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Revisiting the Jevons Paradox of Energy Economics: Empirical Evidence from Bangladesh and India

Muntasir Murshed[1]

The significance of enhancement in energy consumption in order to boost the respective national output level within any economy cannot be denied. Moreover, the United Nation's 2030 Sustainable Development agenda had also called for an improvement in efficiency of energy-use through the adoption of renewable energy technologies in particular, with the ultimate goal of attaining sustainability in global energy supply. The rationale behind escalating the associated efficiency levels is that by doing so the level of energy consumption can be reduced which would complement the direct energy conservation policies as well. However, there has been ambiguity with regard to the precise relationship between efficiency in use and consumption of energy. The aim of this paper is to shed light on the energy efficiency-energy consumption nexus in context of the two South Asian Lower Middle-Income Countries, Bangladesh and India. The study makes a novel attempt at investigating the 'Jevons Paradox' by disaggregating energy consumption into primary and secondary energy consumption and by expressing each of these as separate functions of energy-use efficiency and other control variables. This study considers annual data stemming from 1990 to 2016 and employs Fixed Effects (FE), Random Effects (RE) and Three-Stage Least Squares (3SLS) panel regression tools for robustness check. Furthermore, the paper also analyses the long run causal linkages using the Granger causality tests. In light of the estimated results, evidence of a Jevons paradox is found in the context of non-renewable energy, electricity and coal consumption. In addition, no long-run causal association is found to exist.

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1. Introduction

The role of energy in enveloping several macroeconomic activities across the globe has experienced astronomical emphasis and recognition over the past decades. Energy, as an input, has gone on to augment conventional production functions that were traditionally biased towards considering capital and labor as the only inputs (Amin and Murshed 2017a). Thus, the energy-growth nexus has been a key genre of research amidst researchers and policymakers all over the globe as perceived from the corresponding well-documented literature (Menegaki and Tugcu 2017; Kahia *et al.* 2017; Kais and Sami 2016; Omri 2014). Underscoring the potentials of energy, its adequate availability is considered to be one of the most intriguing public agendas to which governments have to comply with in order to complement their respective macroeconomic development targets. In line with this notion of energy supply-sufficiency, the United Nation's 2030 Sustainable Development agenda has specifically outlined the prime significance of ensuring reliable, clean and affordable energy worldwide as

[1] Programme Associate (Research), Centre for Policy Dialogue (CPD), Bangladesh
Email: muntasir.murshed@northsouth.edu

mentioned in the 7th Sustainable Development Goal (SDG). It is believed that attainment of all the other 16 SDGs could well be put to a cliffhanger provided sustainability in energy supply to match the surging energy demand is not ensured. This goal is primarily bound by the underlying belief that energy and its appropriate availability within an economy can catalyze multifaceted development programs and improve the overall well-being of the population worldwide.

However, following the brisk growth in the global demand for energy with time and the fact that most of the primary energy resources are confined in specific regions across the globe, the prospects of energy supplies meeting the corresponding demand worldwide exhibits a dismal picture. It is expected that the global energy demand is likely to account for a 30% increment by 2040 (International Monetary Fund 2016) which could well go on to outweigh the energy supply provided no effective measures are adopted to boost energy generation and reserves across the globe. In addition, the associated negative impacts of energy consumption, non-renewable energy, in particular, should also be kept into consideration when adopting energy reform frameworks. Use of conventional energy resources is believed to be the leading contributor to climate change which makes the developing nations worse-off due to being the most vulnerable to the atrocities of climate change (Ozturk and Acaravci 2010; Chang 2010; Soytas *et al.* 2007; Hadley *et al.* 2006). Consumption of energy worldwide is estimated to account for almost 60% of the total greenhouse gaseous emission, the prime factor attributing to climate changes across the globe. The surging demand for energy thus also imposes the threat of boosting such greenhouse emissions which is more likely to be generated from the Asian nations that are expected to exhibit large increments in their respective total energy demand arising from rapid demographic and economic growths in the associated countries. Thus, along with increasing energy supply to match energy demand, it is also crucial to keep the energy demand growths into check and balance without marginalizing the growth strategies pursued by the economies. In solidarity with this notion, the UN's SDG agenda not only calls for raising energy supply but also stresses on enhancing the energy-use efficiency levels which could effectively curb the energy demand by lowering the amount of energy required per unit of output produced.

Enhancement in the level of efficiency with respect to energy-use is argued to operate as an indirect energy conservation measure which would complement the direct conservation measures in the form of reducing the use of energy. One of the targets under the SDG 7 aims at doubling the global rate of improvement in energy-use efficiency with the ultimate aim of ensuring reliable energy supply in a sustainable framework. Moreover, the SDG7 further highlights the importance of enhancing energy-use efficiency by calling out for international cooperation to boost energy efficiency worldwide. It is anticipated that such efficiency improvement can attribute to global energy demand going down by as much as one-third by the end of 2040 (International Energy Agency 2015). Thus, it is of utmost importance to investigate the efficacy of energy efficiency improvements in attaining the underlying goal of energy conservation which provides motivation for studies to be undertaken in this field. The effectiveness of energy-use efficiency enhancements with respect to curtailing energy-use has been analyzed using the Jevons paradox which advocates in favor of a positive interlinkage between energy efficiency improvement and energy consumption, challenging the justification of such efficiency-enhancing energy policies. The aim of this paper is to probe into the associated nexus between these two key variables in a disaggregated approach, in light of the

Jevons paradox, in the context of the two South Asian emerging economies Bangladesh and India between 1990 and 2016. These countries have traditionally experienced mismatches between their respective energy demands and supplies and as a consequence have experienced the corresponding anti-development impacts. Thus, along with greater energy generation policies, these countries have also gone on to tap energy-use efficiency enhancement strategies as well. However, the question to be addressed in this regard is whether such strategies have resulted in a reduction in the respective energy demands or have these strategies boomeranged driving energy consumptions up. The following questions are specifically addressed in this paper:

1. Is there any statistical evidence suggesting the Jevons paradox with regards to disaggregated energy consumption?
2. Is there any causal association between the energy consumption and energy efficiency variables?

The remainder of the paper is structured as follows. Section 2 provides an overview of energy efficiency and its importance in the economy. This is followed by the review of literature in section 3 which is subdivided into two subsections with the former providing a conceptual framework engulfing the energy efficiency-energy consumption theoretical space while the latter expresses a critical review of the corresponding relevant empirical literature. Section 4 explains the empirical model used and specifies the variables included in the dataset. The econometric tools used for empirical analyses are given in section 5 while section 6 reports and discusses the results obtained. Finally, section 7 the concluding remarks and outlines the implications derived from the estimated results.

2. The Economics of Energy Efficiency

Energy efficiency can directly reduce the energy expenditure and curb the per unit cost of energy-use. In addition, energy efficiency enhancement can also indirectly lead to positive externalities in the form of reduced greenhouse emissions prolonging climate change. In simple terms, energy efficiency enables the best possible use of energy that is available for consumption through technological innovation. It actually advocates in favor of utilizing the minimum amount of energy resources for maximization of comfort conditions. According to Cutler and Christopher (2006), energy efficiency can be interpreted as a reduction in the quantity of energy used per unit service provided. Instead of directly putting a limit to energy-use, improvement in energy efficiency puts forward the idea of extracting maximum output from a given amount of energy input which further justifies the augmentation of energy inputs into the conventional capital-labor production functions. It has been empirically recognized that it is very crucial from the perspective of any developing countries to ensure the most efficient use of its indigenous energy in the productive sectors. The underlying belief behind energy efficiency improvement is that the energy saved through efficient use within the economy could be employed in other potential sectors spawning faster rate of economic development.

Energy efficiency is one of the quickest and cheapest ways to increase the amount of energy available for use. According to International Energy Agency (2015), energy efficiency is the world’s most important fuel. Investments in energy efficiency provide such massive savings that the energy saved completely eclipses the energy generated by most forms of generation.

This "first fuel" is incredibly important to the world's efforts to reduce fossil fuel use and carbon emissions and therefore should be extended greater importance, the new report argues. Energy efficiency has also been referred to as a "hidden fuel" as the degree of global investment in energy efficiency and the resulting energy savings are quite large. Power plants creating electricity and our own home's use of natural gas or heating oil causes pollution in the air and emissions of greenhouse gases that can contribute to the risks of global climate change. More than half of all greenhouse gases in the air come from power plants and the use of natural gas. By using less energy, you help fight global climate change by reducing the greenhouse emissions.

