

Research paper

Renewable energy development in Bangladesh: The role of oil price, macroeconomic factors and policies

Sakib Bin Amin^{*}, Mahatab Kabir Khandaker, Farhan Khan

Department of Economics, North South University, Dhaka, Bangladesh



ARTICLE INFO

Keywords:

Renewable energy
BVAR
ARDL
Oil price
Green transition

ABSTRACT

This paper develops a fit-for-purpose Renewable Energy (RE) demand model to empirically examine the effects of Oil Price Shock (OPS) along with macroeconomic factors and policies in order to critically analyse how RE Development (RED) is influenced in the Bangladesh economy. We use annual data covering from 1985 to 2019 for the empirical analysis. We first check for cointegration using the Johansen-Juselius (JJ) and the Autoregressive Distributed Lag (ARDL) bounds tests and find that the concerned variables are not cointegrated in the Long-Run (LR). Therefore, we apply the Bayesian Vector Autoregression (BVAR) to investigate the Short-Run (SR) impacts. We reveal that a positive OPS increases RE Consumption (REC) with a lag effect. Moreover, positive shocks to RE Investment (REI) and Foreign Direct Investment (FDI) tend to increase REC, while a positive shock in GDP dampens REC. We recommend institutional reforms to pave the way for effective RED for the green transition in Bangladesh.

1. Introduction

Firms, households, social sectors, and governments utilise energy as one of the most important drivers of their daily operations and have been widely acknowledged in the literature, coined as the “lifblood” of the economy. A minimum amount of energy is argued to be necessary for any economy to evolve past the point of subsistence consumption by several authors, including Amin (2015), Rehman et al. (2019), and Azam et al. (2015). Since 2010, there has been a 1.6 % average increase in the global energy demand and with 2.05 % peak growth rate during the year 2018–2019 (BP Statistical Review of World Energy, 2020).

Additionally, assuming the existing consumption pattern continues and no changes in policy are taken into account, the energy demand would rise by 1.3 % every year until 2040. Population increases, shifting lifestyles, improved production, household compliance, and economic development are all root causes of rising energy consumption. Furthermore, it is crucial to remember that three fossil fuels—oil, gas, and coal—continue to account for the largest global portions of the energy mix. The International Energy Agency (2020) estimates that coal, natural gas, and oil together account for 84.30 % of the primary energy mix globally.

Using an abundance of fossil fuels to suit our everyday requirements has a negative influence on the environment. The literature

demonstrates that over-reliance on fossil fuels results in air and water pollution, habitat loss for species, harm to human health, and an increase in greenhouse gas emissions. China and India produced over 35 % of the world’s total Carbon Dioxide (CO₂) emissions (CE) from fossil fuels in 2018. Moreover, 44 % of all CE in 2018 came from the electrical sector alone (International Energy Agency, 2020). Energy diversification, which has opened multiple avenues of growth for Renewable Energy (RE), is essential since non-renewable resources are not going to last forever, and safeguarding the environment for the future is crucial. Thus, by virtue of its endless supply and decentralised nature, RE not only ensures global energy security but also increases energy resilience and stops the deterioration of the environment.

Bangladesh is one of the most rapidly growing developing economies in the world. Over the last decade, the nation has maintained an average growth rate of nearly 7 %, with moderate sustained growth rates even during the COVID-19 pandemic. Amin et al. (2020) argue that, among other criteria, achieving and sustaining the impressive growth pattern and socioeconomic development of Bangladesh has been linked with quick recovery energy policies. Due to the enormous disparity between the supply and demand of energy in the early 2000s, the energy crisis has gotten much worse. The gap developed due to Bangladesh’s switch in the late 1990s from an agrarian to an industrial economy. As a result of this shift in economic activity, a higher quantity of energy (both

^{*} Corresponding author.

E-mail addresses: sakib.amin@northsouth.edu (S.B. Amin), mahatab.khandaker@northsouth.edu (M.K. Khandaker), farhan.khan09@northsouth.edu (F. Khan).

primary and secondary) was needed, but unfortunately, the supply remained inadequate, leading to a persistent energy crisis (Amin et al., 2022a).¹

Bangladesh, thus, relied mainly on fossil fuels (primarily oil and natural gas) to produce adequate energy (such as electricity) to meet the then growing demand. Even though the crisis has been successfully contained, there is still a significant bias in favour of fossil fuels in the primary energy mix. The primary energy mix for 2020 is illustrated in Fig. 1.² Around 71 % of the primary energy mix depends on fossil fuels (oil, coal, natural gas, LPG, and LNG), where oil and natural gas dominate (14.83 % and 37.05 %, respectively).

Although natural gas is produced domestically, Bangladesh has to import oil to meet the demand for various economic activities. Complete import dependence on oil can lead to several macroeconomic effects through sudden Oil Price Shock (OPS). For instance, excessive subsidies, price discrimination, and welfare loss (Timilsina and Pargal, 2020; Amin, 2015). Moreover, oil price shocks are now more frequent due to changes in geopolitics and calamities like the pandemic, making countries like Bangladesh more vulnerable.

Historical data shows a sluggish upward trend of RE use. The average amount of primary energy derived from renewable sources between 1996 and 2018 was 8511 Kilo Tonnes of Oil Equivalent (KTOE), increasing at an average yearly growth rate of 1.32 % (Fig. 2). The average RE utilisation from 2007 to 2018 was 9152 KTOE, only 1341 KTOE higher than the average of the preceding 11 years (1996–2006). On the other hand, the average percentage of renewables in the electricity generation mix has remained below 5 % over the last 15 years (2006–2020).

Additionally, it is evident that the RE sector has received very little attention while developing an energy strategy for the Annual Development Programme (ADP). The Sustainable and Renewable Energy Development Authority (SREDA), Bangladesh's government body overseeing the RE sector, has also not received a particularly large financial allocation. SREDA only received Tk. 6.01 crore annually on average from 2015 to 2020.

As Bangladesh advances to the next stages of its development journey, it aims to facilitate a green transition by setting the trajectory for generating 40 % electricity from renewable energy by 2041 and 100 % by 2050. In this regard, the nation needs to adhere to an ideal energy policy framework to support the anticipated development and green transition. Hence, it is critical to identify how the dynamics of renewable energy relate to the key macroeconomic indicators of the country, given the growing significance of RE in the energy mix, the fiscal government's budgetary reluctance, and the startling rise in the use of RE in the production and consumption sectors of the economy. This will assist the policy in influencing the expansion of RE through both direct and indirect channels.

Against this backdrop, we aim to analyse the channels through which RE Development (RED) is influenced in Bangladesh economy. The novelty of this paper is threefold. First, we develop a theoretically derived fit-for-purpose RED model for Bangladesh. Second, we provide a

¹ Primary energy refers to “energy embodied in natural resources (e.g., coal, crude oil, sunlight, uranium) that has not undergone any anthropogenic conversion or transformation” (Khalilpour, 2019). On the other hand, secondary energy comes from the transformation of primary energy (e.g., electricity, heat, refined oil, etc.).

² Even though biomass makes up around 27 % of the primary energy mix in Bangladesh, it is separated from the front-line renewable energy sources and excluded from the analysis. The composition of biomass consists mainly of traditional sources (e.g., wood fuels, agricultural by-products, cow dung, etc.), which have differing impacts on the environment, such as deforestation and methane emissions. Moreover, the effect of the concerned macroeconomic shocks is less relevant for fluctuations in the use of biomass. Instead, environmental shocks and natural disasters, such as wildfires or flooding are the main drivers in the structural fluctuations of the availability and use of biomass.

novel ground of methodological innovation by employing a Bayesian Vector Auto Regression (BVAR) and using the Sims-Zha normal-Wishart method to obtain prior and posterior to analyse the Short-Run (SR) changes in the determinants of RED. Third, in light of our findings, we offer insightful policy recommendations to advance Bangladesh's RED.

The remainder of the paper is organised as follows. To identify the gaps in the body of current knowledge, Section 2 conducts a thorough literature review. The theoretical underpinnings of the model, methods, and data employed in the paper are presented in Section 3. The findings and pertinent discussion are presented in Section 4. Section 5 concludes the paper by offering a few policy recommendations and potential extensions to the paper.

2. Literature review

From the broad spectrum, three facets of theoretical and empirical models are prominent in previous literature. The first primarily focuses on the macroeconomic effects of RE and consists of oil price, GDP, and pollution as the determinants. The second spectrum focuses on trade models with the inclusion of renewable energy and oil prices. Finally, the third spectrum focuses on financial development and investment as determinants of RED. Apart from providing a comparative analysis of RED, we review each of these areas of research for the development of a theoretical model, analogous econometric specifications, and methods. Furthermore, we discuss the existing literature from Bangladesh's perspective to show the research gap and novelty. Table 1 summarises the reviewed literature.

2.1. Renewable energy, oil price, GDP, and CO₂ emissions

Sadorsky (2009) investigated the LR relationships of oil price, GDP, and CE on REC in the countries of Canada, the USA, the UK, France, Germany, Italy, and Japan, commonly known as the G7 countries, by conducting the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic OLS (DOLS) on yearly data between 1980 and 2005. The FMOLS results showed that when income, CE, and oil prices increase by 1 %, REC increases by 8.45 %, 5.23 %, and decreases by 0.65 %, respectively.

