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Relationship between Aggregate and Disaggregate Energy with Socio-Economic Development of Bangladesh: An Examination

UmmeMarzana[1] and Sakib B. Amin[2]

This paper attempts to tap into some unexplored areas of Bangladesh's development by analyzing the relationship between aggregate and disaggregate sources of energy usage and socio-economic development. We have conducted a series of tests in this paper to analyze the variables from 1985 to 2014. Our results reveal that both aggregate energy and disaggregate energy Granger cause GDP growth. It is also found that electric power consumption per capita and energy use per capita both Granger cause life expectancy, whereas only electric power consumption per capita Granger causes household final consumption expenditure growth and energy use per capita Granger causes infant mortality rate.

Field of Research: Economics

1. Introduction

Energy has been seen to have a two way relationship with a country's economic growth; as a nation grows, it supplies and consumes more energy or as energy use ascends, its growth accelerates.The impact of energy stretches far beyond economic opulence. Higher supply and access to modern, affordable and reliable energy aid in uplifting the social status of a country's people. The energy challenge is more astringent in the case of developing nations as they face a threefold obstacle of ensuring unswerving access to energy at a reasonable cost both while maintaining reduced emissions of greenhouse gases.

One of the most common and efficient sources of energy is electricity that enables the achievement of a wholesome and sustainable socio-economic development by raising the quality of life at a more rapid rate. In addition to its highly known role as a catalyst for increased economic activity, electricity is particularly important for developing nations as it assists in education, healthcare and in general motivates people, and rural electrification helps in decelerating rural to urban migration by enhancing opportunities for income (Munasinghe, 1995). Even after recognizing electricity as an utmost ingredient for economic and human development, almost 1.2 billion people worldwide are deprived from its access (World Energy Outlook, 2016).

[1]BS Graduate and Corresponding Author, Department of Economics School of Business and Economics, North South University, Bangladesh, Email:marzana19@gmail.com

[2]Assistant Professor, Department of Economics, School of Business and Economics, North South University, Bangladesh, Email: sakib.amin@northsouth.edu

Manifold literatures are available which focus on the relationship between energy and economic or environmental variablesbut not much of those focuses on the social variables for sustainable development for Bangladesh. To the best of our knowledge, after reviewing recent papers published in credible journals we have not come across a paper that looks into such a multivariate framework of the twofold energy usage, in aggregate and disaggregate forms, with that of the socio-economic development for Bangladesh.

Many factors have motivated us while choosing this particular topic. In Bangladesh we often measure development in terms of GDP growth rate and use growth and development interchangeably. GDP growth is the necessary condition and prerequisite for development but it is one of the many aspects of achieving an all inclusive development. Technological, environmental, social, political progress and so forth have to be ensured as well. Hence, our main objective was to explore some of these uncharted areas of development and shed light on energy's function in impacting the social sides of Bangladesh's development.

Analyzing such a relationship is important as it can help illustrate the importance and urgency for the government to devise appropriate energy policies with primary focus on higher electricity access nationwide along with the provision of efficient means of energy usage to ensure sustainable economic and social development for Bangladesh.

Three questions have been primarily addressed in this paper,

1. Does energy or/and electricity have long run cointegrating relationships with the chosen variables of socio-economic development for Bangladesh?
2. Is there existence of long run causality between the cointegrated variables?
3. If so, which sector of energy deserves more attention for policy implication for an all inclusive sustainable development?

The rest of the paper proceeds as follows. The next chapter provides a review of the relevant literature. Chapter 3 describes the methodology. Chapter 4 presents and discusses the results and Chapter 5concludes.

2. Literature Review

Pasten and Santamarina (2012) studied119 countries to assess the relationship between energy and the quality of life (QL) over a 30 year period. They determined that an increase in energy consumption per capita leads to higher levels of QL and small increases in energy use for developing nations with low levels of energy consumption lead to higher increases in the QL index. Gohlke et al.'s (2011) autoregressive model for 41 countries between 1965 and 2005 concluded that in nations characterized with high Infant Mortality Rate (IMR) and low levels of Life Expectancy (LE) in the year 1965, would experience improvements in IMR with increases in the electricity consumption. Leung and Meisen's (2005) standard regression concluded that for 19 low and medium development nations, electricity consumption per capita had strong correlation with Human Development Index (HDI), IMR and GDP per capita whereas a reasonable degree of correlation with LE and maternal mortality.