3. Review of Literature

The review of the literature has been subdivided into two folds with the former providing theoretical framework of the Jevons paradox of energy economics while the latter shedding light on the empirical literature in relevance to the energy efficiency-energy consumption nexus.

3.1. Theoretical Framework

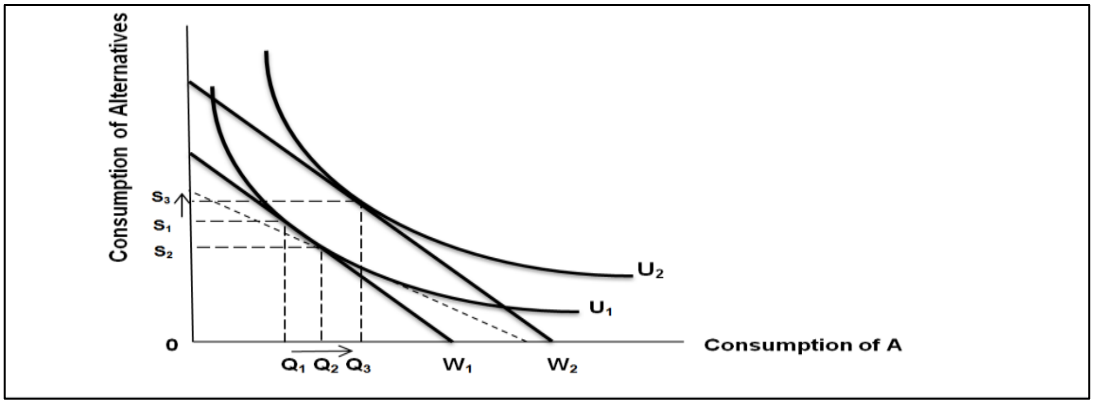
3.1.1. The ‘Jevons Paradox’ of Energy Economics

The justification for enhancement in the efficiency in the use of energy resources with respect to energy conservation was first questioned in the 19th century by the English economist William Stanley Jevons. The author, in his book, put forward the idea that the consumption of coal in England surged despite the technological advancement leading to the emergence of coal-fired steam engines which reduced the overall cost of energy-use in the country and expedited the pace of industrialization in the country (Jevons 1865). Thus, with coal being a finite energy resource, Jevons questioned the efficacy of this technological improvement-induced enhancement in energy-use efficiency in ensuring sustainability of the English coal reserves. Hence, the dilemma engulfing the energy efficiency-energy consumption paradox, which was later on referred to as the ‘Jevons Paradox,' went on to become a widely known puzzle in environmental economics.

Jevons (1865) basically advocated in favor of both the substitution and the income effects collectively contributing to a rise in energy consumption at a higher rate than the expected rate of reduction in energy consumption following an enhancement in the efficiency level of energy-use in the economy. Figure 1 provides an understanding of the two above mentioned effects taking place following a technological advancement leading to the enhancement of efficient use of a particular energy resource (A). As the efficiency increases, the per unit price of consuming A is expected to fall. This will trigger down the relative price of A compared to other relevant alternative energy resources and therefore induce more consumption of A and less consumption of the alternative energy resources. This is classified as the substitution effect increasing consumption of A from Q_1 to Q_2 and reducing the consumption of the alternatives from S_1 to S_2. Simultaneously, a drop in the per unit price of A would also raise the real income of households whereby the household budget schedule will experience a rightward shift (from W_1 to W_2). Thus, consumption of A would rise further up to Q_3 and, at the same instant, the consumption of other alternative energy resources would also go up to some extent (up to S_3).

This is referred to as the income effect. An important thing to note here is that due to the efficiency enhancement in use of resource A, the consumption of other alternative energy resources ultimately also goes up from its initial consumption level (from S_1 to S_3) which can be referred to as an indirect effect whereas the rise in the consumption of A is referred to as the direct effect of efficiency enhancement. This explains how the associated substitution and income effects may altogether attribute to the Jevons paradox in energy economics, contesting adoption of energy-use efficiency policies in light of its effectiveness in conserving energy resources in the economy.

Fig. 1: The Substitution and Income Effects of Energy Efficiency Enhancement



Source: Author's own

3.1.2. The Rebound Effects of Energy Consumption

The Jevons Paradox was later on reexamined by modern environmental and energy economists using the energy consumption Rebound Effects (RE) derived from improvements in energy-use efficiency. The rebound effect simply analyses the behavioral pattern of a household following a drop in the price of energy due to technological innovations uplifting the trend in the efficient use of energy resources. In general, the RE of energy consumption can be classified into direct, indirect and backfire RE.

a) **Direct Rebound Effect (DRE)**: The DRE refers to a rise in the consumption of a particular resource whose price has gone down following a technological improvement-efficiency enhancement regarding its use. This can somewhat be compared to the income and substitution effects suggested by Jevons (1865). For example, the rise in the economy-wide consumption of coal to fire steam-engines in England in the mid-1860s, following the invention of the technologically-efficient steam engines, can be referred to as the DRE of such an efficiency gain.

b) **Indirect Rebound Effect (IRE):** The IRE of energy consumption takes place when an improvement in efficiency in the use of a particular resource leads to a greater consumption of another resource due to an indirect income effect taking place. For instance, a rise in the sale of fuel-efficient cars can result in less amount of income being exhausted in purchasing fuels, whereby the savings can then be used to consume more units of electricity at home. Thus, the technological innovation with respect to efficient use of fuels may lead to a rise in the consumption of electricity which ultimately implies that the overall energy consumption in the economy would go up.

c) **Backfire Rebound Effect (BRE):** The BRE of energy consumption is inextricably linked to the Jevons paradox in the sense that due to this effect taking place the amount of expected energy savings, following an efficiency gain with respect to energy-use, is outweighed by the total rise in energy consumption, putting the ultimate objective of energy conservation to the sword. For instance, if a 10% efficiency gain in the context of a particular energy resource use leads to a more than 10% rise in its consumption, then it is referred to as the BRE of energy consumption.

The RE of energy consumption can be calculated using the formula below (Wang *et al.* 2013):

$$RE = \frac{E_2 - E_1}{E_1 - E_0} \text{ -------------------- } (i)$$

where (E_2-E_1) refers to rebound consumption and (E_1-E_0) refers to expected savings. Thus, equation (i) can be rewritten as:

$$RE = 1 - \frac{E_0 - E_2}{E_0 - E_1} \text{ ---------------------}(ii)$$

The values of the RE range between infinite negative and positive values and can also be equal to zero, based on which the RE of energy consumption can be further classified into five subdivisions (Saunders 2008):

a) **Super Conservation:** This refers to a negative value of the RE which takes place when the magnitude of expected energy savings following a gain in energy-efficiency is less than that the actual drop in the volume of energy consumption. For instance, if 10% electricity-use efficiency results in a 12% reduction in the electricity consumption then the overall RE of electricity consumption would equate to -0.2 (or - 20%). Thus, in the super conservation case, energy efficiency improvement policies are pretty much in line with the energy conservation policies.

b) **Zero Rebound:** The RE of energy consumption becomes zero when the expected energy saving derived from a particular energy-use efficiency improvement results in the equal amount of drop in its consumption. For instance, if the 10% enhancement in electricity-use efficiency results in the overall electricity consumption going down by 10% as well, then the RE of electricity consumption would equate be equal to 0. Hence, zero rebound cases also compliment the energy conservation policies.

c) **Partial Rebound**: In the case of partial RE taking place, the value of the RE is positive and ranges between 0 and 1 (i.e. 0 < RE < 1). This takes place when a particular gain from efficiency in the use of a particular energy resource is more than the actual drop in the consumption of that resource. For instance, if the 10% enhancement in electricity-use efficiency contributes to a fall in electricity consumption by merely 7%, then the corresponding RE of electricity consumption would be equal to 0.3. Therefore, in the case of partial RE taking place, energy conservation policies partially corroborate policies aimed at enhancing energy-use efficiencies.

d) **Full Rebound:** Full RE takes place in the case when the expected savings in energy-use due to an efficiency enhancement does not contribute to a reduction in the overall energy consumption. Under such circumstance, the total energy rebound is equal to the total expected energy savings. For example, if the 10% enhancement in electricity-use efficiency leaves the overall electricity consumption in the economy unchanged, then the RE of electricity consumption would be equal to 1 which implies that there is 100% rebound in consumption of electricity. Thus, energy conservation policies in such cases would clearly contradict the justification of enhancing energy-use efficiencies.

e) **Backfire Rebound:** This takes place when the expected gain from efficiency enhancement with respect to the use of a particular energy resource is less than the magnitude of the rise in the consumption of that resource. As a result, the RE takes a value of more than 1 (i.e. RE > 1). For instance, if the 10% rise in the electricity-use efficiency stimulates a 20% rise in the overall electricity consumption, then the RE would be equal to 2 which implies that there is a 200% rebound in electricity consumption. Thus, in cases of backfire rebounds taking place, the Jevons paradox emerges jeopardizing the prospects of energy conservation via energy-use efficiency improvement strategies.

