Impact of Foreign Direct Investment on Energy Consumption: Empirical Evidence

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The paper investigates the association between foreign direct investment (FDI) and energy consumption within the purview of trade liberalization and economic growth from 1971 to 2014 in Bangladesh, employing the Auto Regressive Distributive Lag (ARDL) bounds testing approach. The study result depicts a negative impact of FDI on energy consumption in both the long and short run. Moreover, the study results persist robust to alternative measurements and estimators. Furthermore, a unidirectional causal relationship moving from energy consumption to foreign direct investment supports the institutional strength of the energy sector. Therefore, policymakers should undertake a pragmatic policy for the best utilization of FDI in the energy sector and reinforce local firms' absorptive capability to internalize FDI-centric information spillover in energy conservation.

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Introduction

Energy consumption is considered a crucial instrument and integral to accelerating economic productivity, economic growth (Belke, Dobnik, and Dreger 2011) and sustainable development (Kahouli 2017). In this case, the energy security issue has become a critical phenomenon as stated in the three crucial sustainable development goals (SDGs 7, 9 and 13), underlining green energy, innovation, and green finance for sustainable development. Even a sustainable development/productivity mechanism requires much and significantly cleaner energy (Sharmin and Tareque 2020; Shahbaz and Lean 2012). Thus, energy consumption is directly associated with sustainable development that helps determine a country's social and economic progress (Mahmood et al. 2014).

However, in 2009, Bangladesh experienced sluggish growth in supplying the energy demanded for materializing the sustainable development goals. In consequence, the prospective plan targeting 2021 includes securing a vital expansion to address this supply shortage via improving user efficiency, encouraging private sector investment and diversifying energy sources (Ministry of Planning 2020). Bangladesh has maintained an average 7 percent GDP growth over a decade, graduating from Least Developed Countries to Lower Middle-Income status in 2015. The estimated final energy consumption is around 55.50 mtoe (Million tonnes of Oil Equivalent), averaging about a 6% increase in energy consumption annually (Ministry of Power, Energy and Mineral Resources 2021). Aiming to achieve Vision 2041, the Bangladesh government targeted adopting energy development strategies (including adopting new capital outlays in energy generation, transmission, and distribution; diversifying the energy mix from natural gas to renewable energy and cleaner coal technologies; conserving energy; and optimum use of existing installed power generation capacities) for securing energy security and sustainability (Government of Bangladesh 2020). However, the energy developments have critical implications for climate change and have also caused increasingly severe environmental issues such as Greenhouse Gas (GHG) emissions, especially CO_2 and air pollution (Wang et al. 2011; Rauf et al. 2018) through the linkage between energy consumption and carbon emission. Therefore, the developing countries are considering the issue of adopting energy-efficient technology, which may lead to a reduction in carbon emissions relative to energy use via the usage of renewable energy. Relevant to this, Yuan et al. (2009) suggested ways of reducing energy use, such as improved energy policy, introducing developed energy-efficient technology and strict energy-use regulations.

Pertaining to this background, most developing economies consider the foreign direct investment (FDI) inflows as an alternative measure to tackle the countries' economic problems (Amoako and Insaidoo 2021). In Bangladesh, the investment requirements for the energy sector are estimated at USD 7.5 billion by 2021 and an additional USD 21 billion by 2030; both the public and the private sectors of Bangladesh have to struggle to match this investment capacity (Mahbub and Jongwanich 2019). In this regard, the Bangladeshi government encourages FDI inflows in the energy sector, given previous implemented supportive policies (such as, tax exemption on royalties, technical know-how, and technical assistance fees, and on the interest of foreign loans). FDIs to the energy (power, gas and petroleum) sector in 2015–2016 amounted to USD 208 million, accounting for 10% of total FDI flows. In addition, they increased to USD 606.71 million, accounting for around 24.2% of total flows (Bangladesh Bank 2021). FDI as an external source of finance influences the total investments of a country as well as being a source of innovation that can promote energy efficiency to stimulate economic growth (Doytch and Narayan 2016). In this context, globalization also appears to be the key agent in consolidating economic integration among developing countries which have restructured their economic policies by eliminating obstacles and enacting friendly policies in foreign trade and investment. However, massive competition exists among them to attract FDI (Latief and Lefen 2019).

FDI inflows transfer technology, knowledge and management practices to the host country along with the capital. According to Brucal, Javorcik, and Love (2019), developed economies prefer to shift their multinational companies and industries to developing economies (because of their strict and high environmental standards), and they primarily endeavour to replicate the energy-efficient and clean technologies of host countries. In earlier days, Blomström and Kokko (1996) claimed that FDI inflows are the simplest means of technology transfer to developing countries, as they often come with the latest packages of technology and innovations. In this case, FDI can bridge the 'idea gaps' between developed and developing countries as it integrates technological advancement and skills acquisition to maximize production (figure 1).

South Asian countries represent themselves as the fast-growing economies in the world. The region has witnessed a relatively favourable population growth, energy use, and per capita income. This region utilizes domestic and external investments in power supply, fuel, and infrastructure, prioritizing the effectiveness of these investments. The welfare and standard of life of its citizens have substantially increased because of the significant advantages of a highly managed acceleration of the energy system of this region (International Energy Agency 2019). In fact, these countries largely depend on crude oil and gas imports due to the shortage of local energy sources, where FDI has a significant share in energizing the energy sector of this area (Latief and Lefen 2019).

As in other developing economies, the demand for energy consumption in Bangladesh has gradually risen with its population growth and economic activities. FDI is assumed to support the least developed and developing countries, especially Bangladesh, in several ways. First of all,