The findings of Sandusky (2009) motivated numerous empirical studies. For instance, Payne (2012) used the Toda-Yamamoto long-causality test to understand the causal relationship between REC, real GDP, real oil prices, and CE in the USA from the data period of 1949–2009. The study revealed that although there is no causality, a one standard deviation shock in real GDP and CE initially dampened REC but eventually increased REC after 5 years and 4 years, respectively. On the other hand, using FMOLS, Apergis and Payne (2014) found that for the 25 OECD countries, a 1 % rise in GDP increases REC by 0.345 %, a 1 % rise in CE increases REC by 0.352 %, and a 1 % increase in real oil prices increases REC by 0.450 %.

Karacan et al. (2021) used the Vector Error Correction Model (VECM) and the Canonical Cointegrating Regression (CCR) method to examine the impacts of oil price, CE, and GDP on REC in Russia across the period of 1990–2015. The VECM and CCR results posit that when GDP increases by 1 %, REC increases by 0.99 % and 0.20 %, respectively, with CE having no significant results. However, when oil price increases by 1 %, REC reduces by 0.43 % and 0.14 %, respectively. This happens due to the substitution lag effect since Russia's primary and electricity generation mixes are high depended on fossil fuels.

For the case of ASEAN for the period 1995–2018, using the panel ARDL estimator, Pata et al. (2023) discovered that REC only lowers CE in the SR and does not impact environmental quality in the LR. Furthermore, there is no connection between environmental deterioration and renewable energy. It was argued that this could result from the ASEAN countries' inefficient use of renewable energy.

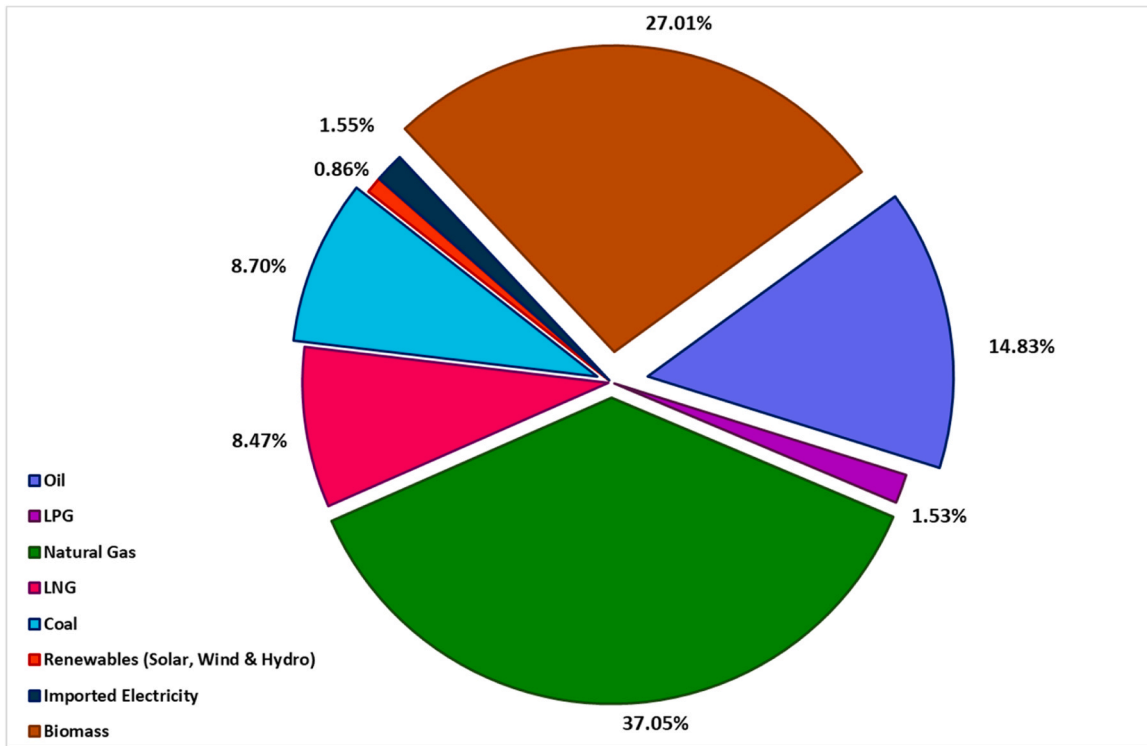


Fig. 1. Primary Energy Mix of Bangladesh in 2020. Source: Hydrocarbon Unit (2021)

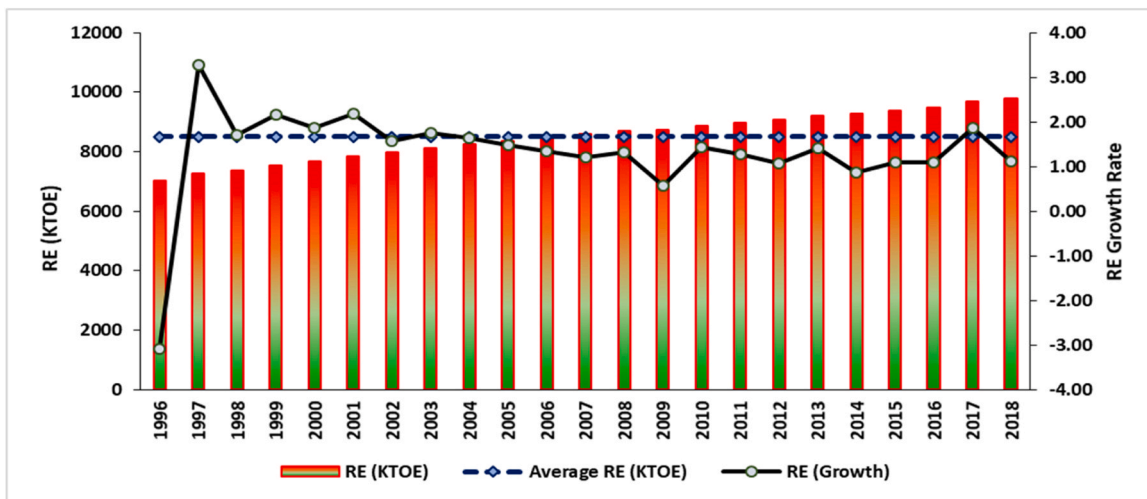


Fig. 2. RE Scenario in Bangladesh. Source: International Energy Agency (2020)

2.2. Renewable energy, GDP, trade, and oil price

Omri et al. (2015) analysed how CE, GDP, real oil prices, and trade openness affect REC in 64 global countries by employing the Difference Generalised Method of Moments (Diff-GMM) and System GMM (Sys-GMM) on annual data from 1990 to 2011. The study concluded that a 1 % increase in real oil prices, international trade, and GDP increases REC by 0.26 %, 0.17 %, and 0.20 %, respectively.

In the case of Tunisia, Brini et al. (2017) investigated the inter-linkages between REC, international trade, oil price, and GDP. In the LR, they revealed a bidirectional causal relationship between REC and GDP. Moreover, a 1 % increase in REC reduces GDP by 0.397 % and 11.99 %,

whereas a 1 % rise in oil price increases GDP by 0.039 % and 1.175 % in the SR and LR, respectively.

Using a panel dataset of 14 top emerging countries from 1980–2015, Zeren and Akkus (2020) evaluated the connection between trade openness and REC using a panel dataset of 14 top emerging nations. The Commonly Correlated Mean Group (CCEMG) estimate indicated that a significant contributing cause to the decline in trade openness (ratio of imports and exports) for these emerging countries in the LR was the growing usage of renewable energy. This is because most renewables are consumed close to their production facilities, and thus provide an avenue to shift from imported fossil fuels. Additionally, the unidirectional causal relationship between REC and trade openness was found,

Table 1
Summary of Literature Review.