3.2. Empirical Findings

In an attempt to understand the Jevons paradox, York and McGee (2016) undertook a study to empirically probe into the energy-use efficiency and energy consumption relationship from both economic and environmental perspectives. The study was based on two folds with the initial section providing a critical review of existing literature suggesting a positive correlation and causal association between energy efficiency and energy consumption while the latter section provided conclusions based on a panel data investigation on the aforementioned relationship in the context of data on all the countries enlisted in the World Bank (2014) for which relevant data between 1960 and 2010 was available. The authors used a panel random-effects Generalized Least Squares (GLS) model in which growths in per capita energy consumption, electricity consumption and carbon-dioxide (CO_2) emission were expressed as separate functions of respective efficiencies, controlling for GDP growth per capita, urbanization, dependency ratio and manufacturing sector's contribution to the GDP. The results from the regression analyses revealed the positive correlations between the dependent variables and the respective efficiencies, providing evidence of Jevons paradox and partial RE taking place. In light of their statistical findings, the authors opined that more efficient countries accounted for relatively higher growth rates in per capita energy consumption, electricity consumption and CO_2 emission. The authors also pointed out that these positive linkages between consumption and efficiency may not necessarily be due to the direct association between these variables. Rather, there may be indirect associations leading to these positive correlations since it was found that factors driving development in the panel of countries actually attributed to greater volumes of energy and electricity consumption and CO_2 emissions. The results were in line with Polimeni *et al.* (2008) and Sorrell (2015).

One of the most comprehensive studies of the Jevons paradox across the globe was conducted by Polimeni and Polimeni (2006). The authors probed into the relationship between energy efficiency gain and energy consumption by debunking the conventional myths adhering to technological liberation. The study encompassed cross-sectional time series data for the year 2003 in the context of a large number of countries grouped in terms of specific regions including North America, Central and South America, Western Europe, Asia, Africa and the Middle East. The rationale behind these classifications was to comprehend whether region-specific macroeconomic disparities played a role in causing the Jevons' paradox to possibly exist in some segments of the World while not in the others. The study time series cross-section regression tools to estimate two models. In the first model, energy consumption was expressed as a function of growth rates of GDP, energy intensity and population in order to investigate whether the Jevons paradox existed in the macro level while, in the second model, the population variable was intentionally dropped. The regression results provided statistical evidence regarding a positive correlation between energy intensity growth and energy consumption across all the regions which implied the possible existence of the Jevons paradox in the associated countries. However, the estimated coefficients attached to the energy intensity growth variable exhibited double a value of more than 1 in the cases of North America and Asia which meant that improvements in the efficiency level of energy-use were the main drivers of energy consumption in these regions whereby the magnitude of the backfire RE of energy consumption are relatively higher, further questioning the effectiveness of pursuing energy efficiency policies to conserve energy in these two regions. It was also specifically highlighted in the study that the growth in energy intensity on average increased energy consumption in Asia by 5 times compared to that caused by its GDP growth.

In pursuit of the goal linked to assessing the efficacy of energy efficiency policies in China, Wang *et al.* (2013) conducted an empirical analysis of the RE of residential electricity usage across 30 provinces in China. The authors incorporated panel data from 1996 to 2010 to form an Error-Correction Model (ECM) for the analyses of both short and long-term direct RE of electricity consumption. Panel unit root and cointegration tests were applied in the study while the panel fixed effects estimation tool was judged to be the optimal regression technique based on the results of the Hausman test. In light of the regression results found, the authors asserted that there was an existence of direct RE of electricity consumption in the Chinese provinces, however, the magnitude of the RE varied across time frames since the long-term RE found in the analysis outweighed the short term RE by 2%. Keeping these findings into deep consideration, the authors also expressed their opinions in favor of adjusting these RE of residential electricity consumption into the energy efficiency policies taken by the provincial governments of China as the failure to do so would hamper the efficacy of such policies.

In order to assess the impacts of South Korea's energy efficiency policies, to promote green growth, on the nation's energy consumption and greenhouse gaseous emissions, Gunderson and Yun (2017) put forward arguments against the efficacy of South Korea's National Strategy for Green Growth (NSGG) based on energy-use efficiency enhancement and greater renewable energy-use throughout the country. The authors opined that ever since the implementation of the NSGG, the total energy-use and greenhouse gaseous emissions in the country have drastically gone up resulting in the Jevons paradox and thereby challenging the effectiveness of the NSGG in attaining its prime objectives which include climate change mitigation, self-sufficiency in energy generation, green industrialization and enhancement in quality of life in South Korea. However, evidence of backfire RE of energy consumption and escalating emission of greenhouse gases has marginalized the efficacy of the NSGG. As a result, the authors have suggested for increased public participation in environmental decision-making and degrowth of highly energy-intensive industries contributing to the acceleration in the growth of total energy-use in South Korea. The conclusions implied that transition towards the adoption of renewable energy resources within an economy in order to ensure sufficient supply of energy is subject to hindrances arising from the Jevons paradox existing in South Korea whereby its NSGG had been subject to several limitations in achieving its targeted outcomes.

The Jevons paradox in light of the association between vehicle fuel-use efficiency and miles traveled in the United States (US) was analyzed by Munyon *et al.* (2018). The study basically aimed to empirically test whether an efficiency enhancement with respect to energy consumption does lead to a rise in the consumption of energy, despite controlling for all the other variables that may stimulate energy consumption. The control variables considered in this study included household income, driver's age, household size and structure, driver's employment status, the condition of the vehicle, population density, and fuel price. Cross-sectional data from the US national household travel survey, for the year 2009, was used in this study from which a sample was generated using a Random Digit Dialing (RDD) method and Computer- Assisted Telephone Interviewing (CATI) technology. The data was then hired to generate and regress a model that expressed vehicle miles traveled, used to proxy energy consumption, as a function of distance traveled in miles, and the aforementioned control variables. The corresponding results suggested that, despite assuming the other control variables to be constant, the Jevons paradox holds in the context of the vehicle fuel-use efficiency and fuel consumption relationship in the US as a 1% enhancement in fuel efficiency led to a 1.2% increase in fuel consumption providing support to the backfire RE taking place.

In contrast, many studies have provided statistical evidence against the Jevons paradox taking place with respect to consumption elasticities in the context of particular energy resources. For instance, in a study by Belaid *et al.* (2018), the association between residential gas consumption and gas-use efficiency induced gas price cuts were analyzed using relevant French annual time series data from 1983 to 2015. The underlying motivation behind this research was derived from the objective of conservation of French gas reserves whereby the econometric tools were hired to investigate the direct RE of residential gas demand in the nation. The study used Autoregressive Distributed Lag (ARDL) bounds testing approach to identify long-run cointegrating equations between the variables considered in the regression model which also provided the long run RE of gas demand France. In addition, ECM approach was also tapped to identify the RE in the short run as well. The econometric model incorporated in this paper involved a double-log linear model in which residential gas demand was expressed as a function of gas price indicators and other control variables. The corresponding results obtained in this paper provided evidence of 53% and 60% direct RE of residential gas demand, respectively, taking place in France and nullified the existence of any backfire RE.

A possible limitation of the aforementioned studies would be their involvement in a somewhat aggregated response of energy consumption following an improvement in the efficiency in energy-use. However, this paper takes a more disaggregated approach to the energy consumption-efficiency nexus by spitting energy consumption with respect to the renewability concept and source. Moreover, this paper also adds an additional dimension to this relationship by addressing the change in energy consumption from the greenhouse gaseous emission side, assuming a positive association between energy consumption and greenhouse gaseous emissions.

