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Questioning the Effectiveness of Trade Openness in Facilitating Renewable Energy Transition: A Panel Data Analysis

Muntasir Murshed[1]

The aim of this paper is to bridge the gap in the literature by empirically shedding light on the impacts of trade openness on facilitation of renewable energy transition in 38 selected countries across South Asia, Southeast Asia, Sub Saharan Africa, Latin America and Caribbean Islands. Annual data in, panel framework, stemming from 2000 to 2014 is incorporated in this paper and the Three-Stage Least Squares (3SLS) panel data estimation methodology is applied. In addition, Granger causality tests, and its pre-requisites are also considered to understand the long run causal associations as well. In light of the estimated results, it is found that trade openness, in general, does not contribute to renewable energy within the economy but it does enhance the energy use efficiency. Moreover, the results in this paper support the fact that inflow of FDI is conducive to the attainment of most of the energy sustainability targets enlisted under the United Nations 2030 Sustainable Development Agenda. The paper also finds evidence suggesting a paradoxical effect of remittances with regard to the overall renewable energy transition. According to the results, the inflow of remittance increases the consumption of renewable energy but it simultaneously reduces its share of the total energy consumption as well. Thus, this paper can be a cornerstone in designing crucial public policies aimed at facilitation of renewable energy use in quest of attainment of energy sustainability across the globe.

JEL Classifications: O13, P2, Q42, D12, F35

Key Words: trade openness, renewable energy consumption, renewable energy share, 3SLS, Granger causality

Field of Research: Energy Economics

1. Introduction

The paramount role of energy resources as a crucial input in all economic activities was given nominal importance in the past when labor and capital were considered to be the major factors of production. However, with time, energy gradually augmented into the conventional production functions and has eventually gone on to become the utmost key factor of production in the modern era (Amin 2015). It is also presumed that energy is at the core of attaining economic, social and environmental prosperity across the globe (United Nations, 2010). The indispensable role of energy in structuring the development

[1] Centre for Policy Dialogue, Dhaka, Bangladesh,
Email: muntasir.murshed@northsouth.edu

patterns in an economy and eventually dictating its rate of overall development have also been acknowledged in the United Nation's declared Sustainable Development Goals (SDG). More precisely, SDG 7 particularly addresses the significance of energy availability in the economy and calls for ensuring greater access to affordable, reliable, sustainable and modern energy across the globe.

The underlying notion behind enhancing energy access worldwide is based on the fact that the existing energy systems across the world are inefficient and insufficient to match the escalating world demand for energy which would presumably marginalize the global achievement of the Millennium Development Goals (MDGs). Moreover, energy consumption is eloquently important in terms of enhancing the standard of living in the poorest of economies around the globe (World Summit on Sustainable Development 2002). The magnitude of this need for improving energy access within an economy is relatively greater in context of the developing economies and the Lower Middle-Income Countries (LMICs), primarily due to the prolonged energy crises within these nations. Moreover, enhancing uninterrupted and modern energy availability in these nations are further presumed to contribute to their poverty alleviation, development of human capacities, and socioeconomic and environmental developments as well (O'Connor 2010).

It is to be noted that SDG 7 of the UN has specifically been structured with the aim of attaining the overall energy sustainability from multiple aspects and sectors within the economy. For instance, one of the targets enlisted under this particular goal is to increase the access and use of clean, affordable and reliable energy resources mainly through achieving higher electrification rates within all economies. In addition, this has to be coupled by strengthening the reliance on renewable energy use and gradually reduce the dependency on conventional non-renewable environment unfriendly sources of energy (Amin, Murshed and Jannat 2017). Thus, increasing electricity generation using renewable sources would not only mitigate the predominant energy crises within an economy but it would also curb the volumes greenhouse gaseous emissions, to a large extent. In addition, this particular SDG also urges for escalation of energy use efficiencies all throughout the globe which would also indirectly put a hold on the energy deficits faced by the developing economies in particular. However, following the dismal states of financial and energy resource constraints in the low income and LMICs, it is grim for these nations to achieve sustainability in energy supply, merely because lack of funds often hamper and delay renewable energy transitions in these countries and also act as a barrier towards improving energy use efficiencies (Bowden and Payne 2009).