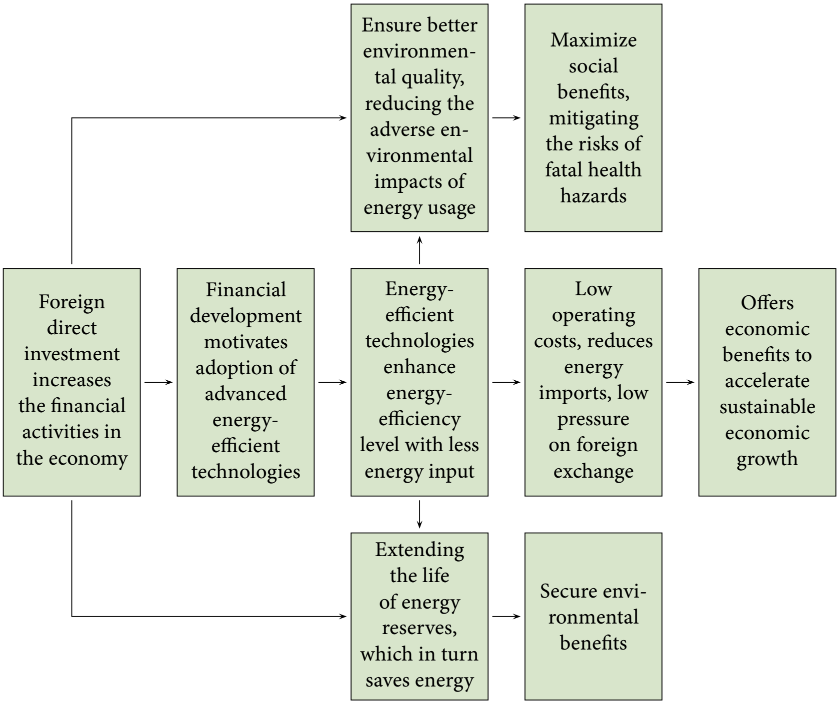

FIGURE 1 Linkages between Energy Consumption and Foreign Direct Investment (FDI) Nexus

it enhances low domestic investment because of the resource scarcity in these countries. Secondly, FDI can create employment opportunities, escalate local competition and other affirmative externalities (for example, transfer of technological knowledge and expertise, ideologies etc.). Although Bangladesh proposes worthwhile investment facilities for overseas investors and adopts stimulating policies to magnetize FDI, it can be called one of South Asia's most open FDI systems (Khatun and Ahamad 2015).

The rationale for choosing Bangladesh for our investigation includes the following. Firstly, as a developing country in South Asia, Bangladesh is considered one of the most climate change-vulnerable countries in the world, and the country is not highly prepared to meet the risk. Furthermore, FDI increases the status of energy consumption and facilitates the energy-induced emissions level, which requires setting the country's development goal. Secondly, Bangladesh intends to become an industrial economy by 2041 to exploit the potential of globalization (trade, remittances, FDI) and internal resources (workforce and natural resources, i.e. energy, blue economy, green economy). Therefore, the study looks into how FDI as an external or globalization dynamic is playing a role in strengthening the ability of internal dynamics, i.e. energy consumption in the context of Bangladesh. Furthermore, this study answers the question relating to the effective utilization of FDI in the energy sector to offset the negative externalities of energy consumption for achieving the SDG goal by 2030. Finally, conducting this study justifies the objective view of FDI in the energy sector of Bangladesh. In addition, available studies that have inspected the nexus between foreign direct investment and energy consumption of Bangladesh are scanty. In contrast, previous studies mainly delve into the association between FDI and economic growth.

The contribution of this study to the prevailing literature is myriad. First, the FDI-energy consumption nexus-related reverse findings, and representing these findings' rationale in the context of Bangladesh, are our value addition to the energy economics literature. Second, integrating both the inward (GNI per capita) and outward (trade openness) dynamics to investigate the FDI-energy consumption nexus in Bangladesh is our novel approach, using variables. Third, our study result is consistent in different, alternate measurement parameters, i.e. FMOLS, CCR, and DOLS, ensuring the robustness of findings emerging from the ARDL-based co-integration technique. The robustness check procedures also support the model's authenticity in inquiring into the FDI-energy consumption nexus in Bangladesh. Notably, our findings from a robust econometric technique reveal a negative relationship between FDI inflows and energy consumption in the context of Bangladesh. Moreover, this study's results may significantly help Bangladesh's policymakers design the appropriate policies concerning FDI employment in the energy consumption-related growth process.

The organization of this paper is as follows. Section 2 describes the FDI and energy nexus in Bangladesh and Section 3 examines the relevant literature concerning FDI and energy consumption. Section 4 illustrates the model, data, and methodology. Section 5 reports the empirical results. Section 6 includes the relevant discussions and Section 7 concludes with policy recommendations.

FDI and Energy Nexus in Bangladesh

In recent years, significant investments, e.g. FDI in energy and power sectors, have been encouraged through various policy supports in the con-

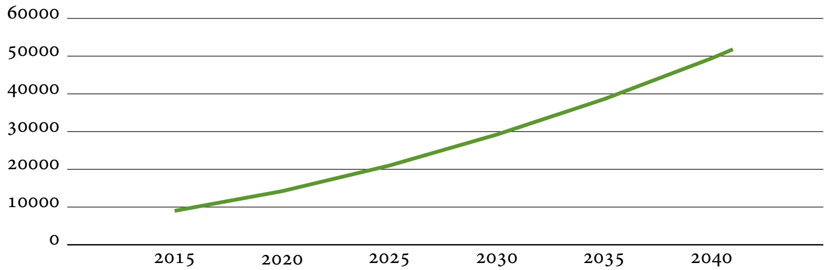

FIGURE 2 Forecast Power Demand up to 2041, in MW (based on data from Ministry of Power, Energy and Mineral Resources 2016)

text of Bangladesh to meet the increasing energy demands. The Power Sector Master Plan (Ministry of Power, Energy and Mineral Resources 2016) reveals that Bangladesh will witness a changing pattern of future electricity demand as economic activities have changed and increased simultaneously. It also forecasts a substantial rise in demand for energy (figure 2), particularly electricity in commercial, industrial, and public services (metro rails, special economic zones, and other services).

Apart from electricity generation and its use in Bangladesh, the policymakers of Bangladesh intend to source a substantial amount of primary energy from coal and renewable energies to reduce the pressure on gas and petroleum usage. There are variances in PSMPs and electricity generation in targeted amounts of sources, use of fuel, and technology. Indeed, the energy mix has been transforming but not that portion set in the PSMPs. As primary energy, natural gas is contributing considerably. No significant development is shown in coal usage. Renewable energy has had no crucial role. There exists an enormous change in technology used for generating electricity. In addition, gas and steam turbines used in power plants are fewer, while combined cycle usage in power plants has been increasing. The Power Sector Efficiency Master Plan (PSEMP) suggests that the government of Bangladesh has settled the goal to develop energy intensity by 20 percent by 2030 in comparison with the 2013 level (Khondaker and Ali 2019). However, the Government of Bangladesh has allocated inadequate resources due to various rivalries arising in the social sectors. Therefore, the local and foreign private sectors may be the critical source of investment for Bangladesh's energy and power sector. As domestic private investment is not near enough, the country requires wider-scale investments for the installation of local coal and natural gas and power plants in the country.