4. Empirical Model and Specification of Data

The regression models used in this paper consider a system of six individual models in which energy consumption indicators are exclusively expressed as functions of energy-use efficiency and other control variables that can influence the changes in the associated energy consumption. The novelty of this paper is portrayed in the manner that the energy consumption variable has been divided into two broad categories: secondary and primary energy. The system of equations engulfing the regression models is as follows:

$$LnREC_{it} = \beta_0 + \beta_1 LnEI_{it} + \beta_2 LnGNIPC_{it} + \beta_3 LnGS_{it} + \beta_4 LnPOP_{it} + \beta_5 LnNODA_{it} + \beta_6 LnREMIT_{it} + \beta_7 LnFDI_{it} + \varepsilon_{it} \text{ ---------------------------------- } (iii)$$

$$LnNREC_{it} = \beta_8 + \beta_9 LnEI_{it} + \beta_{10} LnGNIPC_{it} + \beta_{11} LnGS_{it} + \beta_{12} LnPOP_{it} + \beta_{13} LnNODA_{it} + \beta_{14} LnREMIT_{it} + \beta_{15} LnFDI_{it} + \varepsilon_{it} \text{ ---------------------------------- } (iv)$$

$$LnEC_{it} = \beta_{16} + \beta_{17} LnEI_{it} + \beta_{18} LnGNIPC_{it} + \beta_{19} LnGS_{it} + \beta_{20} LnPOP_{it} + \beta_{21} LnNODA_{it} + \beta_{22} LnREMIT_{it} + \beta_{23} LnFDI_{it} + \varepsilon_{it} \text{ ---------------------------------- } (v)$$

$$LnNGC_{it} = \beta_{24} + \beta_{25} LnEI_{it} + \beta_{26} LnGNIPC_{it} + \beta_{27} LnGS_{it} + \beta_{28} LnPOP_{it} + \beta_{29} LnNODA_{it} + \beta_{30} LnREMIT_{it} + \beta_{31} LnFDI_{it} + \varepsilon_{it} \text{ ---------------------------------- } (vi)$$

$$LnCC_{it} = \beta_{32} + \beta_{33} LnEI_{it} + \beta_{34} LnGNIPC_{it} + \beta_{35} LnGS_{it} + \beta_{36} LnPOP_{it} + \beta_{37} Ln NODA_{it} + \beta_{38} LnREMIT_{it} + \beta_{39} LnFDI_{it} \text{ ---------------------------------- } (vii)$$

$$LnOC_{it} = \beta_{40} + \beta_{41} LnEI_{it} + \beta_{42} LnGNIPC_{it} + \beta_{43} LnGS_{it} + \beta_{44} LnPOP_{it} + \beta_{45} LnNODA_{it} + \beta_{46} LnREMIT_{it} + \beta_{47} LnFDI_{it} + \varepsilon_{it} \text{ ---------------------------------- } (viii)$$

where the subscripts i and t denote the cross-section (country) and the corresponding time (year), respectively, while ε refers to the error terms. The energy consumption indicators used in this model include REC, NREC, EC, NGC, CC and OC respectively referring to renewable energy consumption, non-renewable energy consumption, electricity consumption, natural gas consumption, coal consumption and oil consumption. The justification for disaggregating the energy consumption variables is based on the motive of identifying the possible disparities in their consumer demand behavior. The energy efficiency variable in all the six models was proxied by the energy intensity indicator EI. The control variables include GNIPC, GS, POP, NODA, REMIT and FDI referring to gross national income per capita, government spending, population growth, net official development assistance, remittance inflow and foreign direct investment inflow respectively. The GNIPC is included in the model to account for the economic-growth effects on energy consumption which can also provide an explanation for the change in energy consumption following an income effect. The population growth rate is included with an a priori expectation of a positive relationship with energy consumption.

Similarly, the justification behind augmenting the models by the government spending variable can be drawn from the fact that the government's expenditure on power projects can boost energy generation in the economy which can simultaneously raise energy consumption as well. Finally, the three modes of foreign exchange inflows in the form of NODA, FDI and REMIT are also included anticipating a possible income-effect driven energy consumption change following these inflows.

All the variables in the model are expressed in their natural logarithms and the relevant data is incorporated from the year 1990 to 2016. Table 9 in the appendix provides formal definitions, units of measurement and corresponding data sources of all the variables included in the model.

5. Methodology

5.1. Panel Unit Root Tests

At first, the entire data set incorporated in the paper is tested for the presence of unit roots using a couple of panel test of stationarity.

5.1.1. The Levin, Lin and Chu (LLC) Test

The LLC test (2002) is a first generation panel unit root test that hinges on the assumption that unit root is a homogeneous process. The term 'homogeneous' denotes that the test is estimated assuming a common Autoregressive (AR) structure for all the cross-sectional units in the form of countries considered in the panel. Let us consider the Augmented Dickey-Fuller (ADF) regression model below to get a clear understanding of the LLC test:

$$\Delta y_{it} = \alpha_i y_{i,t-1} + \sum_{L=1}^{\rho_i} \theta_{iL} \Delta y_{i,t-L} + \delta_{mi} d_{mt} + \epsilon_{it} \quad \text{(ix)}$$

where $\Delta y_{it} = y_{i,t-1}$, $\alpha i = -(1-\rho_i)$, d_{mt} is the vector of deterministic variables, $\delta_{mi}$is the corresponding vector of coefficients for model m and ε_{it} is a white noise error term for i = 1, …, N cross-sections and t = 1, …, T time periods. The homogeneous unit root assumption implies that $\alpha_i = \alpha$ for all i. The LLC test null hypothesis is that each individual series of the panel cross-sections contain a unit root (H_0: $\alpha = 0$ for all i). The null is tested against the alternative hypothesis that the individual series does not contain a unit root (H_1: $\alpha \neq 0$ for all i). The probability value of the estimated t-statistic for each of the series provides the result of stationarity with the rule of thumb being if the probability value, with respect to a particular series across all cross-sections, is below 10% level of significance, then the null hypothesis can be rejected implying the series to be stationary. Due to the limitations of the LLC test in the form of being heavily dependent on the assumption of homogeneous unit root across all the cross-sections and being more restrictive in the sense that is assumes all cross-sections to have or not have a unit root which needs ρ to be homogeneous across all i, the other panel unit root tests are conducted as well.

5.1.2. The Im, Pesaran and Shin (IPS) Test

Unlike the LLC test for panel unit root which assumes a homogeneous unit root process, the IPS test (2003) allows for a heterogeneous value of α_i. The IPS suggests a unit root testing method based on averaging individual unit root test statistics. The basic equation for IPS is as follows:

$$\Delta y_{i,t} = \propto_i + \ \rho_i y_{i,t} + \sum_{j=1}^{\beta} \varphi_{ij}\, \Delta y_{i,t-j} + \epsilon_{i,t} \quad \text{……………………………… (x)}$$

where $y_{i,t}$ represents each of the variables under consideration in the model, α_i is the individual fixed effect, and β is selected to make the residuals uncorrelated over time. The null hypothesis is that each individual series of the panel cross-sections contain a unit root (H_0: α = 0 for all *i*) which is tested against the alternative hypothesis is that for each individual series at least one of the cross-section does not contain a unit root (H_1: α_1 < 0, for *i* = 1, 2, …, N_1; H_1: α_1 = 0, for *i* = N_1 + 1, N_1 +2, …, N). The probability value of the estimated *w*-statistic for each of the series provides the result of stationarity with the rule of thumb being if the probability value, with respect to a particular series across all cross-sections, is below 10% level of significance, then the null hypothesis can be rejected implying the series to be stationary.