Paper	Data	Area	Methodology	Main Findings
Sadorsky (2009)	1980–2005	G7 countries	FMOLS, DOLS, SUR	GDP and CE have a positive relationship with REC, but oil price has a negative relationship with REC in the LR.
Payne (2012)	1949–2009	USA	Toda-Yamamoto causality	RE legislation positively affects REC, unexpected shocks to real GDP and CE positively impact REC.
Apergis and Payne (2014)	1980–2011	25 OECD countries	FMOLS	Real GDP, CE, and real oil prices positively affect REC in the LR.
Karacan et al. (2021)	1990–2015	Russia	VECM, CCR	An increase in oil price reduces REC, and an increase in GDP increases REC.
Pata et al. (2023)	1995–2018	ASEAN	Panel ARDL	REC only lowers CE in the SR and has no impact on environmental quality in the LR.
Omri et al. (2015)	1990–2011	64 countries	Diff-GMM and Sys-GMM	CE, GDP, real oil prices and trade openness positively affect REC.
Brini et al. (2017)	1980–2011	Tunisia	ARDL	Bidirectional causality between REC and GDP exists, an increase in REC reduces GDP, and an increase in oil price increases GDP in the LR.
Zeren and Akkuş (2020)	1980–2011	14 top emerging countries	CCEMG	REC reduces trade openness in the LR.
Wang et al. (2023)	1998–2018	122 countries	FMOLS and DOLS	Trade openness spurs pollution haven hypothesis, resulting in lower REC.
Ashfaq et al. (2024)	1990–2018	G20 countries	DARDL	Strong economic growth and globalisation on RE but no effect of trade openness.
Amin et al. (2022c)	1990–2018	5 South Asian countries	Heterogeneous estimators	Financial development reduces REC in the LR.
Kazemzadeh et al. (2023)	1985–2017	49 countries	PVAR	Strong Granger causal link between the variables REC

Table 1 (continued)

Paper	Data	Area	Methodology	Main Findings
Uddin (2023)	2001–2020	China	BVAR	and financial development. 13.75 % of REC can be explained by financial development in the LR.
Shu et al. (2023)	1990–2020	G7 countries	Method of Moment Quantile Regression	Strong endogeneity between RE and green finance. U-shaped relationship between renewable energy research and development investment and environment quality.
Khandker et al. (2018)	1980–2015	Bangladesh	Granger Causality	Bidirectional causality between FDI and REC.
Islam et al. (2022)	1990–2019	Bangladesh	DARDL	GDP, urbanisation, FDI, and institutional quality affect REC positively, while physical infrastructure affects REC negatively.
Sarker et al. (2022)	2001–2016	Bangladesh	Time Series & SWOT	Higher REC leads to higher economic growth in Bangladesh.

further fortifying the estimation results.

Wang et al. (2023) comprehensively investigate the influence of renewable energy usage, trade accessibility on economic growth and CE while considering the various development levels of 122 nations for the period 1998–2018. Using the FMOLS and the DOLS, they found that the impact of trade openness is heterogeneous across different regions. On the other hand, trade openness is linked with the pollution haven hypothesis, resulting in lower REC. Ashfaq et al. (2024) used Dynamic ARDL (DARDL) to find the SR and LR dynamics of economic growth, trade openness, and REC on a panel dataset of G20 countries from 1990–2018. The results suggested a strong SR and LR impact but no significant effect on trade openness.

2.3. Renewable energy, financial development, and investment

Amin et al. (2022c) analysed the influence of financial development on renewable energy consumption for South Asian countries using data covering from 1990 to 2018. Using robust panel heterogeneous estimators, they found that increased financial development leads to a 0.07–0.15 % reduction in REC in the LR.

With a sample of 49 countries, Kazemzadeh et al. (2023) assessed the relationship between REC and financial development using a dataset covering 1985–2017. Using a Panel VAR (PVAR) framework, PVAR found a strong Granger causal link between the variables REC and financial development. Additionally, variance decomposition revealed that 13.75 % of REC can be explained by financial development in the LR.

Uddin (2023) used BVAR on annual data from 2001–2020 of China

to find impulse responses of RE on green finance, private energy investment, GDP, and Foreign Direct Investment (FDI). The results suggest strong endogeneity between RE and green finance, weak endogeneity with private energy finance and GDP, and low endogeneity with FDI.

Shu et al. (2023) explored the influence of renewable energy research and development investment on the quality of the environment of the G7 countries with data from 1990–2020. Using the method of moment quantile regression, they found that renewable energy research and development investment tend to have a U-shaped relationship with environmental quality. Furthermore, bidirectional causalities were found among all the variables of interest.

2.4. Bangladesh perspective

Khandker et al. (2018) used data from 1980–2015 to find the Granger Causality of FDI and REC and found a bidirectional causality between FDI and REC. Moreover, Islam et al. (2022) used data from 1990–2019 to find the effect of GDP, FDI, domestic investment, urbanisation, and physical infrastructure on REC using DARDL analysis. Results showed that an increase in GDP, FDI, domestic investment, and better institutional quality improves REC, but an increase in urbanisation and improvement of physical infrastructure reduces REC.

Sarker et al. (2023) examined the interrelationship of economic growth and renewable energy in Bangladesh from 2001 to 2016. Estimation results indicated that using renewable energy positively affects Bangladesh’s economic growth. Moreover, A SWOT analysis provided a roadmap for policy initiatives for LR RED.

Although the existing literature has indicated numerous studies on renewable energy from Bangladesh’s perspective, there is a dearth of theoretically backed empirical evidence of RED, and different macroeconomic indicators discussed earlier. Only a few empirical studies initially discuss the dynamics of various macroeconomic variables on renewable energy development without adequate theoretical underpinnings. Therefore, we aim to contribute to the body of literature from Bangladesh’s perspective by developing a fit-for-purpose model to

$$\geq \ln \omega p_t - \ln \lambda - (1 - \beta) \ln \theta K_t - (1 - \beta) \ln \mu L_t - (1 - \beta) \ln \omega OC_t - (1 - \beta) \ln \omega REC_t + (1 - \beta) \ln \omega OC_t = 0$$

analyse RED and potential policy implications.

3. Model, methodology, and data

This section is divided into three sub-sections. Section 3.1 derives the model used in the empirical analysis. Sections 3.2 and 3.3 detail the methodology and data, respectively.

3.1. Model

We extend Amin et al. (2021), Amin et al. (2020), and Yoshino and Taghizadeh–Hesary (2014) and utilise the production function expressed by Eq. (1). In this functional form, we disaggregate energy consumption into oil and renewable energy consumption as additional variables apart from the conventional variables.

$$Y_t = f(K_t, L_t, OC_t, REC_t) \tag{1}$$

Where, Y_t = real GDP, K_t = capital (also denotes investment), L_t = labour, OC_t = oil consumption, and REC_t = renewable energy consumption. For deriving the RE demand model, we first express the functional form of the production function of Eq. (1) into a Constant Elasticity of Substitution (CES) production function, which is shown by Eq. (2).

$$Y_t = [\theta K_t^\beta + \mu L_t^\beta + \omega OC_t^\beta + \omega REC_t^\beta]^{\frac{1}{\beta}} \tag{2}$$

In Eq. (2), θ , μ , ω , and ω are the shares of capital, labour, oil consumption and RE consumption respectively in the production function. β is the CES parameter. The profit function is defined by Eq. (3) for maximising production.

$$\Pi_t = P_t Y_t - w_t L_t - r_t K_t - op_t OC_t - p_t^r REC_t \tag{3}$$

In Eq. (4), P_t = real price level, r_t = investment rent, w_t = labour wage, op_t =per unit oil price, and p_t^r = per unit RE price. We next formulate the Lagrangian function or the objective function for maximising the production set.

$$\mathcal{L}_t = P Y_t - w L_t - r K_t - op_t OC_t - p_t^r REC_t - \lambda [Y_t - f(Y_t)] \tag{4}$$

The First Order Condition (FOC) of the objective function with respect to OC_t is as follows:

$$\begin{aligned} \frac{\partial \mathcal{L}_t}{\partial OC_t} &= 0 \\ &\geq -op_t + \lambda \frac{\partial f(Y_t)}{\partial OC_t} = 0 \\ &\geq -op_t + \lambda \left[\frac{1}{\beta} \{ \theta K_t^\beta + \mu L_t^\beta + \omega OC_t^\beta + \omega REC_t^\beta \}^{\frac{(1-\beta)}{\beta}} \{ \beta (\omega OC_t)^{\beta-1} \} \right] = 0 \\ &\geq op_t - \lambda \left[\{ \theta K_t^\beta + \mu L_t^\beta + \omega OC_t^\beta + \omega REC_t^\beta \}^{\frac{(1-\beta)}{\beta}} \{ (\omega OC_t)^{\beta-1} \} \right] = 0 \\ &\geq \ln op_t - \ln \lambda - \frac{(1-\beta)}{\beta} \ln [\theta K_t^\beta + \mu L_t^\beta + \omega OC_t^\beta + \omega REC_t^\beta] - (\beta-1) \ln \omega OC_t = 0 \end{aligned}$$

$$\begin{aligned} &\geq \ln op_t - \ln \lambda - (1-\beta) \ln \theta K_t - (1-\beta) \ln \mu L_t - (1-\beta) \ln \omega REC_t = 0 \\ &\geq (1-\beta) \ln \omega REC_t = \ln op_t - \ln \lambda - (1-\beta) \ln \theta K_t - (1-\beta) \ln \mu L_t \\ &\geq \ln \omega REC_t = \left[\frac{1}{(1-\beta)} \right] \ln op_t - \left[\frac{1}{(1-\beta)} \right] \ln \lambda + \left[\frac{(\beta-1)}{(1-\beta)} \right] \ln \theta K_t + \left[\frac{(\beta-1)}{(1-\beta)} \right] \ln \mu L_t \end{aligned} \tag{5}$$

Eq. (5) is a derived demand function that shows the interlinkages of renewable energy consumption, numerous macroeconomic variables, and oil prices. It is worth noting that the value of $\ln \lambda$, the shadow price of the Lagrangian objective function, can be expressed as a function of GDP and labour by taking the FOC of the objective function with respect to labour.³