The Engle and Granger Error Correction Model, and Toda and Yamamoto approach of Asghar's (2008) cross country study of five South Asian nations revealed Bangladesh experienced no co integration between GDP and total energy consumption, whereas a unidirectional Granger causality from GDP to electricity consumption meaning higher economic growth may lead to higher consumption of electricity. Interestingly Fatai (2014) established diverse results. Out of the 18 Sub-Saharan African countries studied,Eastern and Southern Sub-regions experienced unidirectional causality from energy consumption to economic growth whereas for Western and Central there was no such causality.

Energy consumption, demand and its effect on human life and economic sustainability variesfor every nation, thus we attempt toshift spotlightto a different direction from that of the above mentioned studies. Rather than studying cross country energy and development scenarios like the above we opt for a more singular approach and the rationale behind this is that results from such country specific studies can provide a stepping stone for home policymakers to make macroeconomic changes that cater specifically to the particular nation's development goals.

Positive impacts on literacy rates from the increased lighting in rural Assam have been established by Kangawa and Nakata (2008). Their regression model ascertained that an increase in the adoption and availability of electric lighting appliances potentially result in an increase in the literacy rate above 6 years.A bi-directional causality between economic growth and energy consumption was depicted in a study by Sulaiman (2014) for Nigeria, implying that higher energy consumption leads to higher economic growth and vice-versa. The modified version of the Granger Causality test of Sulaiman's (2014) study resulted in a unidirectional causality from energy consumption to CO_2 emissions. Amin et al. (2012)shows unidirectional causal relationships from Real GDP to Energy Use and from Energy Use to CO_2 emissions but no causal relationship between Real GDP and CO_2.

Fujii et al. (2018) revealed in their paper that fertility and adoption of electricity have an inverse relationship where the adoption of the latter results in the fall in the former by one or more child(ren). The other outcome of their study was the positive impact of electricity, from dispersion of information via mass media, on the nutritional status on children under the age of 5. The authors use household survey data which is notorious for recall bias; hence to avoid such an issue and provide a macroeconomic approach we make the use of aggregate data from the WB.

An evident feature of the above mentioned literature is that all of the papers focus on any one or few aspects of socio-economic development and our paper helps to bridge this gap byamalgamating the multiple factors that either impact or are influenced by energy sources. The studies conducted either include electricity consumption or energy usage, not both, and analyze their relationship with only some factors of socio-economic development, such as fertility (e.g. Fuji et. al, 2018), CO_2 (e.g. Sulaiman, 2014) and GDP (e.g. Asghar, 2008), to mention a few. More importantly, almost all of the literature, with a very small exception, fails tofocus on Bangladesh in particular.

3. Methodology

The Augmented Dickey Fuller (ADF) Unit Root test was carried out at ‘levels’ and ‘first differences’ to check for the presence of unit root (stationarity), which led to the findings that some variables are non-stationary and hence cannot be regressed without making them stationary thusthese were de-trended. Then, we conducted the Johansen Cointegration test to find out possible linear combinations of the variables.

In time series analysis, non-stationary data have been notorious to lead to spurious regression unless there exists at least one cointegrating relationship. This method provides a unified framework for estimation and testing of cointegration relations in the context of Vector Autoregressive (VAR) error correction models. For this approach it is important to estimate an Unrestricted Vector of Autocorrelation of the form:

$$\Delta x_t = \alpha + \theta_1 \Delta x_{t-1} + \theta_2 \Delta x_{t-2} + \theta_3 \Delta x_{t-3} + \cdots\cdots + \theta_{k-1} \Delta x_{t-k+1} + \theta_k \Delta x_{t-k} + u_t$$

Where, Δ is the difference operator, x_t is a *(n x 1)* vector of non-stationary variables (in levels) and u_t is also the *(n x 1)* vector of random errors. The matrix Θ_k contains the information on the long run relationships between the variables. If the rank of $\Theta_k = 0$, no cointegration exists between the variables, whereas if rank, *r*, is equal to 1, one cointegrating vector exists and if $1 < r < n$, multiple cointegrating vectors are present. Johansen and Juselius (1990) have derived the ‘trace test’ and the maximum ‘Eigen value test' for checking cointegration properties. The former assesses the null hypothesis that there are at most *r*cointegrating vectors whereas the latter assesses the null hypothesis that there are exactly *r* cointegrating vectors in x_t.