5.1.3. Maddala and Wu Test

The Maddala and Wu (1999) panel unit root test, a first generation non-stationarity test, is actually a Fisher-type test combining the probability values from unit root tests for each cross-section in the panel. In similarity with the IPS test, the heterogeneity of the unit root process is considered in this test. This can be shown using the following equation:

$$P = -2 \sum_{i=1}^{N} ln\, p_i \quad \text{…………………………………….. (xi)}$$

where p_i is the probability value of any individual unit root test for any cross-section and *P* is distributed as Chi-square with 2N degrees of freedom where N is the total number of cross-sections considered in the panel. The probability values are obtained from the estimated Augmented Dickey-Fuller (ADF)-Fisher and the Phillips-Perron (PP)-Fisher Chi-square test statistics. The null hypothesis is that each individual series of the panel cross-sections contain a unit root (H_0: p_i = 1 for all *i*) which is tested against the alternative hypothesis is that for each individual series at least one of the cross-section does not contain a unit root (H_1: p_i < 1). The probability values of the estimated ADF-Fisher Chi-square and PP-Fisher Chi-square statistics for each of the series provide the result of stationarity with the rule of thumb being if the probability value, with respect to a particular series across all cross-sections, is below 10% level of significance, then the null hypothesis can be rejected implying the series to be stationary. Maddala and Wu (1999) find that for high values of T and N the Maddala and Wu-Fisher-test is chosen over the IPS test as size distortions are smaller at comparable power. For smaller values of T and N, however, IPS and LLC seem to be preferable over Maddala and Wu-Fisher-tests. The unit toot tests are followed by the Kao (1999) panel cointegration test.

5.2. Kao Cointegration Test

The Kao (1999) test for cointegration between variables in panel data framework tests a regression model under the null hypothesis of no cointegration. There are two types of Kao (1999) cointegration test, the Dickey-Fuller type and the Augmented Dickey-Fuller type tests. In the context of the Dickey-Fuller type test the model can be specified as follows:

$$Y_{it} = \beta_{i+}\rho X_{it} + \cdots \epsilon_{it} \quad \text{……………………………….(xii)}$$

where

$$Y_{it} = Y_{it-1} + \in_{it} \text{……………………………….(xiii)}$$

$$X_{it} = X_{it-1} + \in_{it} \text{……………………………….(xiv)}$$

The parameters β_{it} are the fixed effect varying across the observations in the cross-sections, ρ is the slope coefficient parameter, Y_{it} and X_{it} are the random walks for all cross-sections. A pre-requisite to this test is that the residual ε_{it} should be stationary at their first difference I(1). From here, the Dickey-Fuller test can be applied to the estimated residual using the equation:

$$\hat{e}_{it} = \theta \hat{e}_{it-1} + \vartheta_{it} \quad \text{……………………………….(xv)}$$

From here, the null hypothesis of no cointegration against the alternative hypothesis of cointegration can be given as follows:

H_0: θ = 1 [no cointegration]
H_1: θ < 1 [cointegration]

The panel unit root and cointegration tests preceded the regression analyses.

5.3. Three-Stage Least Squares (3SLS) Estimation

Endogeneity problem in data series is a key issue whereby the OLS estimation assumptions are violated making this regression methodology inappropriate. Thus, the Three-Stage Least Squares (3SLS) simultaneous equations model estimation technique (Zellner and Theil, 1962) provides the solution to the endogeneity problem faced in the OLS estimation. For instance, heteroscedasticity in data violates one of the assumptions of OLS estimation method, however, in the 3SLS method although the structural error terms may be correlated across the simultaneous equations, it is assumed that within each equation the error terms are both serially uncorrelated and homoscedastic.

The term 3SLS reflects a certain mechanism of estimation that combines a set of simultaneous equations model, sometimes known as Seemingly Unrelated Regression (SUR), with Two-Stage Least Squares (2SLS) estimation. It is basically a type of Instrumental Variables (IV) estimation that allows correlations of the unobserved error terms across several equations and enhances the efficiency of equation-by-equation regression by considering such correlations across the simultaneous equations. Unlike the 2SLS approach for an array of simultaneous equations, which separately estimates the slope coefficients of each equation, the 3SLS methodology estimates all coefficients instantaneously. The estimation technique hinges on the assumption that each equation is at least just-known since unknown equations are not considered in the 3SLS estimation. As the name suggests, the 3SLS estimation procedure involves estimation of a model of simultaneous equations in three stages. In the first stage, 2SLS method is incorporated to estimate the residuals of the simultaneous equations. The second stage involves the addition of the optimal instrumental variable using the estimated residuals to develop the disturbance variance-covariance matrix. Finally, the third stage involves a joint estimation of the set of simultaneous equations using the optimal instrument. For robustness check, this paper also considers the fixed and random effects panel data estimation tools.

5.4. Fixed Effects Panel Estimation Techniques

Given the heterogeneity of the data set in terms of countries belonging to different income groups and levels of development, the fixed effects panel estimation techniques are considered to be appropriate, over the pooled Ordinary Least Squares (OLS) methods, in this paper. In contrast to the pooled OLS estimation that provides a common constant across all cross sections, the fixed effects estimation technique allows for cross section-specific constants. The fixed effects estimator can also be classified as the Least- Squares Dummy Variables (LSDV) since it incorporates a dummy variable for each cross-section to include different constants (Asteriou and Hall, 2007). A simple fixed effects model can be given by:

$$Y_{it} = A_i + \partial_1 X_{1it} + \partial_2 X_{2it} + \cdots + \partial_3 X_{kit} + U_{it} \text{ .... (xvi)}$$

where Y and X are dependent and independent variables, respectively. The subscripts ‘i' denotes a particular cross section or country and can take any value from 1 to N (i.e. I = 1, 2, …, N). The other subscript ‘t’ is used to denote the time period (t = 1, 2, …, T). The constant term is given by A which varies according to the value of i. This model can be rewritten in matrix form as well:

$$Y = DA + X\partial' + U \text{ .... (xvii)}$$

where D is the dummy variable that allows different cross section-specific estimates for each of the constant term.

5.5. Random Effects Panel Estimation Techniques

As an alternative to considering the individual-specific intercept as a fixed effect of that unit, the individual effect may be considered and viewed as a random draw from a distribution as given below:

$$Y_{it} = \ \partial\, X_{it} + [U_i + \epsilon_t] \text{ .... (xviii)}$$

where the expression within the parenthesis is a composite disturbance term, with the U_i being a solitary draw per unit. This abovementioned model could be consistently estimated by OLS estimation tools, but that would be inefficient in not taking the nature of the disturbance process into consideration. A key assumption of the random effects model is that U_i is independent of the explanatory variables X_i. It is mandatory to hold these assumptions since, if not sustained, the random effects estimator will generate inconsistent estimates as the explanatory variables would be correlated with the composite disturbance term.

When the sample size is large, a random effects model estimates K parameters, whereas a fixed effects model estimates (K-1) + N parameters, with the sizable loss of (N-1), where K and N denote the number of parameters and regressors respectively. In contrast to fixed effects, the random effects estimator can identify the parameters on time-invariant regressors at the individual level. Hence, once the appropriateness of the random effects model is ensured, it is more efficient and allows a wider range of statistical inference.

5.7. Granger Causality Test

When we take y and x as the variables of interest, then the Granger causality test (Granger, 1969) determines whether past values of y add to the explanation of current values of x as provided by information in past values of x itself. If previous changes in y do not help explain current changes in x, then y does not Granger cause x. In a similar way, we can examine if x Ganger causes y just be interchanging them and carrying out this process again. There could be four probable outcomes: (a) x Granger causes y (b) y Granger causes (c) Both x and y granger causes the other and (d) neither of the variables Granger causes the other.

In this paper, the causality tests among all the concerned variables are conducted. For this the following set of equations are estimated:

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \cdots\cdots + \alpha_l x_{t-l} + \beta_1 y_{t-1} + \cdots\cdots + \beta_l y_{t-l} + u_t \quad \text{(xix)}$$

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \cdots\cdots + \alpha_l y_{t-l} + \beta_1 x_{t-1} + \cdots\cdots + \beta_l x_{t-l} + v_t \quad \text{(xx)}$$

The authors consider the above set of equations for all possible pairs of (x, y) series in the group. The reported F-statistics are the Wald statistics for the joint hypothesis. After confirming the long run causalities between the variables considered in the model, the VECM approach provides the short run causal relationships.

EViews 7.1 and STATA 15 software are used in this paper to execute the econometric tests.

6. Results

The corresponding results following the unit root tests are reported in table 1. It is pretty evident from the estimations that all the variables considered in this paper are stationary at their first differences I(1) despite being non-stationary at levels I(0). Thus, the possibility of the regression analyses that are to be done, later on, being spurious is nullified.