³ w is normalised to 1.

$$\begin{aligned}
 & -w_t + \lambda \left[\frac{1}{\beta} (\theta K_t^\beta + \mu L_t^\beta + \rho OC_t^\beta + \omega REC_t^\beta)^{\frac{(1-\beta)}{\beta}} \left\{ \beta (\mu L_t)^{\beta-1} \right\} \right] = 0 \\
 & \geq -w_t + \lambda \left[\frac{1}{\beta} \left\{ (\theta K_t^\beta + \mu L_t^\beta + \rho OC_t^\beta + \omega REC_t^\beta)^{\frac{(1-\beta)}{\beta}} \right\} \left\{ \beta (\mu L_t)^{\beta-1} \right\} \right] \\
 & = 0
 \end{aligned}$$

$$\begin{aligned}
 & \geq -w_t + \lambda \left[\left\{ (Y_t)^\beta \right\}^{\frac{(1-\beta)}{\beta}} \left\{ (\mu L_t)^{\beta-1} \right\} \right] = 0 \\
 & \geq -\ln w_t + \ln \lambda + (1 - \beta) \ln Y_t + (\beta - 1) \ln \mu L_t = 0
 \end{aligned}$$

$$\begin{aligned}
 & \geq \ln \lambda = (\beta - 1) \ln Y_t + (1 - \beta) \ln \mu L_t
 \end{aligned}$$

After plugging the value, a simple algebraic computation leads to Eq. (6).

$$\ln \omega RE_t = \left[\frac{1}{(1-\beta)} \right] \ln \rho p_t - \left[\frac{(\beta-1)}{(1-\beta)} \right] \ln Y_t + \left[\frac{(\beta-1)}{(1-\beta)} \right] \ln \theta K_t + \left[\frac{2\beta-2}{(1-\beta)} \right] \ln \mu L_t \tag{6}$$

Following Yoshino and Taghizadeh-Hesary (2014) and the findings of Amin et al. (2021), we drop labour from the reduced form of Eq. (6), which can be expressed by Eq. (7). Nevertheless, we have also estimated a labour-augmented BVAR model, but as found by Amin et al. (2021), the effect of labour on renewable energy is nearly non-existent. The result can be made available upon request.

$$\ln REC_t = \rho^o \ln \rho p_t + \Phi \ln Y_t + \Psi \ln K_t \tag{7}$$

Where, $\ln REC_t = \ln \omega RE_t$, $\ln \theta K_t = \ln K_t$, $\rho^o = \left[\frac{1}{(1-\beta)} \right]$, $\Phi = - \left[\frac{(\beta-1)}{(1-\beta)} \right]$, $\Psi = \left[\frac{(\beta-1)}{(1-\beta)} \right]$

In this paper, investment is divided into three categories: general investment, renewable energy investment, and FDI. This is because disaggregation allows to pinpoint exactly which types of investment contribute to what aspects of RED, whereas aggregate investment (i.e., summation of general investment, renewable energy investment, and FDI) may not allow for intuitive interpretations of changes in REC. Besides renewable energy investment, FDI seems to be a plausible factor for facilitating RED in Bangladesh for two reasons. First, technology and skills transfer (Sinani and Meyer, 2004; Nasim et al., 2023). Bangladesh has been attracting FDI by establishing Economic Processing Zones (EPZs) across the country, where foreign investors not only invest money for different production activities but also transfer technology and skills, especially in the cases of energy efficiency and energy transition within EPZs and across the country. Second, market signals through Corporate Social Responsibility (CSR). CSR activities by multinational foreign firms could work as a catalyst to increase firm-level REI, as evident in the literature (Stawicka, 2021; Tiwari et al., 2022; Peng and Chen, 2023).

As general investment has a very small impact on RED, especially in the context of Bangladesh, it is not considered in the estimated model.⁴

⁴ Even though, by definition, general investment captures non-renewable investment, we found no significant effect on RED. This could happen because the non-renewable share is smaller than other types of investment within the spectrum of the general investment category. The additional IRFs from an extended model are not reported; nevertheless, they can be delivered upon request.

Additionally, we have added energy market reform variables as exogenous controls to the model. The final model can be shown in Eq. (8) for econometric analysis:

$$\ln REC_t = \alpha_0 + \rho^o \ln \rho p_t + \Phi \ln Y_t + \psi \ln REI_t + \psi \ln FDI_t + \theta \overline{\mathcal{R}}_d + \varepsilon_t \tag{8}$$

Where, $\ln REC_t$ =natural logarithmic transformation of renewable energy consumption (in KTOE), $\ln \rho^o$ = natural logarithmic transformation of international crude oil price per cubic metre (in USD), $\ln Y_t$ = natural logarithmic transformation of real GDP (in USD), $\ln REI_t$ and $\ln FDI_t$ = natural logarithmic transformations of renewable energy investment (in USD) and FDI inflow (in USD), respectively. $\overline{\mathcal{R}}_d$ = reform variables mentioned in Imam et al. (2019) and Zhang et al. (2008). These reform variables are namely, privatisation in the power sector, the establishment of an independent regulatory body, and the corruption level. Finally, α_0 and ε_t are the constant and error terms, respectively.

3.2. Methodology

We perform the Augmented Dickey-Fuller (ADF) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) stationary tests to check the stationarity of the variables. After checking the stationarity properties, we use the Johansen-Juselius (JJ) procedure of cointegration (Johansen and Juselius, 1990). However, the asymptotic properties of the JJ procedure become spurious and misinterpret the cointegration trend when there is a higher number of lagged variables, and the sample size is relatively small (Amin et al., 2020). As a result, we also apply the ARDL Bounds test procedure augmented with Kripfganz and Schneider (2020) critical values and approximate probability values derived from surface regressions.

The Vector Autoregression (VAR) framework is used for two main reasons. First, the VAR framework allows us to analyse the IRFs of various structural shock processes without a series of monotonous estimations of shock processes. Second, the VAR framework can address the issue of simultaneity bias. A simultaneity issue might appear in the analysis because of reverse causality due to the nature of the independent variables in the derived model. For instance, there could be reverse causalities among income, renewable energy, and price. These potential reverse causalities could lead to a biased shock effect and improper policy conclusions. The VAR framework can address this issue by estimating a reduced form of a system of equations.

Nevertheless, the VAR framework can sometimes lead to spurious results. This primarily occurs due to over-parameterisation in the reduced system of the equation estimation process. Since over-parameterisation, given the small sample size, leads to inconsistent results, we use BVAR instead of the traditional VAR modelling framework. BVAR was proposed by Sims (1984) and later updated by Sims and Zha (1998) and Lütkepohl (2005). The general BVAR (p) framework can be expressed by Eq. (9).

$$Y_t = \vartheta_0 + \sum_{j=1}^p \Pi_j Y_{t-j} + \eta Z_t + \varepsilon_t \tag{9}$$

Where, Y_t is a K vector of all the endogenous variables with chosen pth lag order. η is a $K \times (d-1)$ matrix that captures the effects of exogenous coefficients. Finally, ε_t is the error term vector with normal distribution with zero mean and constant variance. Assembling the variables on the right side into the $(KP + d)$ vector of x_t and the matching coefficients into B, we get:

$$x_t = (Y_{t-1}', \dots, Y_{t-p}', 1, F_t')' \tag{10}$$

$$B = (\Pi_1, \dots, \Pi_p, \vartheta_0, \eta) \tag{11}$$

Now, rewriting Eq. (9) gives us Eq. (12) which can be further written in stack form by Eq. (13):

Table 2
Overview of the Dataset.

Criteria	LNREC	LNREI	LNOP	LNRY	LNFDI
Mean	8.95	1.30	7.44	28.95	18.32
Median	8.96	1.38	7.25	28.92	19.06
Maximum	9.16	3.35	9.12	29.81	21.76
Minimum	8.71	0.01	6.08	28.25	12.42
Std. Dev.	0.13	0.65	1.01	0.47	2.81
Skewness	-0.10	0.46	0.34	0.21	-0.46
Kurtosis	1.72	4.61	1.58	1.83	1.85
Jarque-Bera	2.14	4.57	3.31	2.06	2.81
Probability	0.34	0.10	0.19	0.36	0.25

Note: reform variables are not reported in the table because they are dummies.

$$Y_t' = x_t' B + \epsilon_t' \tag{12}$$

$$Y = XB + E \tag{13}$$

With the assumption of normal distribution within the multivariate framework, a multivariate normal distribution for Y can be written as:

$$(Y|B) \sim N((X \otimes I_k)\beta, I_T \otimes \Sigma) \tag{14}$$

The over-parameterisation is restricted through a shrinkage method by feeding the model with logical priors. For priors, we use the Sims-Zha (normal-Wishart) method where the prior matrix is calculated from the actual dataset.⁵ After estimating the model with BVAR, we generate IRFs with a positive 1 Standard Deviation (S.D.) shock to every explanatory variable. Finally, the parameter stability test is done through the CUSUM test.