Considering the capital-intensive characteristics and the technological requisites of the energy sector, the government of Bangladesh encourages FDI inflows by introducing different convenient policies for foreign investors. Nevertheless, the inflows of FDI to Bangladesh are not convincing as the country still witnesses political instability, bureaucratic inertia, corruption, poor governance, and a poor law and order situation. All of these elements are determined as the leading causes of the poorly motivated investment environment in the country. Apart from this, foreign investors in electricity-intensive manufacturing industries are worried about the poor quality of electricity (Khondaker and Ali 2019).

Extant Literature Review

A substantial amount of literature is available that has demonstrated the contribution of FDI to energy consumption in developing economies; those studies reveal equivocal or mixed evidence, mostly its indirect influence. Most of the studies reveal that FDI could have an effect on overall output indirectly (if not directly) via knowledge and technology transfer or spillovers in the FDI receiving countries (Adams and Opoku 2015; Agbloyor et al. 2014; Doytch and Uctum 2011; Vu and Noy 2009; Zeng et al. 2020). Both the negative and positive effects of FDI on energy consumption prevail in the literature.

In this context, Cole (2006) states that the effect of FDI is diverse in the level of economic growth, economic formation, energy price and so on, since different countries embrace diverse conditions. Borensztein, De Gregorio, and Lee (1998) opined that FDI could help develop the productivity of enterprises through adopting advanced machinery-technology and management systems. In contrast, Mielnik and Goldemberg (2002) showed that FDI growth could shrink the intensity of energy consumption for their studied 20 developing countries. By establishing scale-structure-technology modelling, Antweiler, Copeland, and Taylor (2001) found that FDI could change the economic contribution, but not improve the energy consumption intensity. Omri and Kahouli (2014) confirm the growth (causality moving from energy to growth) and feedback hypothesis for relative per capita income in middle and low-income countries, respectively, during 1990–2011. Apergis and Tang (2013) find a positive relationship between the growth hypothesis and income level for a panel of 85 countries over the 1975–2007 period.

Hübler (2009) examined the effect of FDI and trading on energy-saving technology by employing CGE modelling. He found that FDI and trading could develop the technology of energy-saving and decrease the intensity of energy consumption in the context of China. Shahbaz, Khan, and Tahir (2013) ascertain a bidirectional effect between energy use and trade.

Conversely, Herrerias, Cuadros, and Orts (2013) report an inverse relationship between imports and energy intensity utilizing a panel model with provincial data from 1985 to 2008. Sadorsky (2010) investigated the energy-FDI relationship for 22 developing countries, showing that FDI enhances energy consumption. He also stated that inflows of FDI generate liquidity that encourages investment in new power plants and factories to move up energy demand. Del Bo (2013) examined the spillover impact of the electricity sector in European countries, exploring whether industrial agglomeration could encourage FDI productivity spillover. Lee (2013) delved into the FDI-energy relationship employing panel cointegration techniques for 95% of G20 countries covering the period 1971–2009; the study detected no influential indication of an FDI relationship with clean energy use.

Alam et al. (2015) show that FDI was positively associated with energy consumption for the SAARC region over the period of 1975–2011. Reinvestigating electricity consumption, Zaman et al. (2012) found that FDI significantly increases electricity consumption in Pakistan during 1975–2010. Interestingly, the study of Paramati et al. (2018) revealed that FDI is one of the ways to guarantee efficient energy consumption. Salim et al. (2017) investigated the relationship between energy use and FDI inflows for China. The study explored whether FDI essentially enhances energy demand by enhancing the functions of industrialization (manufacturing) and transportation. Shahbaz et al. (2018b) utilized the data from the Netherlands and Ireland for the time of 1970Q1–2015Q4 by employing a quantile autoregressive distributed lag model. They detected that energy consumption relates to globalization intensely and positively in the long run.

Adom, Kwakwa, and Amankwaa (2018) found that FDI did not stimulate the efficiency of energy in the long run for African countries during 1970–2014 using the Stock-Watson dynamic OLS technique. Using OLS regression, fixed effect, generalized method of moments (GMM), and random effect instruments, Muhammad and Khan (2019) examined the impact of energy use, FDI, capital and CO_2 emissions on the economic growth of 34 Asian host and 115 source economies from 2001 to 2012. The study findings reveal that all these indicators contribute considerably to the output of these two groups of countries. From the viewpoint of growth, the study suggests encouraging FDI in both host and source economies. Pan et al. (2020) examined the qualitative role of FDI on energy efficiency in 30 provinces of China during 2003–2016. The study used slacks-based measure data envelopment analysis (SBM-DEA) first for estimating energy efficiency and then used seemingly unrelated regression (SUR) technique for empirical estimation to investigate the impact of FDI quality on energy efficiency. The study finds that FDI quality has a significant role in promoting energy efficiency from the national level perspective, and this contribution of FDI is also true in coastal and inland areas from the regional-level viewpoint in China.

Lin and Kwan (2016) explored the level of FDI spillover in geographic areas and spatial diffusion by using the data of Chinese companies. The result depicted that FDI benefits domestic firms mainly in their neighbouring areas via knowledge spillovers that have broader geographical capacity. Khatun and Ahamad (2015) investigated the causal linkages between FDI and energy as well as the power sector, and output of Bangladesh from 1972 to 2010. It found a strong positive and unidirectional short-run causal association from FDI to energy use and also from energy use to GDP growth. Empirical results also revealed a causal linkage for the equation of energy use in the long run. Using questionnaires and semi-structured interviews, Mahbub and Jongwanich (2019) investigated the determinants of the FDI firms for making decisions in the energy sector. Their findings indicate that among regulatory, economic and financial, political, and societal aspects, only regulatory aspects are the most influential for FDI-firms.

The above literature shows both the positive and negative relationship between FDI and energy use in the context of different economies. But FDI is highly effective in the rising economies as they are utilizing the potential of FDI in their growth process. Although Bangladesh is an emerging economy in terms of its growth, this sort of shortage of literature leads us to carry out this study, which will fill the paucity of literature in this particular context in Bangladesh.

Model, Data and Methodology

In this section, the empirical model specification is detailed with the rationalization of variable inclusion in the model, including their sources as well as the elaborated methodology (i.e. ARDL bound testing techniques).