Diversification in use of energy resources is said to be critical in order to upsurge the level of energy supply within an economy. Thus, the concept of energy transition, in order to primarily increasing the overall volume of Renewable Energy Consumption (REC), within the economy has emerged as an effective development tool across the world. However, the course of diversifying the use of various types of natural energy resources in the Least Developed Countries (LDCs) is often restrained courtesy insufficient amounts of energy investments in those countries. Against this backdrop, a plausible solution to this problem could be to ensure proper utilization of the international fund inflows into those countries (Mert and Bölük 2016). The relevance of foreign inflows in facilitating the energy

sustainability sub-agenda of the UN has also been addressed in the SDGs declaration. Notably, an integral part of the SDG 7 also stresses on increasing international cooperation and particularly catalyzing inflow of Foreign Direct Investments (FDIs) that are to be invested in projects which are inextricably associated to the aim of uplifting energy efficiencies and stimulating REC within the recipient countries (Lee 2013). However, in order to catalyze the inflow of foreign funds into the growing economies, increasing Trade Openness (TO) is referred to be a useful macroeconomic tool (Farhani and Ozturk 2015). Several studies in the existing literature have also concluded on the positive role of TO in stimulating favorable outcomes in the levels of environmental degradation, particularly via the carbon dioxide emissions.

Another major hindrance towards adoption and consumption of renewable energy is the limitations encountered the LDCs in terms of underdeveloped energy infrastructure and the poor state of technical expertise. It is believed that dismal energy infrastructures impede the development of the energy sector and hampers renewable energy adoption in these countries (Bhattacharya *et al.* 2016). On the other hand, technological constraints and inadequately skilled expertise have often hampered incorporation of renewable energy technology into the national energy frameworks in these countries (Karekezi *et al.* 2013). However, these obstacles, by and large, could be overcomed through enhancement in TO whereby inflow of foreign currencies can be used for development of the existing energy infrastructure in the recipient economies (Kirkpatrick *et al.* 2006). Simultaneously, enhancing openness through liberalization of trade can also result in technological spillovers which would effectively lessen the deficit in skilled expertise required in these economies (Jha 2009).

Although, a plethora of studies have linked TO to energy consumption in general, there has not been extensive research to examine the interconnectedness between TO, mainly with regard to foreign funds inflow, and REC. Against this backdrop, this paper attempts to bridge the gap in the empirical literature by statistically investigating the effects of TO enhancement and international inflows on REC in context of 38 selected economies across South Asia, Southeast Asia, Sub Saharan Africa, Latin America and Caribbean islands. The underlying notion behind this study is to understand the dynamics between TO and consumption of renewable energy which could lead to crucial policy implications regarding strategic planning for future renewable energy mix within these countries. The following questions are specifically rekindled in this paper:

1. Does enhancing openness to trade facilitate renewable energy transition?
2. Can TO be linked to enhancement in efficiency in energy use?
3. Does the foreign currency inflows contribute to the relatively greater use of renewable energy?

The remainder of the paper is structured as follows. Section 2 provides the review of existing literature while section 3 displays the regression model and specifies the attributes of the dataset considered in this paper. Section 4 outlines the methodology of research while the estimated results of the econometric analyses are reported in section 5. Finally, concluding remarks in light of the findings are provided in section 6.

2. Review of Literature

The key role of TO in influencing energy use, in general, within the economy has been extensively compiled in literature (Apergis and Payne, 2009; Nasir and Rehman, 2011; Jayanthakumaran *et al.* 2012; Nasrin and Anwar, 2014; Sbia *et al.* 2014*;* Al-Mulali and Ozturk, 2015; Kasman and Duman, 2015; Dogan and Turkekul 2016). However, a study particularly focusing on the renewable energy usage and TO nexus is a relatively new area of research.