Table 1: Panel Unit Root Test Results at First Difference, I (1)

Variable	Levin, Lin and Chu	Im, Pesaran and Shin	Maddala and Wu		Decision on Stationarity
	t-Stat.	W-Stat.	ADF--Fisher Chi-Square Stat.	PP-Fisher Chi-Square Stat.	
D(LnREC)	-3.74*	-3.20*	16.90*	16.17*	Stationary
D(LnNREC)	-3.24*	-3.16*	17.58*	20.06*	Stationary
D(LnEC)	-3.97*	-3.39*	17.88*	19.98*	Stationary
D(LnNGC)	1.83	-2.51*	18.90*	35.25*	Stationary
D(LnCC)	-5.48*	-3.47*	62.39*	57.32*	Stationary
D(LnOC)	-4.27*	-3.58*	17.91*	17.55*	Stationary
D(LnEI)	-6.25*	-5.24*	26.67*	34.63*	Stationary
D(LnGNIPC)	-3.33*	-2.81*	14.68*	15.178	Stationary
D(LnGS)	-1.41***	-2.59*	13.53*	11.60*	Stationary
D(LnNODA)	-2.40*	-3.80*	21.25*	185.77*	Stationary
D(LnFDI)	-1.33***	-3.77*	19.90*	37.11*	Stationary
D(LnREMIT)	-3.14*	-2.36*	17.42*	22.60*	Stationary
D(LnPOP)	-2.17**	-1.49	10.26**	46.14*	Stationary

*Notes: Considering trend and intercepts. *, ** and *** denote statistical significance at 1%, 5% and 10% levels; Automatic maximum lag and lag length of 6 was selected based on Schwarz Information Criteria (SIC).*

The long-run associations between the variables are tested tapping the Kao (1999) residual-based cointegration test of panel data and the estimated results are provided in table 2. The results implicate that in case of all the six regression models put forward in this paper, the null hypothesis of no cointegration can be rejected at 1% level of significance following the statistical significance of the estimated ADF statistics. Hence, in light of these findings, it can be asserted that the variables employed in the regression models are associated in the long run which fulfills the pre-requisite of performing the causality tests.

Table 2: Kao Residual Cointegration Test Results

Model	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
ADF Statistic	-4.75*	-4.71*	-3.98*	-4.75*	-2.03*	-4.03*

*Notes: Null Hypothesis: No Cointegration; The optimal lag length selection based on SIC. * , ** and ** denote statistical significance at 1%, 5% and 10%, respectively.*

The regressions followed the panel unit root and cointegration tests. This paper considered both the 3SLS and the fixed and random effects approach to panel data regression for robustness check. The estimated slope coefficients obtained from the 3SLS regression corroborate to the ones generated from the random effects estimation. The estimated coefficients in the context of all the six regression models considered in this paper are presented chronologically in tables 3, 4, 5, 6, 7 and 8.

In table 3, the estimated coefficient attached to LnEI is negative and statistically significant as well. This implies that an improvement in energy-use efficiency leads to a fall in consumption of renewable energy validating the super conservation RE hypothesis. This implies that in the context of renewable energy, an efficiency enhancement energy conservation strategy is effective whereby the Jevons paradox does not hold. This is pretty much contradicting to the concluding remarks made by Gunderson and Yun (2017) in which the authors advocated against energy-efficiency enhancement policies to promote green growth in South Korea. In addition, the results also suggest negative and statistically significant associations of LnREC with LnGS, LnREMIT and LnFDI while with LnPOP a positive and statistically significant association is also found.

Table 3: The regression results in context of model (iii)

Dependent Variable: LnREC						
Regression	**3SLS**		**Fixed Effects**		**Random Effects**	
Regressor	**Coeff.**	**Standard Error**	**Coeff.**	**Robust St. Error**	**Coeff.**	**Robust St. Error**
LnEI	-0.701*	0.069	-0.798*	0.007	-0.701*	0.019
LnGNIPC	-0.298*	0.039	-0.094*	0.001	-0.298*	0.059
LnGS	-0.140*	0.035	-0.210***	0.025	-0.140**	0.058
LnPOP	0.533*	0.059	-0.190**	0.005	0.533*	0.062
LnNODA	0.016	0.014	-0.011	0.013	0.016	0.031
LnREMIT	-0.126*	0.017	-0.094	0.022	-0.126*	0.021
LnFDI	-0.013*	0.004	0.004*	0.000	-0.013*	0.000
Intercept	2.496*	0.637	16.759*	0.459	2.496*	0.079

*Note: *, **, and *** denote statistical significances at 1%, 5% and 10% respectively.*

The regression results in the context of model (iv) are provided in table 4. From the table it is evident that the Jevons paradox does hold in the context of consumption of non-renewable energy resources as the estimated coefficient attaché to LnEi is positive and statistically significant. Moreover, the value of the coefficient is greater than one which implies the backfire RE taking place. Thus, energy efficiency increments are not in line with the reduction in non-renewable energy-use in the economy. This is an alarming finding from the perspectives of Bangladesh and India since such a relationship would impose barriers towards these countries in making a clean-energy transition to facilitate their green growth strategies. In contrast to that in the case of renewable energy, this finding corroborates to the findings by Gunderson and Yun (2017). Furthermore, the regression results also denote that apart from population growth and inflow of FDI, all the other regressors exhibit a positive association with consumption of non-renewable energy.

Table 4: The regression results in the context of model (iv)

Dependent Variable: LnNREC						
Regression	**3SLS**		**Fixed Effects**		**Random Effects**	
Regressor	**Coeff.**	**Standard Error**	**Coeff.**	**Robust St. Error**	**Coeff.**	**Robust St. Error**
LnEI	1.194*	0.110	1.282*	0.001	1.194*	0.012
LnGNIPC	0.464*	0.062	0.280**	0.006	0.464*	0.055
LnGS	0.349*	0.056	0.412	0.069	0.349*	0.098
LnPOP	-0.552*	0.094	0.102	0.036	-0.552*	0.108
LnNODA	0.001	0.022	0.025	0.013	0.000	0.029
LnREMIT	0.214*	0.027	0.186	0.044	0.214*	0.042
LnFDI	-0.006*	0.014	-0.017**	0.000	-0.001*	0.001
Intercept	-5.394*	1.015	-18.265*	0.169	-5.394*	0.558

*Note: *, **, and *** denote statistical significances at 1%, 5% and 10% respectively.*

The regression estimates in the context of model (v), as reported in table 5, provides a clear picture of the positive relationship between LnEC and LnEI as the estimated coefficient is found to imply the backfire RE taking place, validating the existence of the Jevons paradox in the context of consumption of electricity across Bangladesh and India.

Table 5: The regression results in the context of model (v)

Dependent Variable: LnEC						
Regression	**3SLS**		**Fixed Effects**		**Random Effects**	
Regressor	**Coeff.**	**Standard Error**	**Coeff.**	**Robust St. Error**	**Coeff.**	**Robust St. Error**
LnEI	1.795*	0.222	1.964***	0.177	1.795*	0.143
LnGNIPC	0.548*	0.125	0.192	0.103	0.548*	0.028
LnGS	0.017	0.114	0.139	0.174	0.017	0.223
LnPOP	-0.443**	0.191	0.825***	0.085	-0.443	0.297
LnNODA	-0.012	0.045	0.035	0.067	-0.012	0.039
LnREMIT	0.431*	0.056	0.376	0.121	0.431*	0.115
LnFDI	0.046*	0.014	0.016*	0.000	0.046*	0.003
Intercept	-3.033	2.059	-27.995**	0.780	-3.033	3.499

*Note: *, **, and *** denote statistical significances at 1%, 5% and 10% respectively.*

A possible reason behind the energy-use efficiency policies being ineffective in curbing the electricity demand could be explained by the fact that the demand for electricity could be driven by the economic growth policies pursued by the respective governments in these countries. This is further supported by the estimated coefficient attached to LnGNIPC which is found to be positive and statistically significant as well. Thus, this backfire RE with relevance to the demand for electricity is in very much in line with the remarks put forward by York and Mcgee (2016).