MODEL

Earlier literature highlighted mixed evidence on the nexus of energy and FDI. Smyth and Narayan (2015) stated that this result is desired given the 'differences in econometric approaches, institutional characteristics in specific countries, model specification, variable selection and time period.' The same statement is also given by Coers and Sanders (2013), who illustrated that the indicators of energy consumption 'are very sensitive to model misspecification and careful testing of specifications is required.' To control these issues, we have followed the combined energy-FDI-income-trade model suggested by Salim et al. (2017):

$$\text{EC} = f(\text{FDI}, \text{Y}, \text{TO}), \tag{1}$$

where EC denotes energy consumption in per capita form, FDI stands for the FDI inflow, Y represents real income in per capita form and TO is trade openness. For the purpose of empirical estimation, equation 1 is transformed into a linear form that gives:

$$\text{LEC}_t = \beta_1 + \beta_2\text{LFDI}_t + \beta_3\text{LY}_t + \beta_4\text{LTO}_t + \mu_t. \tag{2}$$

Here the subscript t and μ_t denote the studied time and the stochastic errors, respectively. The association of the letter 'L' in equation 2 illustrates that all variables are transformed into natural logarithms, and β embodies the long-run elasticities, which is to be estimated.

The study attempts to scrutinize the association between energy consumption and inward FDI within the purview of income and trade openness. The existing literatures argue that this nexus is mostly subject to the level of economic growth an economy possesses. FDI represents an influential dynamics of energy consumption in our model. The extant literature review reveals that if FDI provides a helpful diffusion instrument for international transmission of energy-conserving practices, we assume a negative β_2 coefficient in equation 2.

Such a trend represents the domination of the composition and technique impact on the scale effect (Salim et al. 2017). Since per capita income remains an increasing trend, it helps the people of the country to consume more energy. Thus, we presume the positive symbol of the β_3 coefficient in equation 2.

In addition, export promotion is significantly remarkable; it can impact the energy consumption level through direct and indirect channels in Bangladesh's economy. Directly, export promotion increases energy demand to assist growth in the production scale. Indirectly, exports in large volumes include intermediate goods and raw materials to be transported to, and a higher volume of finishing exporting goods to be shipped from, the industrial production areas. All of these require more energy to energize the logistic functions of the export-oriented industry. In contrast, the existing literature argues that imports may be an effective tool to improve the worldwide flow of energy-efficient technology, contributing to a negative linkage between imports and energy use, in particular non-durable goods like transportation equipment and domestic appliances. To explain this scenario, the study calculates trade openness by the percentage of the total imports and exports to real GDP, as followed by Salim et al. (2017). Given the total amount of tradable items from Bangladesh to the international market, we anticipate the mark of the β_4 coefficient in equation 2 to be positive, showing the positive relationship between exports and energy use.

Data

In this study, we mainly use per capita energy consumption (EC) and foreign direct investment (FDI) data for Bangladesh to capture how inward FDI is contributing to the demand and supply of energy. It is obvious that, except for FDI, other variables could have a significant impact on energy consumption. So, ignoring those variables could result in estimation bias in understanding the energy-FDI scenario. From this viewpoint, the study includes per capita GNI (Y) and trade openness (TO) as control variables, following Salim et al. (2017), for controlling the omitted variable and simultaneity bias.

This paper examines the annual observations from Bangladesh of all variables spanning from the year 1971 to 2014 based on data availability: World Development Indicators (WDI) provides the data on per capita energy consumption only up to 2014, while the other variables are available up to 2020.

For uniformity in the definitions and data collection methods, we took all the data properties from the WDI database preserved by the World Bank (2019). Table 1 reveals detailed definitions, sources and descriptive properties of the studied variables.

The time-series data of per capita energy consumption and the inflows of foreign direct investment are depicted to inspect the movement of FDI inflow towards the energy consumption in Bangladesh in figure 3. Figure 4 shows the net inflows of foreign direct investment by major sectors during FY 2021 (in million US$) in Bangladesh.

TABLE 1 Variable Definition, Data Source and Descriptive Statistics

Variables	Definition	Source
EC	Energy consumption (kg of oil equivalent per capita)	WDI
Y	GNI per capita (in constant 2010 US$)	WDI
FDI	Foreign direct investment, net inflows (% of GDP)	WDI
TO	Trade (% of GDP)	WDI

Descriptive Measures	LEC	LFDI	LY	LTO
Mean	4.8840	6.1974	−2.4210	3.2063
Standard Deviation	0.2731	0.3323	2.1929	0.3573
Minimum	4.4632	5.7969	−7.0570	2.3975
Maximum	5.4348	6.9216	0.5512	3.8735

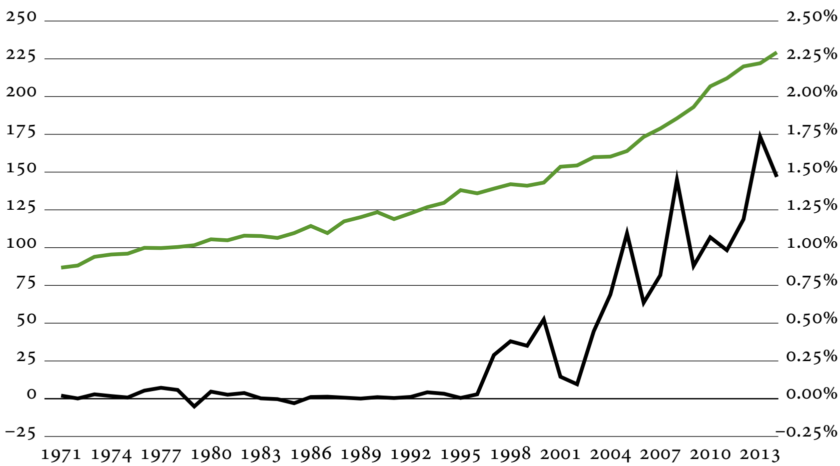

FIGURE 3 Energy Consumption and FDI Scenario (green – energy use in kg of oil equivalent per capita, black – FDI, net inflows in percent of GDP)

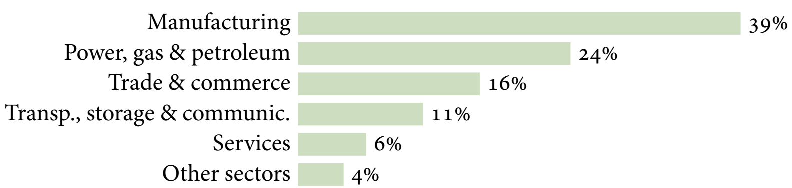

FIGURE 4 Net FDI Inflows (in million US$)

NOTES Both agriculture and fishing and construction are included in the other sectors. Based on data from World Bank (2019) and Bangladesh Bank (2021).