The short run and long-run causal associations between TO, economic growth and REC were also explored by Sebri and Ben-Salha (2014). The authors considered annual time series data from 1971 to 2010 in context of the BRICS countries: Brazil, India and South Africa. ADF-MAX and Zivot-Andrews unit root tests, ARDL bound testing approach to cointegration and VECM Granger causality tests were performed to predict the possible interconnectedness between the aforesaid macroeconomic variables. The long-run estimates revealed that a unidirectional causality was found to be running from TO to REC in context of India while in the short run the causal association was found to be bidirectional for Brazil and South Africa only. Furthermore, the authors concluded that economic growth is a crucial determinant of REC in the BRICS countries since the causal association between these two variables were bidirectional across time periods.

Shakouri and Yazdi (2017), in an attempt to comprehend the dynamic relations between TO and renewable and overall energy consumption, used South African annual time series data stemming from 1971 and 2015. In line with the estimated results following the ARDL bounds testing approach and the Granger causality tests, the authors concluded that TO was efficient in stimulating changes in total use of energy resources. More precisely, a bidirectional causal linkage was found between TO and REC while a unidirectional causal association was found to be running from TO to overall energy consumption in South Africa. A drawback of this study was that the authors only considered long-run causality tests with no real effort to analyze the short run causalities.

The association between TO and energy consumption across the high, middle and low-income countries was probed by Shahbaz *et al.* (2014). The authors incorporated annual data ranging from 1980 to 2010 for a panel of 91 countries and used panel cointegration, homogeneous non-causality, heterogeneous causality and homogeneous causality tests in their study. The estimated outcomes from the cointegration test revealed that TO and energy consumption were related in the long run. In addition, the homogeneous non-causality test findings revealed that there is a quadratic relationship between these two variables depicting an inverted U-shaped relationship curve for the subpanel of high-income countries while for the middle and low-income countries subpanels the relationship portrayed a U-shaped curve. The results from the causality tests provided evidence suggesting a bidirectional causality between TO and energy consumption which implied that openness invariably determines overall energy consumption within the economy. The bidirectional causality was also found to hold in the context of Malaysia in light of the conclusions made by Shahbaz *et al.* (2015). Moreover, the authors also emphasized that TO exert an indirect stimulus on energy consumption by attributing to

affluence which in turn stimulated to an intensification in consumption of energy resources in Malaysia.

In order to unearth the specific mode of linking between TO and clean energy consumption as well as energy demand, Sbia *et al*. (2014) conducted a paper on the UAE using quarterly data from 1975Q1 to 2011Q4. The authors hired unit root tests under structural breaks, Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration and Vector Error Correction Model (VECM) Granger causality approach. In line with their findings, the authors concluded that a rise in the degree of TO gives rise to a simultaneous fall in the demand for energy by the local population of the UAE. However, the causality findings revealed unidirectional causal associations running from TO to clean energy consumption and the overall energy consumption only in the long run. In the short run, a bidirectional causality was also found to exist between TO and CO_2 emissions which can be interpreted as a rise in the consumption of non-renewable energy resources.

The inflow of remittances is also believed to influence changes in the overall energy consumption patterns within the recipient nations. In a paper by Akcay and Demitras (2015), the justification of making efficient use of the remitted funds to influence energy consumption, in general, was put forward. The authors resorted to using Moroccan annual data to conduct Johansen cointegration and Vector Error Correction Model (VECM) approach to identify the possible relationships between these two variables of interest. With relevance to their estimations, the authors asserted that there was a long run equilibrium linkage between the two variables and also a unidirectional causality, both in the short and long runs, were found to be running from remittances to energy consumption. In addition to this direct influence of remittances on energy consumption, the authors also commented in favor of an indirect effect on energy consumption via the channel of economic growth in particular.