3.3. Data

Annual dataset covering from 1985 to 2019 is used for the empirical analysis. Data on real GDP, FDI, REC, REI, international Oil Price (OP) are taken from World Development Indicators (World Bank, 2023), International Energy Agency (2020), and BP Statistical Review of World Energy, (2020), respectively. Energy sector reform variables are taken from Amin et al. (2021). An overview of the dataset is provided in Table 2. The statistical computations and econometric estimations and relevant tests have been done using the STATA and Eviews statistical platforms.

4. Results and discussions

Table 3 shows the non-stationarity in all the variables at their level form but stationarity at their first differenced form. Therefore, we can conclude that all the variables are I (1).

Next, Table 4 and Table 5 show the cointegration results. We discover the evidence of no cointegration among the variables of interest from the Johansen cointegration. We further aim to confirm the Johansen cointegration results with the ARDL bounds cointegration test. The ARDL bounds cointegration test also confirms the absence of meaningful cointegration among the variables of interest since the F-statistics is much lower than I (1) critical values. The cointegration test results indicate that we should focus on only SR analysis rather than LR analysis.

After confirming the absence of cointegrating relationships, we move on to analyse IRFs generated from the BVAR estimation. Results of the IRFs from positive 1 S.D. shocks from the explanatory variables can be seen from Fig. 3. It is clearly evident that a 1 S.D. positive shock in oil price reduces REC in the very SR (till around 2 years). However, after 2 years onwards, the effect of OPS increases REC till 3.5 years with a peak effect of 15 basis points (bps). The effect starts decreasing from 4th year, and finally stabilises after 5 years. As OPS is realised in Bangladesh, in

Table 3
Unit Root Test Results.

ADF Var	I(0)		I(1)	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
LNREC	-1.19	-2.45	-6.65***	-6.79***
LNRY	6.55	-1.06	-2.32	-4.85***
LNOP	-0.81	-2.03	-5.38***	-5.33***
LNFDI	-2.44	-0.54	-5.39***	-6.04***
LNREI	1.93	-2.17	-3.40**	-6.15***
KPSS Var	I(0)		I(1)	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
LNREC	0.75**	0.12**	0.18	0.08
LNRY	0.74***	0.20**	0.44*	0.06
LNOP	0.47**	0.11*	0.15	0.16
LNFDI	0.40*	0.13**	0.05	0.05
LNREI	0.47**	0.11*	0.18	0.08

Note: ***, **, and * depict significance at 1 %, 5 %, and 10 %, respectively. ADF performs under the null hypothesis that the series is non-stationary against the alternative hypothesis that the series is stationary. KPSS performs under the null hypothesis that the series is stationary against the alternative hypothesis that the series is not stationary.

Table 4
ARDL Bounds Cointegration Test Results.

Criteria	Value	10 %		5 %		1 %	
		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
Model F-Static (LNREC)	1.57	2.03	3.13	2.32	3.50	2.96	4.26
Model F-Static (LNRY)	0.25	3.03	4.06	3.47	4.57	3.89	5.07
Model F-Static (LNOP)	1.35	2.20	3.49	2.56	3.49	3.29	4.37
Model F-Static (LNFDI)	2.87	2.20	3.09	2.56	3.50	3.30	4.40
Model F-Static (LNREI)	0.84	1.90	3.01	2.26	3.48	3.10	4.44

Table 5
Johansen Cointegration Test Results.

Hypothesised No. of CE(s)	Trace Test	Probability	Max-Eigen Test	Probability
None	60.44	0.2	20.51	0.72
At most 1	39.93	0.23	17.69	0.52
At most 2	22.24	0.29	13.03	0.45
At most 3	9.21	0.35	9.09	0.27
At most 4	0.12	0.73	0.12	0.73

Note: The test is run only on intercept only.

the very beginning, REC decreases due to the result of a substitution lag effect mentioned by Amin and Khan (2020).

The sudden increase in oil prices creates an upward pressure on the oil import balance. Given that Bangladesh is highly dependent on oil commodities, the government reallocates resources (i.e. investment funds, subsidies, etc.) from relatively less important energy commodities to manage higher import bills as well as increase other front-line fossil fuels usage to continue the ongoing production activities. This is essentially how the substitution lag is transmitted, and the consumption level of RE in the very beginning declines. However, as economic agents mostly follow rational expectations, there will be an increase in different activities to increase RE share in the activity-wise energy mix to mitigate the adverse effects of oil shocks, which will result in a rise in REC to some degree (Zhao et al., 2021). The main reasons behind the slow rise in REC due to a positive OPS are the prevailing market dynamics, RE technology, and policy ineffectiveness (Payne, 2012).

When 1 S.D. positive shock in aggregate income is injected into the model, we find that REC decreases till 2nd year (around -46 bps). From 3rd year onwards, the shock effect tends to converge towards a steady state. The shock effect diminishes after around 5.5 years. Even though

⁵ For details, see Sims and Zha (1998).

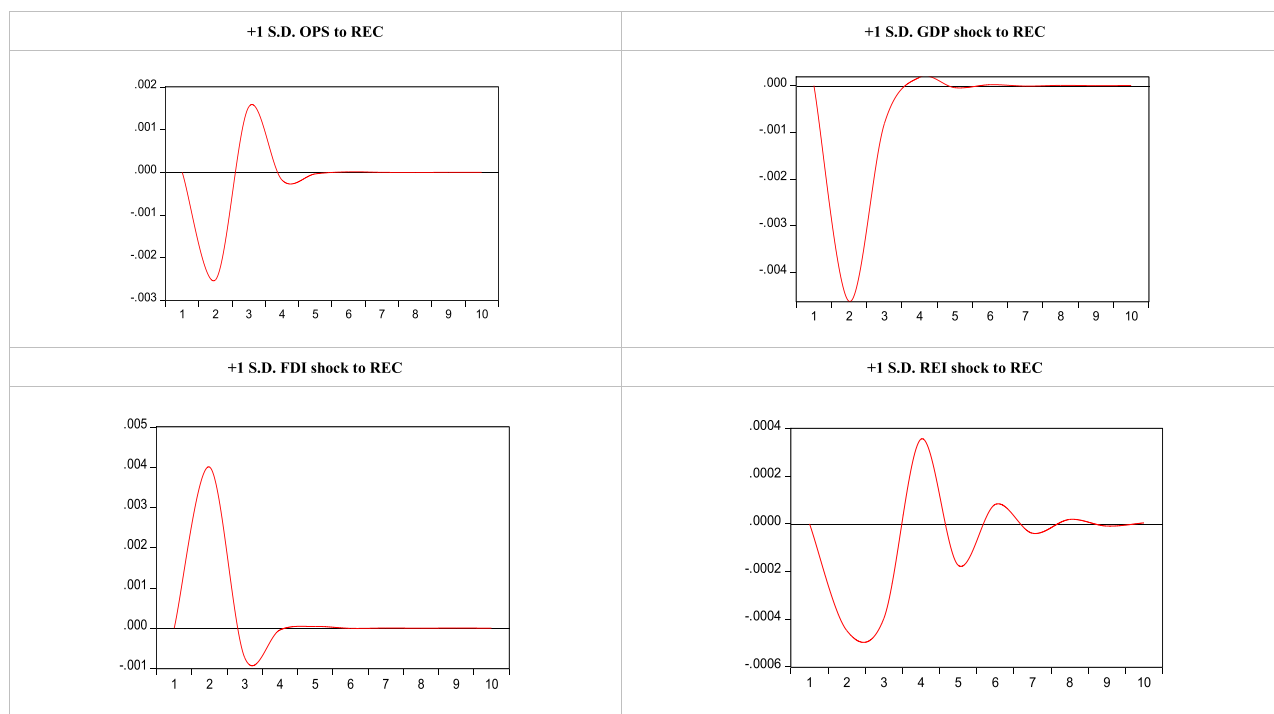


Fig. 3. BVAR Model IRFs.

existing literature argues that energy is a normal good (Karacan et al., 2021; Narayan, 2016; Kahsai et al., 2012; Sadorsky, 2009; Ozturk, 2010), we reveal that the notion considering RE is not straightforward. As soon as income increases, REC decreases due to the prevailing demand structure for secondary energy sources. An excellent example of a secondary energy source from Bangladesh's context is electricity (Amin, 2015). As income increases, demand for electricity surges due to various reasons such as the use of energy-intensive compliances (e.g., different production equipment), the firm's forward-looking profit nature (i.e. higher income to higher investment, and then higher production and profit), electricity theft, and many more. Fossil energies are used primarily because of their significant benefits, such as being easily available and relatively more straightforward to process for electricity generation, in order to fulfil the growing demand promptly. As a result, the primary energy balance has typically been significantly skewed toward fossil fuels during the past few decades.

The intuitive discussion goes hand in hand with the notion of the Social Exchange Theory (SET) proposed by Emerson (1976). The SET claims that a person's attitude toward a given activity is influenced by the prospective advantages that may result from engaging in the activity. Agents within a group or society enter the trade-off process if the advantages outweigh the drawbacks. When the advantages of traditional non-REC are more important than those of RE sources from the standpoint of energy consumption, agents prioritise traditional non-REC (Amin et al., 2022). One can anticipate greater investments in non-energy development as a result. Additionally, as the financial industry develops, the investment concentration would rise. As a result, the REC spectrum would continue to shrink.