Once cointegrations were established we went for the Granger Causality test to check the existence and direction of long run causality among the cointegrated variables. According to cointegration analysis, the cointegration between two variables validates at least one direction of causality between them. Engle and Granger (1987) have pointed out that the incidence of non-stationary variables often result in ambiguous and false conclusions in the Granger causality test hence possible to deduce a causal long run relationship between non-stationary time series when the variables are cointegrated.

If *y* and *x* are the variables of interest, then the Granger causality test establishes that whether previous values of *y* add to the justification of current values of *x* as provided by information in past values of *x* itself. If past changes in *y* do not assist in explaining current changes in *x*, then *y* does not Granger cause *x*. Similarly, we can investigate whether *x* Granger causes *y* or not by interchanging them and conducting the same process again. There are four possible outcomes,

1. Neither variable Granger cause each other
2. *y* Causes *x* only
3. *x* Causes *y* only
4. Both *x* and *y* Granger cause each other

‘Energy Use per Capita’, kg equivalent of oil, has been used to substitute for aggregate energy whereas ‘Electric Power Consumption per Capita’, also known as ‘Electricity Consumption per capita’, kWh, as the proxy for the disaggregate energy. Energy Use per capita shall be expressed as ENERGY and Electricity Consumption per capita as ELECTRICITY for the rest of the paper. Infant Mortality Rate(IMR), Life Expectancy(LE), Total Fertility Rate (TFR), Female Literacy Rate(FLR) and Carbon Dioxide (CO_2) Emissions, have been taken as proxies for social variables, whereas Gross Domestic Product (GDP) growth rate and Household Final Consumption Expenditure (HHC) express the economic indicators of development.

The long run causal relationships help shed light on the socio-economic conditions of Bangladesh allowing policymakers to work out policies or programs bearing in mind the more influential type of energy usage for strengthening the social and economic aspects of life for Bangladeshi residents.

In this paper two causality tests will be conducted, one between ENERGY and the seven social and economic variables and, another between ELECTRICITY and the same variables. For this the following sets of equations will be estimated:

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \cdots\cdots + \alpha_l x_{t-l} + \beta_1 y_{t-1} + \cdots\cdots + \beta_l y_{t-l} + u_t$$
$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \cdots\cdots + \alpha_l y_{t-l} + \beta_1 x_{t-1} + \cdots\cdots + \beta_l x_{t-l} + v_t$$

For all possible pairs of *(x, y)* series in the group, the reported F-statistics are the Wald statistics for the joint hypothesis $\beta_1 = \beta_2 = \beta_3 = \ldots\ldots\ldots\beta_l = 0$.

Various rationales have been borne in mind when selecting the variables. Better and cleaner electrification leads to reduced generation of electricity from fuel burning sources resulting in lower greenhouse gases emissions like CO_2thus positively affecting health and environment helping to build human capital and restoring suitable business environment as well.This fall in dependency on such harmful sources of energy frees up significant portion of the time of underprivileged and rural females enabling them to allocate time for education and economic activities resulting in a positive impact on FLR and desired negative influences on IMR and TFR which in turn boost the economy and lift up the nation’s social status.

Electrification and higher availability of other energy sources allow people to access enhanced lighting, exposure to modern media and electronic devices, increased labor market opportunities, allowing them to better care for their infants and engage in advanced family planning activities which help combat high fertility as insistent population growths accompanied by high fertility rates is a recipe for disaster for countries at the lower end of the income spectrum.

Due to higher prevalence of electric and energy services rural and urban poor households will be able to possess advanced technological devices like mobile phones and televisions, which will enhance communications and raise awareness of healthcare facilities and methods, possess refrigerators to store vaccines, and preserve food, and modern stoves to prepare food, in a hygienic and healthy way. All of these pose a favorable impact on LE, IMR and TFR. Similarly, possession of such devices is a clear indication of increased HHC which is both an indication and stimulus of economic growth.

All the data have been collected from the World Development Indicators (WDI) online database of the World Bank (WB) and the Bangladesh Bureau of Statistics (BBS) for 1985 to 2014 for which 30 observations are available at most.