Methodology

We employ the autoregressive distributive lag (ARDL) approach (Pesaran and Shin 1998; Pesaran, Shin, and Smith 2001) to find the short-run and long-run association between the variables. The ARDL procedure encompasses some advantages compared to the conventional cointegration techniques. Firstly, the method allows a mixed integration order of the modelled time series variables. As it controls specious regression to select the optimal lag, this general-to-specific modelling method maintains the long-run equilibrium association among the data variables. Secondly, an optimal structure of lag does not just check the serial correlation of errors but also offers a reliable estimation of the existence of endogenous variables. Thirdly, it yields consistent short-run and long-run estimates with a limited number of samples. Given the small sample size (44 samples), this method confirms effective hypothesis testing based on asymptotic theory. Lastly, a dynamic unrestricted error-correction model (ECM) incorporating short-run adjustment with long-run equilibrium can be obtained from the ARDL technique by following linear regression. The ARDL demonstration of equation 2 is written as follows:

$$\begin{aligned}\Delta \mathrm{LEC}_t = {} & \alpha_0 + \beta_1 \mathrm{LEC}_{t-1} + \beta_2 \mathrm{LFDI}_{t-1} + \beta_3 \mathrm{LY}_{t-1} + \beta_4 \mathrm{LTO}_{t-1} \\ & + \sum_{i=1}^{p} \gamma_i \Delta \mathrm{LEC}_{t-i} + \sum_{j=0}^{p} \gamma_j \Delta \mathrm{LFDI}_{t-j} \\ & + \sum_{k=0}^{p} \gamma_k \Delta \mathrm{LY}_{t-k} + \sum_{l=0}^{p} \gamma_l \Delta \mathrm{LTO}_{t-l} + \varepsilon_t \end{aligned} \quad (3)$$

$$\begin{aligned}\Delta \mathrm{LFDI}_t = {} & \alpha_0 + \beta_1 \mathrm{LEC}_{t-1} + \beta_2 \mathrm{LFDI}_{t-1} + \beta_3 \mathrm{LY}_{t-1} + \beta_4 \mathrm{LTO}_{t-1} \\ & + \sum_{i=1}^{p} \gamma_i \Delta \mathrm{LEC}_{t-i} + \sum_{j=0}^{p} \gamma_j \Delta \mathrm{LFDI}_{t-j} \\ & + \sum_{k=0}^{p} \gamma_k \Delta \mathrm{LY}_{t-k} + \sum_{l=0}^{p} \gamma_l \Delta \mathrm{LTO}_{t-l} + \varepsilon_t \end{aligned} \quad (4)$$

$$\begin{aligned}\Delta \mathrm{LY}_t = {} & \alpha_0 + \beta_1 \mathrm{LEC}_{t-1} + \beta_2 \mathrm{LFDI}_{t-1} + \beta_3 \mathrm{LY}_{t-1} + \beta_4 \mathrm{LTO}_{t-1} \\ & + \sum_{i=1}^{p} \gamma_i \Delta \mathrm{LEC}_{t-i} + \sum_{j=0}^{p} \gamma_j \Delta \mathrm{LFDI}_{t-j} \\ & + \sum_{k=0}^{p} \gamma_k \Delta \mathrm{LY}_{t-k} + \sum_{l=0}^{p} \gamma_l \Delta \mathrm{LTO}_{t-l} + \varepsilon_t \end{aligned} \quad (5)$$

$$\Delta \text{LTO}_t = \alpha_0 + \beta_1 \text{LEC}_{t-1} + \beta_2 \text{LFDI}_{t-1} + \beta_3 \text{LY}_{t-1} + \beta_4 \text{LTO}_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta \text{LEC}_{t-i} + \sum_{j=0}^{p} \gamma_j \Delta \text{LFDI}_{t-j} + \sum_{k=0}^{p} \gamma_k \Delta \text{LY}_{t-k} + \sum_{l=0}^{p} \gamma_l \Delta \text{LTO}_{t-l} + \varepsilon_t \quad (6)$$

Here Δ denotes the first difference operator, representing the error-correction dynamics, and β_i signifies the long-run relationship. We investigate possible cointegration in equation 3 through performing the significance of F-test on lagged level terms (H_0: $\beta_0 = \cdots = \beta_4 = 0$) and relate to the test statistics of two asymptotic critical bounds, e.g. lower and upper bounds, indicating that the variables are I(0) and I(1), correspondingly. We reject H_0 when the test statistics surpasses their relevant upper bound values and decide that there exists a long-run association between the variables. The validity of the study results through extracting the limited sample critical bounds supported by Narayan (2005).

If there exists a cointegration relationship in equation 3, our next step is to measure its equivalent dynamic unrestricted ECM. Thus, it unites short-run adjustment with long-run stability. In this study, we measure a dynamic unrestricted ECM of equation 3 as follows:

$$\Delta \text{LEC}_t = \alpha_0 + \sum_{i=1}^{p} \gamma_i \Delta \text{LEC}_{t-i} + \sum_{j=0}^{p} \gamma_j \Delta \text{LFDI}_{t-j} + \sum_{k=0}^{p} \gamma_k \Delta \text{LY}_{t-k} + \sum_{l=0}^{p} \gamma_l \Delta \text{LTO}_{t-l} + \lambda \text{EC}_{t-1} + \varepsilon_t \quad (7)$$

Here EC_{t-1} represents the lagged term of error-correction emanating from the long-run co-integrating vector. In addition, Engle and Granger (1987) revealed that causality in co-integrated ECM can also derive from EC (if $\lambda \neq 0$). From the perspective of our study, the former represents the long-run association and the latter shows the short-run dynamics. So, λ's statistical significance divulges that there appears to be an error-correction mechanism to push the variables back after a temporary shock to their equilibrium.