Remittances can be a good means to channel rural electrification rate in developing and countries those are historically overburdened by low rural access to electricity. In a primary survey analysis by Mbaye (2005) on 165 villages across seven regions in Senegal, inward remittances were found to be a key determinant of rural poverty alleviation. According to the survey findings, remittances attributed to energy consumption in those poor villages since the rural households with access to remitted funds had greater access to electricity compared to the non-recipients of remittance, which to some extent defined the disparity in levels of household welfare between the remittance recipient and the remittance non-recipient groups.

In accordance to the UN's SDG declaration to boost FDI inflows into the developing countries to attain energy sustainability, impacts of FDI inflow on the REC behavior in Middle-Income Countries (MICs) was examined by Hagert and Marton (2017) using annual data of 56 MICs from 1990 to 2010. Fixed effects panel data estimation methods were tapped to predict the relationship between the two concerned macroeconomic variables by regressing a linear function that considered REC as the response variable while FDI and other control variables were held to be the explanatory variables. The key control variables in the model comprised of trade openness and inflation in particular.

According to the findings from the regression analysis, the authors commented that REC and FDI inflow are negatively related in the context of the MICs. However, they also suggested that since the magnitude of the negative relationship is not too large, a possible technological diffusion would take place with time whereby the negative effects would be marginalized and may even lead to a rise in renewable energy share of total energy consumption in the long run.

3. Empirical Model and Specification of Data

This paper augments and extends the bivariate model considered by Shahbaz *et al.* (2014). In the model used by Shahbaz *et al.* (2014), consumption or energy resources was specifically expressed as a function of trade openness. This paper modifies the model of Shahbaz *et al.* (2014) by disaggregating the overall energy consumption with respect to the four energy-related indicators, as mentioned in the SDG 7 of the 2030 Sustainable Development agenda of the UN, and expresses each of these variables as separate functions to form a network of simultaneous equations model. Moreover, this paper also includes different sources of foreign currency inflow and other possible control variables as the regressors. The simultaneous equations model in this paper is given as follows:

$$ACFT_{it} = \partial_0 + \partial_1 TO_{it} + \partial_2 FDI_{it} + \partial_3 REMIT_{it} + \partial_4 GDP_{it} + \partial_5 GDP_{it}^2 + \in_{it} \ldots\ldots\ldots\ldots\text{(i)}$$

$$EI_{it} = \partial_6 + \partial_7 TO_{it} + \partial_8 FDI_{it} + \partial_9 REMIT_{it} + \partial_{10} GDP_{it} + \partial_{11} GDP_{it}^2 + \in_{it} \ldots\ldots\ldots\ldots\textit{(ii)}$$

$$REC_{it} = \partial_{12} + \partial_{13} TO_{it} + \partial_{14} FDI_{it} + \partial_{15} REMIT_{it} + \partial_{16} GDP_{it} + \partial_{17} GDP_{it}^2 + \in_{it} \ldots\ldots\ldots\text{(iii)}$$

$$RES_{it} = \partial_{18} + \partial_{19} TO_{it} + \partial_{20} FDI_{it} + \partial_{21} REMIT_{it} + \partial_{22} GDP_{it} + \partial_{23} GDP_{it}^2 + \in_{it} \ldots\ldots\ldots\text{(iv)}$$