4. Results

TheADF Unit Root testiscarriedouttocheckthestationarity of the variables, helping determine the order of the integration of the data series for all the variables. Theresultsaresummarized below,

Table 1: Augmented Dickey Fuller Unit Root Test for the Variables

Panel 1: Levels			
	ADF Statistics (Intercept)	ADF Statistics (Intercept & Trend)	Decision
ENERGY	2.287782	-0.639176	Non-stationary (intercept, and intercept and trend)
ELECTRICITY	4.407103	-0.006349	Stationary (intercept) and non-stationary (intercept and trend)
CO_2	3.572290	-0.104030	Stationary (intercept) and non-stationary (intercept and trend)
LE	-9.376598	-2.300498	Stationary (intercept) and non-stationary (intercept and trend)
IMR	-3.796340	4.808253	Stationary (intercept, and intercept and trend)
GDP	-2.759946	-4.722407	Stationary (intercept, and intercept and trend)
TFR	-1.905567	-4.177601	Non-stationary (intercept) and stationary (intercept and trend)
FLR	-0.316157	-2.114139	Non-stationary (intercept, and intercept and trend)
HHC	-4.507289	-5.125211	Stationary (intercept, and intercept and trend)

Panel 2: First Differences			
	ADF Statistics (Intercept)	ADF Statistics (Intercept & Trend)	Decision
ENERGY	-	-7.112765	Stationary
ELECTRICITY	-	-5.702597	Stationary
CO_2	-	-4.190763	Stationary
LE	-	-8.582976	Stationary
IMR	-	-	-
GDP	-	-	-
TFR	-	-6.592364	Stationary
FLR	-	-5.560643	Stationary
HHC	-		-

Note: All regression is estimated with and without trend. Selection of the lag is based on Schwartz Information Criterion (SIC). EViews 7.0 software automatically selects the most significant lag length based on this criterion.

It is important to mention that unit root tests are notorious for having non-standard and non-normal asymptotic distribution which are greatly affected by the inclusion of deterministic terms, like constant, time trend and others. A time trend tends to reduce the power of the test when included. However, if the true data generating process were trend stationary, a failure to include a time trend would result in a reduction in the power of the test. This loss of power from excluding a time trend when it should be present is more severe than the reduction in power associated with including a time trend when it is extraneous.

The above results clearly show that all variables are stationary in both cases. For the next stage we checked for the presence of any long run linear combination among the stationary variables using the Johansen Cointegration test. The results are as follows.

Table 2: Johansen Test for Cointegration (Trace Test)

Pair	Null Hypothesis	Alternative Hypothesis	Statistics	0.1 Critical Value	Conclusion
CO2 and ELECTRICITY	None	At most one	23.14155	13.42878	Two Cointegrating Relationships
FLR and ELECTRICITY	None	At most one	12.29553	13.42878	No Cointegration
IMR and ELECTRICITY	None	At most one	12.10956	13.42878	No Cointegration
GDP and ELECTRICITY	None	At most one	26.68055	13.42878	Two Cointegrating Relationships
LE and ELECTRICITY	None	At most one	45.52317	13.42878	One Cointegrating Relationship
HHC and ELECTRICITY	None	At most one	31.66209	13.42878	Two Cointegrating Relationships
TFR and ELECTRICITY	None	At most one	12.98078	13.42878	No Cointegration
CO2 and ENERGY	None	At most one	28.25617	13.42878	Two Cointegrating Relationships
FLR and ENERGY	None	At most one	10.07796	13.42878	No Cointegration
IMR and ENERGY	None	At most one	13.50210	13.42878	One Cointegrating Relationship
GDP and ENERGY	None	At most one	19.08114	13.42878	Two Cointegrating Relationships
LE and ENERGY	None	At most one	40.92814	13.42878	One Cointegrating Relationship
HHC and ENERGY	None	At most one	18.75004	13.42878	Two Cointegrating Relationships
TFR and ENERGY	None	At most one	9.787552	13.42878	No Cointegration

Table 3: Johansen Test for Cointegration (Maximum Eigenvalue Test)