Next, we analyse the 1 S.D. shock of FDI on REC in Bangladesh. It is evident from the IRF results that the positive shock in FDI increases REC till 2 years with a maximum peak of 40 bps. After 3 years, the shock effect tends to decline in the economy and is fully realised after 5.5 years with a negligible delayed negative effect in 3rd year. Although existing literature shows evidence of how FDI could amplify the notion of the

pollution haven hypothesis⁶ (Sarkodie et al., 2020; Solarin et al., 2017), there is also some evidence that reveals FDI could potentially be a component for RE augmentation (Zhang et al., 2021; Shah et al., 2021; Mehmood, 2021; Doytch and Narayan, 2016; Hakimi and Hamdi, 2016; Tamazian and Rao, 2010; Khandker et al., 2018).

FDI from multinational firms could improve the environmental quality of the host countries through the transfer of technological skills (i.e. technique effect or composite effect) in the production process. Another channel through which multinational firms could promote REC is Corporate Social Responsibility (CSR). Since it opens new avenues for various REIs, CSR has become known as one of the most broadly accepted strategies for the growth of the sustainable energy industry.

Finally, we reveal an oscillation pattern in the REC after 1 S.D. positive shock in the REI. The shock effect diminishes after 9th year. Besides, the maximum positive response from the positive REI comes from 4th year (around 3.8 bps). The reason behind REC falls as soon as investment shock is injected into the model is the result of the income effect discussed earlier. Amin et al. (2018) mention that RE-related investments expand the horizon of job creation due to the dynamic and decentralised nature of the RE market. This leads to changes in income intensities at different cohorts, resulting in changes in the standard of living that ultimately increase the demand for electricity. Hence, the propensity of RE utilisation falls. However, as RE generation increases due to the higher investment, the consumption of RE increases in different activities. One point to note is that the relatively lower response with oscillation is the result of a relatively low share of REI in the total sectoral energy investment and prevailing income effect phenomenon.

It should be worth mentioning that the above different shock effects do not deviate as we extend the model by controlling the effects of

⁶ The pollution haven hypothesis posits that if the government imposes tighter restrictions on the polluting behavior of firms, the polluting activities, through trade, are shifted from more developed to less developed economies. For more visit <https://www.aeaweb.org/research/charts/environmental-regulation-displacement-batteries>.

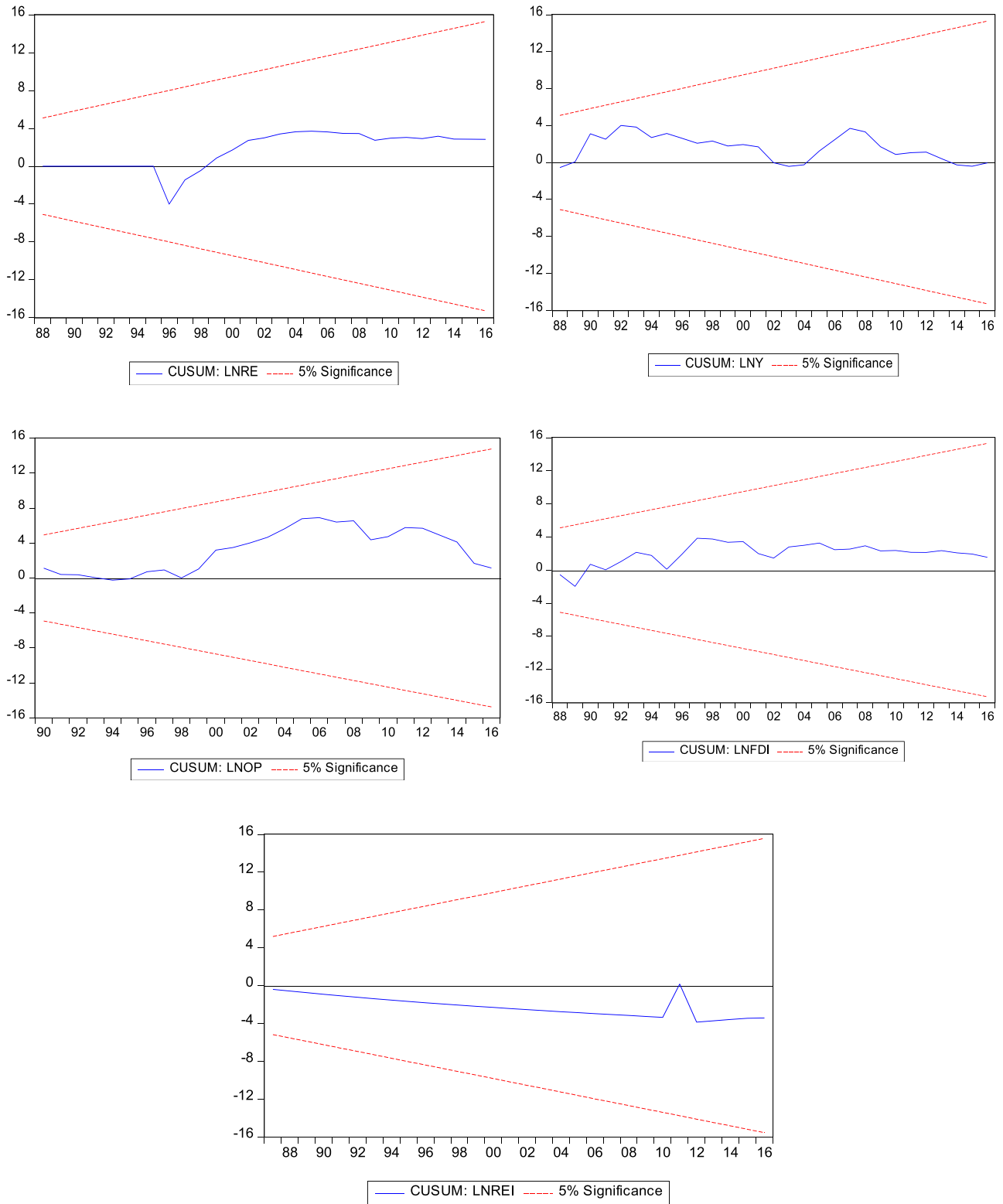


Fig. 4. Stability Plots of the Variables.

Natural Gas Consumption (NGC) or Coal Consumption (CC).⁷ More particularly, as OPS is observed in the extended model, NGC and CC increase, given that these sources are the next best options for ensuring energy security within the immediate periods. Such change eventually reduces the REC in the same time periods (i.e., substitution lag), analogues to previous finding. IRFs of this model are shown in **Figure A1** in the Appendix.

We utilise the novel CUSUM test shown in **Fig. 4** to further verify the stability of the model's variables. In context with exogenous factors (systematic and sudden movements), we discover that all the variables are stable.

5. Conclusion and policy recommendations

This paper analysed how RED is influenced in Bangladesh's macro-economic sphere. For the purpose of the empirical analysis, we have developed a novel RE demand model to capture the explicit effects of oil prices along with macroeconomic factors and policies. We have used annual data covering from 1980 to 2019 and applied standard time series econometric techniques to analyse the data. Within the sample period, we found that all the variables are I(1). We further checked the LR cointegration between the selected variables. Results of the JJ and ARDL bounds cointegration tests revealed the absence of meaningful LR. As a result, to analyse the SR impacts, we have used the BVAR technique. IRFs from the BVAR show that positive OPS increases REC after a lag effect. Moreover, positive shocks to RE-related investment and FDI tend to increase REC. On the other hand, it has been found that a positive shock in GDP (income) dampens the REC.

Even though IRF results indicate that a positive OPS increases REC, the response effect in the economy is significantly low. It indicates that Bangladesh is still vulnerable to oil shocks. Moreover, the negative response of REC due to the positive income shock indicates persisting skewness in the consumption pattern due to the behavioural aspects as advocated by the SET. Combining both of the results reveals that there is an utmost need to increase the share of RE in the primary fuel mix. Furthermore, along with improving renewable technology, there is also a need for bringing a change in the market dynamics with an appropriate set of RE regulatory frameworks.

As previously highlighted by [Amin et al. \(2021\)](#), we strongly emphasise institutional strength, which, considering the shared characteristics of the South Asian nations, should be assured. Among others, [Cai and Aoyama \(2018\)](#) show that the creation of an appropriate framework for regulating and executing a decentralised system is hampered and delayed by fragmentation, or the absence of managerial authority, thus distorting the dynamics of the energy market. Thus, it is challenging for businesses specialising in RE to enter and function in the energy market. Thus, significant priority should be accorded to synchronised institutional reforms through the implementation of regulatory legitimacy in the areas of RE technology exploration, pricing structures, investment mechanisms, market monitoring mechanisms,

demand side management, negotiations for increased cross-border trading within South Asia, and, lastly, knowledge diffusion programmes.