Lastly, the study has performed some diagnostic tests and the selected model is found to be robust against serial correlation, normality and heteroscedasticity. The model's stability is investigated using the cumulative

TABLE 2 Unit Root Tests

Variables	Augm. Dickey-Fuller (ADF) Test		Phillips-Perron (PP) Test		Order of int.
	Intercept	Int. and trend	Intercept	Int. and trend	
LEC	1.6790 (0.9995)	−1.0016 (0.9331)	2.1257 (0.9999)	−1.0016 (0.9331)	
LY	3.9130 (1.0000)	0.0318 (0.9955)	5.5549 (1.0000)	0.0318 (0.9955)	
LFDI	−2.7522 (0.0738)	−3.9907 (0.0164)	−2.5945 (0.1019)	−4.0521 (0.0141)	I(0)
LTO	−1.1336 (0.6938)	−3.3716 (0.0687)	−0.6907 (0.8383)	−3.3716 (0.0687)	
ΔLEC	−8.2525 (0.0000)	−8.6564 (0.0000)	−8.2552 (0.0000)	−9.0149 (0.0000)	I(1)
ΔLY	−2.8737 (0.0000)	−10.166 (0.0000)	−6.8509 (0.0000)	−9.7912 (0.0000)	I(1)
ΔLFDI	−5.4622 (0.0001)	−5.3985 (0.0004)	−9.8337 (0.0000)	−9.6765 (0.0000)	
ΔLTO	−8.3145 (0.0000)	−8.2973 (0.0000)	−9.5748 (0.0000)	−10.002 (0.0000)	I(1)

NOTES Values in parenthesis represent *p*-values.

(CUSUM) and cumulative sum of square (CUSUMSQ) plot. Just as importantly, the fully modified ordinary least square (FMOLS) estimator developed by Phillips and Hansen (1990), the dynamic ordinary least square (DOLS) estimator by Stock and Watson (1993) and canonical cointegration regression (CCR) by Park (1992) are also estimated for ensuring the consistency of the model's long-run estimate.

Empirical Results

This section will comprise a detailed discussion on measures undertaken for analytical purposes, such as unit root tests, the estimates of the ARDL bound testing method, and the estimation output of robustness checking.

UNIT ROOT TESTS

We start our analysis by verifying the integration order for the study variables. This phase is significant as the tabularized critical bounds in ARDL bounds testing are solely relevant to variables which are I(0) and I(1). To check the order of integration of the study variables, the study employs familiar unit root tests such as the Augmented Dickey-Fuller (Dickey and Fuller 1979) and Phillips-Perron (Phillips and Perron 1988) tests.

Both ADF and PP test results are reported considering intercept and intercept with a trend in table 2. All variables are transformed into natural logarithms. A visual investigation of the table depicts that all the selected variables exhibit a unit root at their level form except FDI. The logarithm of FDI remained stationary in all combinations. However, it implies that the other three variables become stationary only after their differencing. Hence, the order of integration of all variables are either I(0) or I(1).

ARDL BOUNDS TESTING

As all the chosen variables of the study are integrated at either level, i.e. I(0), or first difference, i.e. I(1), now we advance to bounds testing in the nexus of energy-FDI, including two control variables: national income and trade openness for Bangladesh. We start by determining the optimal lag structure. In particular, we focus on degrees of freedom by controlling the maximum lag length to 2 prior to the identification of the lag structure using the Akaike information criterion (AIC). Table 3 represents the results of bounds testing, showing that co-integration exists among the variables except for trade openness. Our calculated *F*-statistics are 15.05, 9.44, 17.65 and 7.958, while energy consumption, income growth, FDI, and trade openness are considered as dependent variables.

ARDL LONG-RUN AND SHORT-RUN ESTIMATES

After establishing the co-integration relationship between the targeted variables (energy consumption and FDI) in their respective models, we test the model estimates for equation 3 depicted in table 3. We find a negative (the coefficient is –0.016) and a significant relationship between energy consumption and FDI in the long run. Our empirical result shows that a 1% increase in FDI decreases energy consumption by 0.016%, containing all things constant, which supports the hypothesis that the energy-saving technology of FDI reduces energy consumption, as FDI does not posit any positive impact on energy consumption. The negative linkage may partially take place because FDI in developing countries like Bangladesh may lag behind in automation and industrialization. In addition, the positive spillover effect of FDI through diffusion of new technology or know-how in the energy intensive industries is not properly realized as expected. In the case of explanatory variables, our results depict that per capita income affects the level of energy consumption positively and significantly, indicating that energy consumption of people rises due to economic growth in Bangladesh. Finally, trade openness is positively associated with energy consumption of people.

The short-run coefficient estimates of equation 3 on the basis of optimal lag structure reveal the negative effect of FDI on energy consumption in the short run at the 1% significance level that is also obtained from the long-run result. The contribution of two explanatory variables, such as GNI and trade openness, are not expressed in the short-run due to their short-run insignificance found in the estimation. Furthermore, the coefficient of the error correction mechanism (ECT_{t-1}) is found to be neg-

TABLE 3 Bound Test Results, Estimated ARDL Long-Run and Short-Run Coefficients

Dependent Variable	F_{LEC} (LEC\LFDI, LY, LTO)	Level of Significance	1%	5%
Optimal Lag Structure	ARDL(2, 0, 0, 0)	I(0)	3.65	2.79
F-statistic	15.05474			
Decision	Cointegration exist	I(1)	4.66	3.67

Long-run coefficient estimates	Constant	−0.272749	(0.3165)
	LFDI	−0.016127	(0.0117)
	LY	0.753625	(0.0000)
	LTO	0.157290	(0.0272)
Short-run coefficient estimates	ΔLEC (−1)	−0.321495	(0.0057)
	ΔECT_{t-1}	−0.401399	(0.0000)
Diagnostic test results	Adjusted *R*-squared	0.472391	
	Jarque-Bera normality test	1.151390	(0.5623)
	Breusch-Godfrey Serial Correlation LM	0.197457	(0.6274)
	Heteroscedasticity test: ARCH	0.427957	(0.5047)
	Ramsey RESET test	2.906998	(0.0971)

NOTES Diagnostic tests result based on *F*-statistic; coefficient and tests result *p*-values are in parenthesis.

atively significant at the 1% level in equation 7. This situation confirms the speed of readjustment from any short-run unstable way to long-run equilibrium between the variables. As the ECT_{t-1} coefficient found in the estimation for the short-run dynamic is lower than 1 (−0.40), it indicates the mild (in between lower and medium) speed of adjustment to correct any short-run disequilibrium to long-run stability among the variables used in the model.