	Null Hypothesis	Alternative Hypothesis	Statistics	0.1 Critical Value	Conclusion
CO2 and ELECTRICITY	None	At most one	14.85021	12.29652	Two Cointegrating Relationships
FLR and ELECTRICITY	None	At most one	12.12109	12.29652	No Cointegration
IMR and ELECTRICITY	None	At most one	11.05567	12.29652	No Cointegration
GDP and ELECTRICITY	None	At most one	16.48866	12.29652	Two Cointegrating Relationships
LE and ELECTRICITY	None	At most one	44.65887	12.29652	One Cointegrating Relationship
HHC and ELECTRICITY	None	At most one	22.30318	12.29652	Two Cointegrating Relationships
TFR and ELECTRICITY	None	At most one	12.21029	12.29652	No Cointegration
CO2 and ENERGY	None	At most one	19.60452	12.29652	Two Cointegrating Relationships
FLR and ENERGY	None	At most one	10.02275	12.29652	No Cointegration
IMR and ENERGY	None	At most one	12.90819	12.29652	One Cointegrating Relationship
GDP and ENERGY	None	At most one	12.60035	12.29652	Two Cointegrating Relationships
LE and ENERGY	None	At most one	40.73673	12.29652	One Cointegrating Relationship
HHC and ENERGY	None	At most one	13.14485	12.29652	Two Cointegrating Relationships
TFR and ENERGY	None	At most one	9.392741	12.29652	No Cointegration

Both the trace and the maximum Eigenvalue tests indicate the presence of either one cointegrating relationship for some of the pairs, two between others whereas none between the rest. Evidently CO_2, GDP, HHC and LE are cointegrated with ELECTRICITY while CO_2, GDP, HHC, IMR and LE are cointegrated with ENERGY. Hence, it is safe to say that at least one long run causality among each of the cointegrated pairs is expected.These results provide answer to our first research question mentioned in the introduction.The presence of cointegration has been determined by comparing the statistics value and the critical value, where at at 10% significance level at least one cointegrating relationship exists when the statistics value is greater than the critical value.

The above lets us check for the presence and direction of causality among the cointegrated pairs using the Granger Causality test. The results of the pair wise Granger Causality tests have been provided below.

Table 4: Granger Causality Test

Null Hypothesis	F-Statistic	P-Value	Granger Causality
ELECTRICITY does not Granger Cause CO_2	2.53523	0.1012	No Causality between ELECTRICITY and CO_2
CO_2 does not Granger Cause ELECTRICITY	1.56403	0.2307	
ENERGY does not Granger Cause CO_2	0.76256	0.4779	CO_2 Granger Causes ENERGY
CO2 does not Granger Cause ENERGY	2.90884	0.0748	
GDP does not Granger Cause ELECTRICITY	1.15962	0.3313	ELECTRICITY Granger Causes GDP
ELECTRICITY does not Granger Cause GDP	6.27256	0.0067	
HHC does not Granger Cause ELECTRICITY	0.80464	0.4594	ELECTRICITY Granger Causes HHC
ELECTRICITY does not Granger Cause HHC	5.14712	0.0142	
LE does not Granger Cause ELECTRICITY	1.88099	0.1752	ELECTRICITY Granger Causes LE
ELECTRICITY does not Granger Cause LE	10.1099	0.0007	
GDP does not Granger Cause ENERGY	1.78057	0.1910	ENERGY Granger Causes GDP
ENERGY does not Granger Cause GDP	3.07913	0.0653	
HHC does not Granger Cause ENERGY	0.91050	0.4163	No Causality between ENERGY and HHC
ENERGY does not Granger Cause HHC	1.15305	0.3333	
IMR does not Granger Cause ENERGY	0.73226	0.4917	ENERGY Granger Causes IMR
ENERGY does not Granger Cause IMR	2.89340	0.0757	
LE does not Granger Cause ENERGY	1.29761	0.2924	ENERGY Granger Causes LE
ENERGY does not Granger Cause LE	7.18531	0.0038	

The existence of long run causal relationships in the Granger causality test have been ascertained when the p-value for each of the pair is less than 0.1. The table above reveals the presence of a unidirectional causality running from ELECTRICITY to GDP, HHC and LE, respectively. One way causalities from ENERGY to IMR, LE and GDP are also apparent with an absence of any long run causality between ENERGY and HHC. Thus, the results clearly answer our second research question posed in the introduction.