The corresponding results from regression analyses on model (vi) are given in table 6. According to the estimations, the coefficient attached to LnNGC bears a positive sign and is statistically significant as well. However, a point to note here is that the magnitude of the estimated coefficient is less than one which implies a partial RE taking place whereby efficiency enhancement with respect to energy-use is partially effective and curbing consumption of natural gas. This is a crucial finding from the perspective of Bangladesh, in particular, that has been facing acute shortages in its indigenous natural gas supply following the nation's inability to discover new natural gas fields lately (Amin and Murshed 2017b). Thus, in light of this finding, the Jevons paradox does not fully hold in this case since the rise in NGC is less than the expected reduction in NGC following an energy-use efficiency increment. Furthermore, the other negative and statistically significant estimated coefficients also highlight the importance of public expenditure and inflow of NODA in mitigating natural gas use in Bangladesh and India, thus facilitating greater consumption the alternative renewable and relatively more environment-friendly energy resources.

Table 6: The regression results in the context of model (vi)

Dependent Variable: LnNGC						
Regression	**3SLS**		**Fixed Effects**		**Random Effects**	
Regressor	**Coeff.**	**Standard Error**	**Coeff.**	**Robust St. Error**	**Coeff.**	**Robust St. Error**
LnEI	0.153*	0.303	0.553**	0.023	0.153**	0.069
LnGNIPC	0.554*	0.171	-0.291	0.132	0.554*	0.380
LnGS	-0.052	0.156	0.237	0.054	-0.052	0.194
LnPOP	0.022	0.260	3.025*	0.008	0.022	0.234
LnNODA	-0.087	0.613	0.026	0.018	-0.087	0.058
LnREMIT	0.332*	0.076	0.201***	0.087	0.331*	0.030
LnFDI	0.039**	0.020	-0.032	0.131	0.039*	0.012
Intercept	-6.860**	2.804	-66.017*	0.498	-6.859*	1.001

*Note: *, **, and *** denote statistical significances at 1%, 5% and 10% respectively.*

In the context of consumption of the environment-unfriendly energy resource coal, the estimated coefficient attached to LnEI following the regression analyses, on model (vii) as reported in table 7, reveal a strong backfire RE taking place. The large magnitude of this coefficient implies that energy-efficiency enhancement policies are totally ineffective in reducing the use of coal as the corresponding results found implies that the rise in coal consumption is actually 4.7 times more than the anticipated reduction in consumption of coal following an improvement in energy-use efficiency. Thus, the Jevons paradox is justified in this case questioning the advocates those are in favor of implementing energy use-efficiency enhancement policies. The other regression estimates denote that apart from energy-use intensity and inflow of remittances, no other regressors are statistically significant in explaining the movements in consumption of coal.

Table 7: The regression results in the context of model (vii)

Dependent Variable: LnCC						
Regression	**3SLS**		**Fixed Effects**		**Random Effects**	
Regressor	**Coeff.**	**Standard Error**	**Coeff.**	**Robust St. Error**	**Coeff.**	**Robust St. Error**
LnEI	4.718*	1.207	4.972***	0.439	4.718*	0.578
LnGNIPC	0.972	0.680	0.434	0.203	0.971*	0.274
LnGS	0.006	0.620	0.190	0.234	0.006	0.224
LnPOP	1.048	1.037	2.961	1.533	1.048***	0.562
LnNODA	-0.314	0.244	-0.242	0.394	-0.314	0.411
LnREMIT	0.885*	0.302	0.802	0.314	0.884*	0.277
LnFDI	-0.068	0.078	-0.113	0.034	-0.068	0.053
Intercept	-44.698*	11.175	-82.375	27.276	-44.698*	10.230

*Note: *, **, and *** denote statistical significances at 1%, 5% and 10% respectively.*

Finally, the regression results in the context of model (viii) are reported in table 8. A close look at the table suggests that the Jevons paradox with respect to consumption of oil does not hold as perceived from a negative and insignificant estimated coefficient attached to LnEI. In contrast, all the other explanatory variables are found to exhibit positive and statistically significant associations with consumption of oil across Bangladesh and India. This finding justifies the dependence of these nations’ on oil as the predominant source of energy.

Table 8: The regression results in the context of model (viii)

Dependent Variable: LnOC						
Regression	**3SLS**		**Fixed Effects**		**Random Effects**	
Regressor	**Coeff.**	**Standard Error**	**Coeff.**	**Robust St. Error**	**Coeff.**	**Robust St. Error**
LnEI	-0.206	0.260	0.123	0.566	-0.206	0.527
LnGNIPC	0.607*	0.146	-0.088	0.024	0.607	0.392
LnGS	0.245***	0.133	0.484	0.421	0.245	0.249
LnPOP	1.387*	0.223	3.857**	0.070	1.387*	0.450
LnNODA	-0.151*	0.053	-0.058***	0.005	-0.151***	0.089
LnREMIT	-0.254*	0.065	-0.361	0.187	-0.254	0.164
LnFDI	0.035**	0.017	-0.023	0.009	0.035*	0.004
Intercept	-25.617*	2.404	-74.275**	5.004	-25.617*	5.164

*Note: *, **, and *** denote statistical significances at 1%, 5% and 10% respectively.*

The regression analyses are followed by the Granger causality analyses to probe into the long run causal associations between the variables which could provide robustness to the regression findings. The corresponding results from the causality tests are reported in table 10 in the appendix. The results, in light of the estimates, imply that there are no long-run causal relationships between the energy consumption variables and energy-efficiency variable used in this paper. Rather, the estimates suggest long-run unidirectional causalities running from LnPOP to LnREC, from LnPOP to LnNREC, from LnREIMIT to LnNREC, from LnREMIT to LnNGC, and from LnPOP to LnCC implying the effectiveness of these regressors in influencing changes in the respective energy consumption variable. Moreover, bidirectional long-run causal relationships are also estimated to exist respectively between LnFDI and LnNREC, LnNODA and LnEC, LnFDI and LnEC, LnFDI and LnNGC, and LnPOP and LnOC.

7. Conclusions

Keeping the goal of ensuring a sustainable supply of energy across the globe into consideration, energy-use efficiency is believed to be a key instrument for reducing energy demand and conserving energy. However, following an improvement in the efficiency in which energy is used, at times a RE takes place whereby energy consumption rather increases at a level beyond the anticipated level of energy savings, giving rise to the Jevons paradox. Thus, it is of paramount emphasis to probe into the dynamic relationship between energy-use efficiency and energy consumption in order to provide justifications in favor of adopting energy efficiency-enhancing policies within an economy. This is so because macroeconomic pressures can at times go on to attributing to a greater demand for energy resources marginalizing the efficacy of energy conservation policies advocating in favor of improving energy-use efficiencies. In addition, the Jevons paradox analysis is of further significance from the perspective of climate change which is presumed to be inextricably linked to energy efficiency and energy conservation (Brookes 1990 and Saunders 1992).

Against this backdrop, the aim of this paper was to investigate the existence of the Jevons paradox with respect to energy consumption across Bangladesh and India. The novelty of this paper lied in its approach of disaggregating energy consumption with respect to both primary and secondary energy consumption. The estimated results provided evidence suggesting the possible existence of the Jevons paradox in the context of non-renewable energy, electricity and coal consumption. These findings generate key policy implications for emerging economies in South Asia that are in the pipeline of executing a transition towards the adoption of renewable energy options to facilitate green growth. The statistical estimates put forward in this paper revealed backfire RE taking place in the cases of consumption of non-renewable energy as a whole and coal which implied that energy-use efficiency enhancement is contradictory to the attainment of green growth which calls for effective measures to be taken in order to mitigate the RE. Furthermore, the statistical evidence of Jevons paradox holding in the case of electricity consumption is also an area of concern following the fact that Bangladesh and India have had the illustrious history of not being able to match their respective electricity demands whereby disrupted supply of electricity had constrained the development policies in these countries. The overall findings of this paper also raise concerns regarding the possible climate change that can be resulted following the Jevons paradox holding to be true particularly with respect to rising levels of non-renewable energy consumption in countries like Bangladesh and India that are extremely susceptible to the atrocities associated to climate change.

Data constraint was the major limitation constraining the robustness check of the estimated findings that have been outlined in this paper. Following the inadequacy of relevant data, the choice of the energy efficiency indicator had somewhat been constrained and therefore had to be proxied by the intensity of use of primary energy variable. Moreover, due to the same limitation, country-specific analyses o the Jevons paradox could not be done using time-series estimation techniques which would have provided robust results keeping the country-specific disparities between India and Bangladesh into consideration. As part of the future scope of research, this paper can be a starting point to analyze the Jevons paradox, related to energy consumption in a disaggregated manner, incorporating relevant data in the context of larger panels.