Furthermore, we highly recommend supporting international companies that make use of various RE technologies and advocating for REC within the sectors ([Amin et al., 2022b](#)). Additionally, we emphasise developing an REI policy that would aid in facilitating various sorts of investments for the growth of RE in order to combat the oscillation pattern of REI shock. We argue that the primary goal of policy should be to promote investment in renewable energy projects with competitive advantages, such as waste-to-energy facilities in urban or semi-urban regions, solar home systems, small-scale biogas plants located in communities, and small- to medium-photovoltaic grid projects.

Moreover, from the ideas of [Pan et al. \(2019\)](#), we highlight the importance of strategies like targeted financial incentives for the development of RE infrastructure, such as bilateral or multilateral free trade regimes. Additionally, to improve technical cooperation between countries, the adoption of universal principles to increase inter-country REI, exchange of knowledge inside firms, and cooperation with neighbouring countries, we propose the creation of an integrated RE act. Promoting societal awareness would also be helpful because political and consumer agendas tend to overlook the usage of RE as a significant energy source.

Using a similar modelling methodology, an expansion of this paper may be to analyse RED at the disaggregate level. To rethink the national RE policy would give policymakers information on more crucial areas. Besides, analysis of RED from the regional perspective is also an avenue worth exploring. Since we have not included the impacts of the COVID-19 pandemic, an interesting further extension would be to analyse how the different shock responses alter when the pandemic scenario is controlled in the modelling framework.

CRedit authorship contribution statement

Sakib Amin: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Formal analysis, Data curation, Conceptualization. **Mahatab Kabir Khandaker:** Writing – original draft, Visualization, Software, Resources, Formal analysis, Data curation. **Farhan Khan:** Writing – original draft, Visualization, Software, Resources, Formal analysis, Data curation.

Declaration of Competing Interest

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

Acknowledgement

We would like to thank the anonymous reviewers for their valuable comments to enrich the quality of the paper.

⁷ The extension of the model is done by adding NGC and CC as inputs in the economy-wide production function expressed by [Eq. \(1\)](#). The optimisation process, hence, will lead to a REC function with new additional variables (i.e., NGC and CC), assuming wage is normalised to 1. Relevant tests are conducted before applying BVAR, and can be delivered upon request.

Appendix

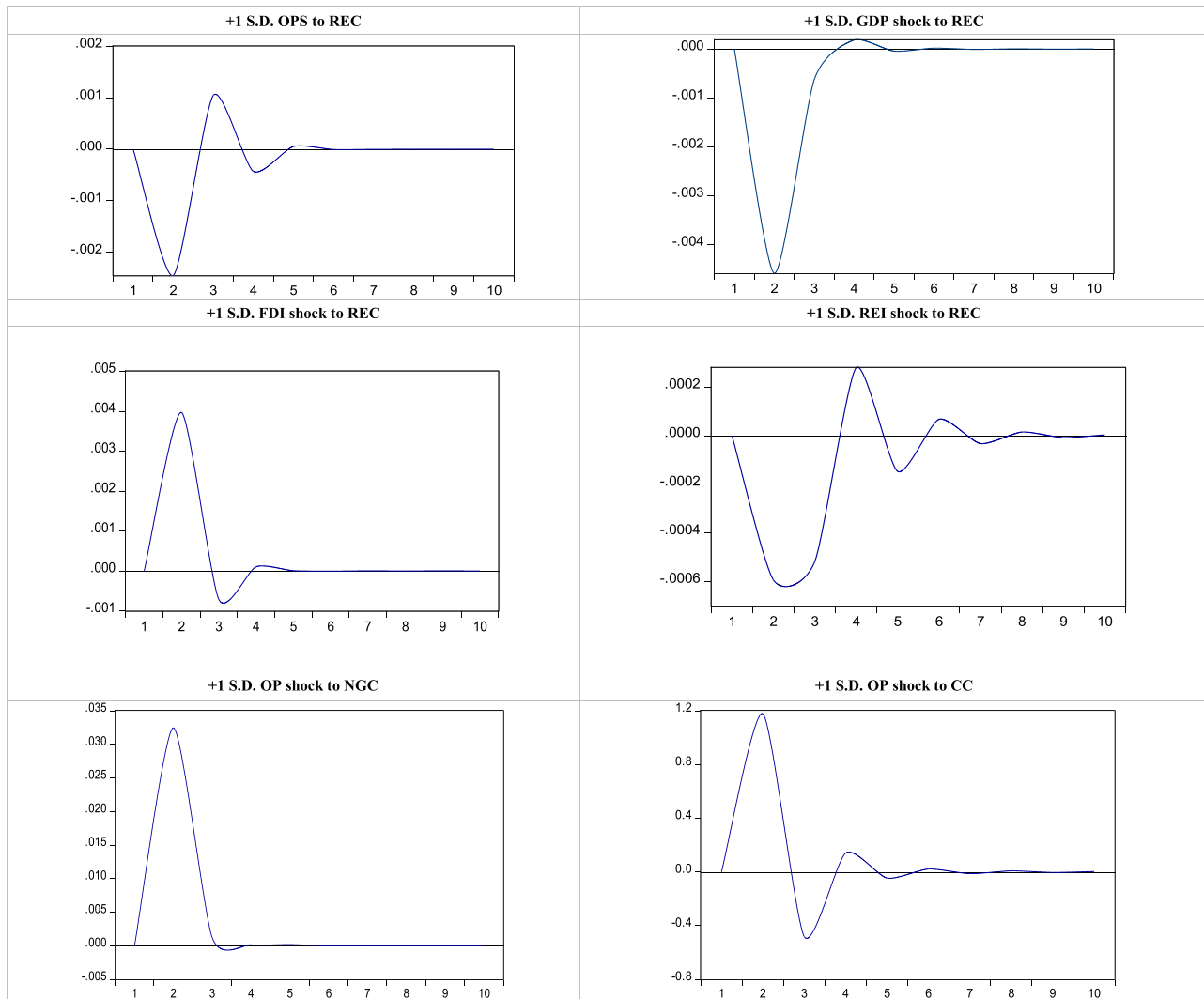


Figure A1. BVAR Model IRFs Controlled for Natural Gas and Coal Consumptions.

Data availability

Data will be made available on request.

References

Amin, S., Jamasb, T., Nepal, R., 2021. Regulatory reform and the relative efficacy of government versus private investment on energy consumption in South Asia. *Econ. Anal. Policy* 69, 421–433.

Amin, S.B. (2015). *The macroeconomics of energy price shocks and electricity market reforms: The case of Bangladesh*. Durham University.

Amin, S.B., Khan, F., 2020. Modelling energy demand in Bangladesh: An empirical analysis. *J. Dev. Areas* 54 (1), 39–52.

Amin, S.B., Khan, F., Rahman, S., 2018. Economic development: Energy and ethical issues in Bangladesh. *Bangladesh. J. Political Econ.* 34, 225–238.

Amin, S.B., Al Kabir, F., Khan, F., 2020. Energy-output nexus in Bangladesh: a two-sector model analysis. *Energy Strategy Rev.* 32, 100566.

Amin, S.B., Amin, Y.N., Khandaker, M.K., Khan, F., Rahman, F.M., 2022b. Unfolding FDI, Renewable Energy Consumption, and Income Inequality Nexus: Heterogeneous Panel Analysis. *Energies* 15 (14), 5160.

Amin, S.B., Khan, F., Rahman, M.A., 2022c. The relationship between financial development and renewable energy consumption in South Asian countries. *Environ. Sci. Pollut. Res.* 29 (38), 58022–58036.

Amin, S.B., Mansur, A.H., Kamal, S.M., Groh, S., 2022a. Powering up a country into the middle-income club: the story of Bangladesh. *Electricity Access, Decarbonization, and Integration of Renewables: Insights and Lessons from the Energy Transformation in Bangladesh, South Asia, and Sub-Sahara Africa*. Springer Fachmedien Wiesbaden, Wiesbaden, pp. 21–52.

Apergis, N., Payne, J.E., 2014. The causal dynamics between renewable energy, real GDP, emissions, and oil prices: evidence from OECD countries. *Appl. Econ.* 46 (36), 4519–4525.

Ashfaq, S., Liangrong, S., Waqas, F., Gulzar, S., Mujtaba, G., Nasir, R.M., 2024. Renewable energy and green economic growth nexus: insights from simulated dynamic ARDL. *Gondwana Res.* 127, 288–300.

Azam, M., Khan, A.Q., Bakhtyar, B., Emirullah, C., 2015. The causal relationship between energy consumption and economic growth in the ASEAN-5 countries. *Renew. Sustain. Energy Rev.* 47, 732–745.

BP Statistical Review of World Energy (2020). *Annual Report*. Accessed July 25, 2024 from (<https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf>).

Brini, R., Amara, M., Jemmali, H., 2017. Renewable energy consumption, international trade, oil price and economic growth inter-linkages: The case of Tunisia. *Renew. Sustain. Energy Rev.* 76, 620–627.

Cai, Y., Aoyama, Y., 2018. Fragmented authorities, institutional misalignments, and challenges to renewable energy transition: A case study of wind power curtailment in China. *Energy Res. Soc. Sci.* 41, 71–79.