The diagnostic tests result reveals that the ARDL model (where energy consumption is the outcome variable) produces the value of adjusted *R*-square (0.472391), which describes the 47% variation in the economic growth, FDI, and trade openness used in the model. In addition, the other tests such as Jarque-Bera, heteroscedasticity, Breusch-Godfrey (serial correlation), and Ramsey RESET tests are employed to check for normality, autocorrelation, residual error, and omitted variable bias, respectively, among the variables.

In the case of all these sensitivity tests, the *p*-values are required to be insignificant based on the *F*-statistic values. As the estimated *F*-statistic values depict the insignificance at 5% level of significance, it indicates that the studied model is accurately specified and the residuals are distributed normally, not heteroscedastic, and not auto-correlated. CUSUM

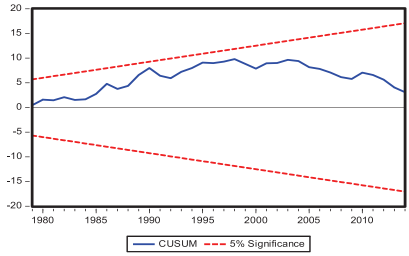

FIGURE 5 Plot of CUSUM Test

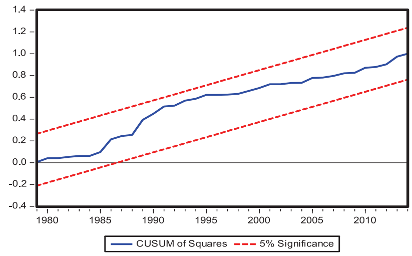

FIGURE 6 Plot of CUSUM of Square Test

and CUSUMSQ tests are also employed to check the model stability. Both CUSUM and CUSUMSQ tests in recursive errors report that the blue line stays within the red line representing a 5% significance, implying the structural constancy in the residuals (figures 5 and 6). Moreover, the outcomes of diagnostic and stability tests show the model's goodness of fit; hence, the co-integration exists in the energy consumption-FDI nexus for Bangladesh.

ROBUSTNESS CHECKS

We also estimate the long-run sensitivity of the study result for equation 3 using three different techniques, namely FMOLS, DOLS and CCR.

Among these estimation procedures, DOLS is treated as more authentic as it includes both leads and lags to rectify autocorrelations and heteroscedasticity (Salim et al. 2017). Table 4 reports that these alternative estimators' coefficient magnitude is somewhat smaller and nearer to their ARDL equivalents. The study result of a negative energy-FDI relationship, and a positive income energy-growth nexus and trade openness-energy nexus stays robust to these techniques.

Table 5 presents Granger causality test results where the null hypothesis, which represents that the energy consumption does not Granger-cause the FDI, was rejected at the 5% level in the short-run, is in line with

TABLE 4 Estimated Long-Run Coefficients to Different Measurements

Variable	ARDL		FMOLS		DOLS		CCR	
	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.
LFDI	−0.016127	0.0117	−0.008179	0.0821	−0.017969	0.0069	−0.009107	0.1007
LY	0.753625	0.0000	0.793835	0.0000	0.762567	0.0000	0.788221	0.0000
LTO	0.157290	0.0272	0.053308	0.3085	0.181580	0.0347	0.063298	0.3256
Constant	−0.272749	0.3165	−0.225363	0.3261	−0.427525	0.0908	−0.224985	0.3691

TABLE 5 Granger Causality Test

LEC does not Granger-cause LFDI			LFDI does not Granger-cause LEC		
Lag	*F*-statistic	Prob.	Lag	*F*-statistic	Prob.
1	8.48240	0.0058*	1	1.40608	0.2427
2	4.90612	0.0129*	2	0.59417	0.5572
3	2.53151	0.0734**	3	0.62432	0.6042
4	2.25893	0.0854**	4	0.54635	0.7030

NOTES * Significance at 5% level. ** Significance at 10% level.

the findings by Lu et al. (2021). But the reserve scenario is not true which indicates that energy-efficient technologies are not still fully functional to reduce energy consumption level since no causation runs from FDI to energy consumption. So, the existence of a unidirectional causal relationship from energy consumption to FDI signifies the existing institutional strength in the energy sector of Bangladesh that may attract foreign investments in the upcoming future.

Discussions

The study results obtained depict that FDI has a significantly negative effect on energy consumption both in the short and long run in Bangladesh's economy. Generally, FDI is considered a significant component of globalization. Theoretically, globalization's influence via FDI on energy consumption is typically analysed in three ways: 'scale effect,' 'technique effect,' and 'composition effect' (Shahbaz et al. 2018a; Islam and Islam 2021). Globalization via scale effect channels expands economic activities and, thus, energy consumption if ceteris paribus (Cole 2006). The technique effect of FDI fosters lower energy usage in economies through importing sophisticated technologies, and finally, it authorizes for accomplishing more economic activities (Antweiler, Copeland, and Taylor 2001; Dollar and Kraay 2004). Lastly, the globalization/FDI-laden composition effect on energy consumption occurs when energy use reduces with the growing economic activities (Stern 2007). From the theoretical perspective, Bangladesh has been experiencing the composition effect of FDI that downsizes the level of energy consumption amid its spectacular growth momentum.

From the empirical point of view, on the other hand, spillover effects, structural effects of factor inputs, and competitive effects can influence the industry structure of the importing country. Bangladeshi industries, particularly the manufacturing sector, are core grounds of FDI employment. The uneven allocation of FDI in each industry negatively impacts the industry structure. This is why the negative impact on Bangladesh's reduction in energy consumption intensity is more significant than the favourable impact (Islam et al. 2021). Furthermore, FDI is largely concentrated in the sphere of high-energy consumption industries. In this case, adopting energy-saving technologies raises the manufacturing costs, which contradicts the FDI premise of profit maximization (Yue, Long, and Zuang 2011).