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Appendix

Table 9: Description and source of the dataset used in this paper

Variable	Definition and Unit of Measurement	Source
REC	Renewable energy consumption is the share of renewable energy in total final energy consumption and is measured as a percentage of total energy consumption.	World Development Indicators (World Bank 2017)
NREC	Non-renewable energy consumption is the share of non-renewable energy in total final energy consumption and is measured as a percentage of total energy consumption.	
EC	Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants. It is measured in per capita kilo Watts per hour.	
NGC	Natural gas consumption is measured yearly in terms of million tonnes of oil consumption equivalent.	BP Statistical Review of World Energy, 2017
CC	Coal consumption is measured yearly in terms of million tonnes of oil consumption equivalent.	
OC	Oil consumption is measured yearly in terms of million tonnes.	
EI	Energy intensity level of primary energy is the ratio between energy supply and gross domestic product measured at purchasing power parity. It is an indication of how much energy is used to produce one unit of economic output. A lower ratio indicates that less energy is used to produce one unit of output. It is measured in terms of Mega Joules per $2011 PPP GDP.	World Development Indicators (World Bank 2017)
GNIPC	Gross national income per capita is the sum of value added by all resident producers plus any product taxes not included in the valuation of output plus net receipts of primary income from abroad divided by the population figure. Data are in current U. S. dollars.	
GS	Government spending includes all government current expenditures for purchases of goods and services (including compensation of employees). It also includes most expenditures on national defense and security but excludes government military expenditures that are part of government capital formation and is measured in current U.S. dollars.	
POP	The total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. The values shown are midyear estimates. Measured in terms of million people.	
NODA	Net official development assistance (ODA) consists of disbursements of loans made on concessional terms (net of repayments of principal) and grants. Net official aid refers to aid flows (net of repayments) from official donors. The data is measured in current U.S. dollars.	
REMIT	Personal remittances comprise personal transfers and compensation of employees and measured in terms of current U.S. dollars.	
FDI	Foreign direct investment refers to direct investment equity flows in the reporting economy and is measured in current U.S. dollars.	

Table 10: The Granger causality test results (Lag=2)

Null Hypothesis	F-Stat.	Decision
Model (iii)		
LnEI does not Granger cause LnREC	1.29	No Causality
LnREC does not Granger cause LnEI	0.36	
LnGNIPC does not Granger cause LnREC	0.15	No Causality
LnREC does not Granger cause LnGNIPC	0.57	
LnGS does not Granger cause LnREC	0.07	Unidirectional Causality from LnREC to LnGS
LnREC does not Granger cause LnGS	6.63*	
LnNODA does not Granger cause LnREC	0.96	Unidirectional Causality from LnREC to LnNODA
LnREC does not Granger cause LnNODA	7.32*	
LnFDI does not Granger cause LnREC	0.34	No Causality
LnREC does not Granger cause LnFDI	1.26	
LnREMIT does not Granger cause LnREC	1.26	No Causality
LnREC does not Granger cause LnREMIT	1.20	
LnPOP does not Granger cause LnREC	5.42*	Unidirectional Causality from LnPOP to LnREC
LnREC does not Granger cause LnPOP	0.29	
Model (iv)		
LnEI does not Granger cause LnNREC	2.01	No Causality
LnNREC does not Granger cause LnEI	1.31	
LnGNIPC does not Granger cause LnNREC	0.28	No Causality
LnNREC does not Granger cause LnGNIPC	0.75	
LnGS does not Granger cause LnNREC	0.14	Unidirectional Causality from LnNREC to LnGS
LnNREC does not Granger cause LnGS	5.59*	
LnNODA does not Granger cause LnNREC	1.24	Unidirectional Causality from LnNREC to LnNODA
LnNREC does not Granger cause LnNODA	3.09***	
LnFDI does not Granger cause LnNREC	3.42**	Bidirectional Causality
LnNREC does not Granger cause LnFDI	6.08*	
LnREMIT does not Granger cause LnNREC	5.24*	Unidirectional Causality from LnREMIT to LnNREC
LnNREC does not Granger cause LnREMIT	1.51	
LnPOP does not Granger cause LnNREC	5.73*	Unidirectional Causality from LnPOP to LnNREC
LnNREC does not Granger cause LnPOP	0.48	
Model (v)		
LnEI does not Granger cause LnEC	0.15	No Causality
LnEC does not Granger cause LnEI	2.15	
LnGNIPC does not Granger cause LnEC	0.07	No Causality
LnEC does not Granger cause LnGNIPC	1.37	
LnGS does not Granger cause LnEC	0.03	Unidirectional Causality from LnEC to LnGNIPC
LnEC does not Granger cause LnGS	2.71***	
LnNODA does not Granger cause LnEC	3.02***	Bidirectional Causality
LnEC does not Granger cause LnNODA	3.10***	
LnFDI does not Granger cause LnEC	4.66**	Bidirectional Causality
LnEC does not Granger cause LnFDI	10.71*	
LnREMIT does not Granger cause LnEC	2.02	Unidirectional Causality from LnEC to LnREMIT
LnEC does not Granger cause LnREMIT	4.34**	
LnPOP does not Granger cause LnEC	1.86	No Causality
LnEC does not Granger cause LnPOP	1.82	
Model (vi)		
LnEI does not Granger cause LnNGC	1.25	No Causality
LnNGC does not Granger cause LnEI	0.23	
LnGNIPC does not Granger cause LnNGC	0.87	No Causality
LnNGC does not Granger cause LnGNIPC	0.56	
LnGS does not Granger cause LnNGC	1.29	No Causality
LnNGC does not Granger cause LnGS	0.11	
LnNODA does not Granger cause LnNGC	0.02	No Causality

LnNGC does not Granger cause LnNODA	4.05	
LnFDI does not Granger cause LnNGC	3.45**	Bidirectional Causality
LnNGC does not Granger cause LnFDI	3.41**	
LnREMIT does not Granger cause LnNGC	6.21*	Unidirectional Causality from LnREMIT to LnNGC
LnNGC does not Granger cause LnREMIT	0.59	
LnPOP does not Granger cause LnNGC	1.19	No Causality
LnNGC does not Granger cause LnPOP	0.77	
Model (vii)		
LnEI does not Granger cause LnCC	0.39	No Causality
LnCC does not Granger cause LnEI	0.28	
LnGNIPC does not Granger cause LnCC	0.08	No Causality
LnCC does not Granger cause LnGNIPC	0.39	
LnGS does not Granger cause LnCC	1.55	Unidirectional Causality from LnCC to LnGS
LnCC does not Granger cause LnGS	3.60**	
LnNODA does not Granger cause LnCC	0.49	No Causality
LnCC does not Granger cause LnNODA	0.88	
LnFDI does not Granger cause LnCC	1.06	Unidirectional Causality from LnCC to LnFDI
LnCC does not Granger cause LnFDI	2.82***	
LnREMIT does not Granger cause LnCC	0.61	No Causality
LnCC does not Granger cause LnREMIT	0.77	
LnPOP does not Granger cause LnCC	12.80*	Unidirectional Causality from LnPOP to LnCC
LnCC does not Granger cause LnPOP	0.17	
Model (viii)		
LnEI does not Granger cause LnOC	0.65	No Causality
LnOC does not Granger cause LnEI	1.40	
LnGNIPC does not Granger cause LnOC	0.31	No Causality
LnOC does not Granger cause LnGNIPC	0.74	
LnGS does not Granger cause LnOC	0.20	No Causality
LnOC does not Granger cause LnGS	1.62	
LnNODA does not Granger cause LnOC	0.31	No Causality
LnOC does not Granger cause LnNODA	0.77	
LnFDI does not Granger cause LnOC	0.61	No Causality
LnOC does not Granger cause LnFDI	1.68	
LnREMIT does not Granger cause LnOC	0.69	No Causality
LnOC does not Granger cause LnREMIT	0.48	
LnPOP does not Granger cause LnOC	2.67***	Bidirectional Causality
LnOC does not Granger cause LnPOP	7.66*	

*Notes: The long-run causality between the variables is determined by the statistical significance of the estimated F-statistics. *, ** and *** denote the statistical significance of the estimated F-statistics at 1%, 5% and 10% levels of significance. Optimal lag selection is based on Schwarz Information Criteria (SIC).*