Doytch, N., Narayan, S., 2016. Does FDI influence renewable energy consumption? An analysis of sectoral FDI impact on renewable and non-renewable industrial energy consumption. *Energy Econ.* 54, 291–301.

Emerson, R.M., 1976. Social exchange theory. *Annu. Rev. Sociol.* 2 (1), 335–362.

- Hakimi, A., Hamdi, H., 2016. Trade liberalization, FDI inflows, environmental quality and economic growth: a comparative analysis between Tunisia and Morocco. *Renew. Sustain. Energy Rev.* 58, 1445–1456.
- Hydrocarbon Unit (2021). *Energy scenario of Bangladesh 2020–2021*. Ministry of Power, Energy and Mineral Resources. Dhaka, Bangladesh.
- Imam, M.I., Jamasb, T., Llorca, M., 2019. Sector reforms and institutional corruption: Evidence from electricity industry in Sub-Saharan Africa. *Energy Policy* 129, 532–545.
- International Energy Agency (2020). *World Energy Outlook 2020*. Accessed July 25, 2024 from (<https://iea.blob.core.windows.net/assets/a72d8abf-de08-4385-8711-b8a062d6124a/WEO2020.pdf>).
- Islam, M.M., Irfan, M., Shahbaz, M., Vo, X.V., 2022. Renewable and non-renewable energy consumption in Bangladesh: The relative influencing profiles of economic factors, urbanization, physical infrastructure and institutional quality. *Renew. Energy* 184, 1130–1149.
- Johansen, S., Juselius, K., 1990. Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. *Oxf. Bull. Econ. Stat.* 52 (2), 169–210.
- Kahsai, M.S., Nondo, C., Schaeffer, P.V., Gebremedhin, T.G., 2012. Income level and the energy consumption–GDP nexus: Evidence from Sub-Saharan Africa. *Energy Econ.* 34 (3), 739–746.
- Karacan, R., Mukhtarov, S., Bariş, İ., İşleyen, A., Yardımcı, M.E., 2021. The Impact of Oil Price on Transition toward Renewable Energy Consumption? Evidence from Russia. *Energies* 14 (10), 2947.
- Kazemzadeh, E., Fuinhas, J.A., Koengkan, M., Shadmehri, M.T.A., 2023. Relationship between the share of renewable electricity consumption, economic complexity, financial development, and oil prices: A two-step club convergence and PVAR model approach. *Int. Econ.* 173, 260–275.
- Khalilpour, K.R., 2019. The Nexus era: toward an integrated, interconnected, decentralized, and prosumer future. In *Polygeneration with Polystorage for Chemical and Energy Hubs*. Academic Press, pp. 27–52.
- Khandker, L.L., Amin, S.B., Khan, F., 2018. Renewable energy consumption and foreign direct investment: Reports from Bangladesh. *J. Account. Financ. Econ.* 8 (3), 72–87.
- Kripfganz, S., Schneider, D.C., 2020. Response surface regressions for critical value bounds and approximate p-values in equilibrium correction models 1. *Oxf. Bull. Econ. Stat.* 82 (6), 1456–1481.
- Lütkepohl, H., 2005. *New Introduction to Multiple Time Series Analysis*. Springer Science & Business Media.
- Mehmood, U., 2021. Renewable energy and foreign direct investment: does the governance matter for CO2 emissions? Application of CS-ARDL. *Environ. Sci. Pollut. Res.* 1–7.
- Narayan, S., 2016. Predictability within the energy consumption–economic growth nexus: Some evidence from income and regional groups. *Econ. Model.* 54, 515–521.
- Nasim, I., Boukhris, M., Kayani, U.N., Bashir, F., Haider, S.A., 2023. Exploring the links between renewable energy, FDI, environmental degradation, and international trade in selected developing countries. *Int. J. Energy Econ. Policy* 13 (6), 418–429.
- Omri, A., Daly, S., Nguyen, D.K., 2015. A robust analysis of the relationship between renewable energy consumption and its main drivers. *Appl. Econ.* 47 (28), 2913–2923.
- Ozturk, I., 2010. A literature survey on energy–growth nexus. *Energy Policy* 38 (1), 340–349.
- Pan, X., Uddin, M.K., Han, C., Pan, X., 2019. Dynamics of financial development, trade openness, technological innovation and energy intensity: Evidence from Bangladesh. *Energy* 171, 456–464.
- Pata, U.K., Dam, M.M., Kaya, F., 2023. How effective are renewable energy, tourism, trade openness, and foreign direct investment on CO2 emissions? An EKC analysis for ASEAN countries. *Environ. Sci. Pollut. Res.* 30 (6), 14821–14837.
- Payne, J.E., 2012. The causal dynamics between US renewable energy consumption, output, emissions, and oil prices. *Energy Sources, Part B: Econ., Plan., Policy* 7 (4), 323–330.
- Peng, X., Chen, B., 2023. How do corporate social responsibility and green finance strategies impact sustainable development in China's renewable energy sector? *Environ. Sci. Pollut. Res.* 30 (45), 100920–100936.
- Rehman, S.A.U., Cai, Y., Mirjat, N.H., Walasai, G.D., Nafees, M., 2019. Energy–environment–economy nexus in Pakistan: Lessons from a PAK-TIMES model. *Energy Policy* 126, 200–211.
- Sadorsky, P., 2009. Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. *Energy Econ.* 31 (3), 456–462.
- Sarker, S.A., Wang, S., Adnan, K.M., Pooja, P., Akhi, K., Akter, K., 2023. Renewable energy in Bangladesh: economic growth and policy perspectives. *J. Sci. Technol. Policy Manag.* 14 (4), 780–797.
- Sarkodie, S.A., Adams, S., Leirvik, T., 2020. Foreign direct investment and renewable energy in climate change mitigation: does governance matter? *J. Clean. Prod.* 263, 121262.
- Shah, M.H., Sultan Salem, B.A., Ullah, I., Alam Rehman, M.Z., Fareed, Z., 2021. Nexus between Foreign direct investment inflow, renewable energy consumption, ambient Air pollution, and human Mortality: A public health perspective from Non-linear ARDL approach. *Front. Public Health* 9.
- Shu, H., Wang, Y., Umar, M., Zhong, Y., 2023. Dynamics of renewable energy research, investment in EnvoTech and environmental quality in the context of G7 countries. *Energy Econ.* 120, 106582.
- Sims, C.A., Zha, T., 1998. Bayesian methods for dynamic multivariate models. *Int. Econ. Rev.* 949–968.
- Sinani, E., Meyer, K.E., 2004. Spillovers of technology transfer from FDI: the case of Estonia. *J. Comp. Econ.* 32 (3), 445–466.
- Solarin, S.A., Al-Mulali, U., Musah, I., Ozturk, I., 2017. Investigating the pollution haven hypothesis in Ghana: an empirical investigation. *Energy* 124, 706–719.
- Stawicka, E., 2021. Sustainable business strategies as an element influencing diffusion on innovative solutions in the field of renewable energy sources. *Energies* 14 (17), 5453.
- Tamazian, A., Rao, B.B., 2010. Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. *Energy Econ.* 32 (1), 137–145.
- Timilsina, G.R., Pargal, S., 2020. Economics of energy subsidy reforms in Bangladesh. *Energy Policy* 142, 111539.
- Tiwari, A.K., Nasreen, S., Anwar, M.A., 2022. Impact of equity market development on renewable energy consumption: Do the role of FDI, trade openness and economic growth matter in Asian economies? *J. Clean. Prod.* 334, 130244.
- Uddin, M.J., 2023. Investigating the impulse responses of renewable energy in the context of China: A Bayesian VAR Approach. *Renew. Energy* 219, 119485.
- Wang, Q., Li, C., Li, R., 2023. How does renewable energy consumption and trade openness affect economic growth and carbon emissions? International evidence of 122 countries. *Energy Environ.*
- World Bank (2023). *World Development Indicators (WDI)*. Accessed 25 June, 2024 from (<https://databank.worldbank.org/source/world-development-indicators>).
- Yoshino, N., Taghizadeh-Hesary, F., 2014. Monetary policy and oil price fluctuations following the subprime mortgage crisis. *Int. J. Monet. Econ. Financ.* 7 (3), 157–174.
- Zeren, F., Akkuş, H.T., 2020. The relationship between renewable energy consumption and trade openness: New evidence from emerging economies. *Renew. Energy* 147, 322–329.
- Zhang, Y., Qamruzzaman, M., Karim, S., Jahan, I., 2021. Nexus between economic policy uncertainty and renewable energy consumption in BRIC Nations: the mediating role of foreign direct investment and financial development. *Energies* 14 (15), 4687.
- Zhang, Y.F., Parker, D., Kirkpatrick, C., 2008. Electricity sector reform in developing countries: An econometric assessment of the effects of privatisation, competition and regulation. *J. Regul. Econ.* 33 (2), 159–178.
- Zhao, Y., Zhang, Y., Wei, W., 2021. Quantifying international oil price shocks on renewable energy development in China. *Appl. Econ.* 53 (3), 329–344.