Thus, on the basis of the tests conducted and the statistical evidence provided in the tables above we are able to conclude that our paper has precisely assessed that both energy sources have major influences on Bangladesh's socio-economic progress, however it is quite evident that ELECTRICITY has higher economic implications whereas ENERGY has higher social implications and our hypothesis of a causal link between ENERGYand HHC seem to have been rejected.

This is clear evidence of novel results derived by our paper when compared to several of the above literature discussed in earlier sections. For example we are able to generate a causality running from ENERGY to GDP whereas Asghar (2008) witnesses an absence of cointegration between the two; similarly our results indicated causality from ELECTRICTY to GDP, quite the opposite from his study. An analogous scenario was witnessed for unidirectional causality from ENERGY to GDP and from $CO_2$to ENERGY for which the results were the opposite for Amin et. al's (2012) study and was opposite in the latter case for Sulaiman's (2014) study relative to this paper.

5. Conclusions

Our paper investigates the energy and socio-economic development nexus for Bangladesh in a multivariate framework between 1985 and 2014. Two models have been put forward to assess the long run causal relationships between aggregate and disaggregate forms of energy usage and the socio-economic development of Bangladesh. The paper aims to look into the untapped areas of development for Bangladesh that embody the social and economic aspects of advancement. The focusof the paper was to answer the questions posed in the introduction, which we have successfully based on the outcomes discussed in section 4, to help provide some directions with regards to policy implementation.

We have been able to establish diverse results for the case of Bangladesh as opposed to several papers cited above, per say the absence of causality between ELECTRICITY and CO_2, and ENERGY and HHC which are contrary to commonintuition such as the positive relationship between electricity consumption and CO_2 emissions, and higher energy consumption with overall consumption of households, as a nation grows.This absence of causality between ELECTRICITY and CO_2 indicates that higher consumption of electricity does not have degrading impacts on the environment, unlike its production, thus depicts the importance of devising policies to encourage increased electricity consumption sans conservation policies.

Similarly, the lack of causality between ENERGY and HHC is also an unexpected one as one would suppose that higher energy use leads to higher consumption by households as energy access in the form of gas connection, electricity and so on would mean increased spending on food, healthcare, and entertainment services. This could be because the significant portion of the population lives in rural and poor urban areas and are dependent on primary and unreliable energy sources. This inclusion of HHC is a case we have not come across in the previous studies.

IMR is a bigger concern for villages and poor urban neighborhoods and its unexpected lack of causality with ELECTRCITY sheds light on the fact that remote areas are still deprived of access to electricity so higher access would generate more conclusive results.

Higher levels of public, private and foreign investments should be made to finance grid expansions as a significant portion of the population does not have access to the national grid and such a situation constrains productive capacities and income generating opportunities.At the same time mass electrification initiatives should be complemented by restructuring of the power generating ingredients mix to reduce the dependency on natural gas as well as other detrimental traditional means of energy.

Our results indicate that ENERGY has greater social, than economic, returns unlike ELECTRICITY. Mass scale programs to ensure higher access and consumption of all forms of energy are imperative. The results suggest that when formulating policies both aggregate and disaggregate energy should be given balanced importance in order to clutch a sustainable socio-economic development. However, Bangladesh is a middle income country with a primary focus on catching up with advanced nations, we believe the government should shift higher focus on ensuring sustainable production and distribution of electricity initially and social progress should follow naturally as the nation grows.

Meanwhile, just raising the access is not enough. As the rural and low income urban households are more disadvantaged it is imperative that they are provided with appliances such as modern stoves, refrigerators, energy saving bulbs, and televisions alongside training programs to enjoy the maximum benefits of increased energy consumption through efficient usage. These actions will only reap maximum paybacks when affordable, uninterrupted, and modern energy is being supplied to every household.

Even though the paper tried to present a conclusive view of the twofold energy and socio-economic development linkage for Bangladesh, just like all papers there were some limitations. The absence of recent and relevant literature in the context of Bangladesh and the short timeframe of data would be a few to name. This paper also opens new gates to further research. We have attempted to provide a unified approach of the role of energy in defining Bangladesh's sustainable development and this should encourage future studies focusing on energy and other socio-economic variables like mother mortality, or government expenditure and socio-economic development nexus for Bangladesh and other South Asian countries. Looking at more disintegrated and specific forms of energy will aid in building more constructive energy specific growth policies.

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