The negative influence of FDI on energy consumption is consistent with Doytch and Narayan's (2016) findings that FDI harms non-renewable energy consumption in low-income countries and favours high-income ones. If we assume energy consumption as a proxy for economic growth, the findings of this study also support our hypothesis. Suppose we discuss the results obtained for real GDP and FDI. In that case, we can see that the results converge towards the intrinsically developed and imported environmentally degrading production technologies used in Bangladesh. Thus, Bangladeshi policymakers have introduced negative externalities by lowering environmental quality, and existing policies have failed to internalize those externalities. According to Pazienza (2019), this scenario is coherent with the OECD countries where FDI-cultivated energy consumption negatively influences environmental quality. In addition, FDI-related energy infrastructure in Bangladesh incurs a significant amount of expenditure and utility costs. However, sector-wise deployment of the FDI has taken place in Bangladesh due to institutional authorities' lack of resources mobilization. Therefore, relevant institutions are responsible for the misuse of or unused expenses and logistics in the energy infrastructure of industrial production (Islam, Ali, et al. 2022; Islam, Irfan, et al. 2022). Thus, FDI inflow negatively impacts the level of energy consumption in Bangladesh.

Our empirical findings of the negative nexus between energy consumption and FDI may also somewhat reveal the Bangladesh-based foreign investors' domination in the labour-intensive sector, which requires less energy compared to their capital-induced correspondents as expressed by Cole, Elliot, and Zhang (2011) and Huang (2003) in the context of China. Bangladesh is an open economy in terms of trade-related capital and labour utilizations for the sake of higher-level industrial production. Despite this, restrictions on the capital-intensive sector may, to some extent, demonstrate low-level energy consumption arising from FDI corresponding to state-owned enterprises (SOEs), which is argued by Elliott, Sun, and Chen (2013), and Herrerias, Cuadros, and Orts (2013). In addition, international diffusion of energy-saving technologies and techniques imported by utilizing FDI might have a significant contribution to inducing an adverse connection between energy consumption and FDI in any economy (Fisher-Vanden et al. 2006; Hübler 2011). FDI affects energy consumption negatively in different developing economies like Bangladesh due to the lack of absorptive abilities. Till now, we have fallen short of utilizing hi-tech technologies brought by FDI from developed countries because of our less institutional capability, hence, Bangladesh is lagging behind in automation and industrialization. The study result is consistent with Mielnik and Goldemberg (2002), Antweiler, Copeland, and Taylor (2001), Hübler (2009), Lee (2013), and Adom, Kwakwa, and Amankwaa (2018). In contrast, the outcome of a negative FDI-energy consumption nexus contradicts the previous study by Khatun and Ahamad (2015) in the context of Bangladesh.

The policymakers of Bangladesh should ensure a friendly environment for foreign investors by managing the bottlenecks that exist in the industrial sector. Trade and industry-related capital stemming from FDI should be exploited for increasing energy consumption in the growth process. Moreover, policymakers should enhance the absorption and utilization capacity of sophisticated technologies and other industrial raw materials brought through FDI for the industrial development of the country. Industrialization requires the increasing demand of energy, which would help augment the level of energy consumption in Bangladesh.

The study result also reveals the positive relationship between output and energy consumption, which is in line with Alam et al. (2012), who studied this nexus in Bangladesh. Although developed economies alone have witnessed a positive relationship between energy consumption and economic growth since World War II (Kraft and Kraft 1978), developing and emerging countries have captured global attention by consuming energy in their growth path. Thus, the proper use of all industry-based inputs of Bangladesh should increase to accelerate economic growth, and hence, it would lead to the efficient consumption of energy. Trade openness impacts energy consumption positively in the context of Bangladesh, and this finding is supported by Nasreen and Anwar (2014). They examined the causal relationship between trade openness, economic growth and energy consumption for 15 Asian countries from 1980 to 2011. Trade openness in any economy impacts the level of energy consumption by way of direct and indirect channels. Trade openness includes the total trade volume as a share of its GDP in percent. Export growth enhances energy demand directly by helping the production scale of growth. Incidentally, a large volume of exports includes raw materials, intermediate goods to be transported, and a higher volume of finishing goods to be shipped from the manufacturing places. This process requires a high energy intensity to fuel the logistic functions of the export-oriented industry.

In contrast, imports can effectively improve the worldwide flow of energy-efficient technology, contributing to a negative linkage between energy use and imports, in particular non-durable products such as transportation equipment and domestic appliances (Salim et al. 2017). However, importing intermediate goods and raw materials for industrial production can help augment energy consumption. Moreover, the economic growth of Bangladesh is mainly export-dependent, though a trade deficit exists due to more imports than exports. In this regard, proper utilization of imported goods and services is critical for Bangladesh to promote trade-led growth; and more export promotion would thus impact energy consumption positively by increasing the energy demand.

Concluding Observations and Policy Recommendations

This study inspects the dynamic linkage between energy consumption and FDI within the purview of income growth and trade openness, covering time-series data from 1971 to 2014 in the case of Bangladesh. Employing the ARDL approach, the empirical results divulge the cointegration among the study's variables. More importantly, we explore the negative impact of FDI on energy consumption both in the short and long run. The results are explored in line with the statement that the impacts of technique and composition effects of FDI illustrate the long-run adaptation towards less energy usage and low carbon in the future economy of Bangladesh. In contrast, the scale effects tend to fuel economic activities that increase energy consumption in the short run (Salim et al. 2017).

As a developing country, Bangladesh intends to achieve energy sufficiency by materializing its vision to be a developed economy by 2041. Apart from internal finance/investment, the country seeks foreign finance/investment to generate more energy to reach the desired growth trajectory. As empirical results reveal that FDI impacts energy consumption, it requires several policy implications. Since FDI negatively affects energy consumption, higher FDI does not lead to greater energy consumption in Bangladesh because of the positive externalities of FDI in energy-conserving practices through the diffusion of new technology. Therefore, we should adopt unified energy-saving and emission-reducing mandates for foreign-invested (FIE) and domestic enterprises while considering FDI scale expansion.

Meanwhile, Bangladesh should increase the proportion of foreign investment, particularly in the technology-intensive industries, and encourage foreign-invested enterprises (FIEs) and FDIs to use and exchange advanced energy-saving technologies. However, more importantly, Bangladesh is yet to enjoy the positive externalities of FDI in the energy sector. Therefore, policymakers should direct their utmost concentration to reduce other non-policy level constraints, such as decision-making delays, political instability, inefficiency in human resource management, lack of good governance, and corruption. Also, policymakers ought to be critical of profit repatriation, rate of investment, and incorporation of local private ownership in the investment process to internalize FDI-relevant positive spillover in energy conservation. In this case, Bangladesh has no alternative but to utilize the resource mobilization potentials of reliable institutions that can be helpful to ease the adverse effect of FDI deployment on the energy consumption level of Bangladesh.

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