy efficiency vision 2050: the role of new economic models and mass digitalization in OECD." *Energy Efficiency,* **15**(1), 1-20.