where the subscripts *i* denotes country (or cross-section) and *t* refers to the corresponding year. ACFT refers to access to clean fuel and technology for cooking, expressed as a percentage of the total population; EI refers to energy intensity level of primary energy (measured in terms of Mega joules/2011 USD PPP) and it is used as a proxy to capture the level of efficiency in energy use in the economy; REC is the renewable energy consumption (measured in terms of Terajoules); RES denotes the share of renewable energy consumption in total final energy consumption. These are the dependent variables in the simultaneous equations model, each of them referring to a particular indicator of energy transition within an economy and are selected on the basis of their inclusion in the SDG7 list of crucial indicators of sustainable energy access. In addition, TO refers to trade openness which is calculated as the sum of total imports and exports and expressed as a share of the GDP; FDI refers to net foreign direct investment inflows in terms of current US$; and REMIT provides the personal remittances received in current US$. This paper has considered these three as the sources of international currencies. As control variables, GDP growth rate and the squared term of the GDP growth rate (used as an instrument) are considered to investigate the linearity of the association between GDP and the dependent variables. Relevant data of the aforementioned variables, in context of 38 selected countries across South Asia, Southeast Asia, Africa, Latin America and the Caribbean Islands, stems from 2000 to 2014 and was acquired from the World

Development Indicators (WDI, 2017) database. Table 6 in the appendix provides the complete list of the countries considered in this paper.

4. Methodology

This paper resorts to the use of Three-Stage Least Squares (3SLS) panel data regression techniques to estimate each of the four simultaneous equations considered in the model, followed by the Granger causality tests of long-run causal associations.

4.1 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) estimation technique (Zellner and Theil, 1962) provides a solution to the endogeneity problem faced in the OLS estimation. For instance, heteroskedasticity 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.This was followed by the panel unit root tests and cointegration analysis which are prerequisites for performing the causal analysis using Granger causality test.

4.2 Panel Granger Causality Test

When y and x are taken 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, it can be examined 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 the equations is estimated:

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \cdots\cdots + \alpha_l x_{t-l} + \beta_1 y_{t-1} + \cdots\cdots + \beta_l y_{t-l} + u_t \quad \text{..... (5)}$$

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \cdots\cdots + \alpha_l y_{t-l} + \beta_1 x_{t-1} + \cdots\cdots + \beta_l x_{t-l} + v_t \quad \text{.....(6)}$$

This paper considers the above set of the 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. STATA 15 software is used to execute the econometric tests throughout this paper.

5. Results and Discussions

The 3SLS estimation technique is employed to understand the possible nature and signs of the relationships between the energy indicators and their determinants. The estimated results in the context of equation (i) are reported in table 1. As perceived from the estimated results, it can be seen that a rise in the TO index attributes to a simultaneous increment in the clean fuel and technology access across the full panel and the Southeast Asian and the African subpanels since the corresponding estimated coefficients of TO are found to be positive and statistically significant at 1% significance level, as well. These results are similar to the conclusions made by Coelho (2005) where the author put forward the importance of South-South and South-North trade involvements in enhancing the use of biofuels in the developing countries. In contrast, a negative relationship between TO and ACFT is also seen in the context of the South Asian and LAC subpanels, but only in the case of the South Asian subpanel, the corresponding estimated coefficient is statistically significant at 10% level of significance. It is also seen that inflow of FDI is effective in enhancing ACFT across all the panel and subpanels which is evident from the respective positive and statistically significant estimated coefficients attached to the variable TO. However, these results are in contradiction to the views of Popp (2012) who argued that the technological spillover leading to greater use of clean energy is less likely to be associated with the inflow of FDI.

Moreover, the results found in this paper also depict that REMIT inflow is statistically significant and positively influencing ACFT only in the context of the Southeast Asian and the African subpanels. Furthermore, the estimated results from the regression also suggest that economic growth has a negative impact on the movements in the ACFT across the full, South Asian and the Southeast Asian cases while for the African and the LAC subpanels the corresponding estimates of the slope coefficients attached to GDP are statistically insignificant in explaining the variation in ACFT. In addition, no evidence of a non-linear relationship between GDP growth and ACFT could be established. Hence, in light of these results, it can be asserted that TO is indeed a determinant of improving ACFT in most of the cases which are also in line with the fact that inflow of FDI is found to be effective in enhancing ACFT in all the five panel and subpanels considered in this paper.

Table 1: The 3SLS Estimation Results in Context of Equation (i)

Dependent Variable ACFT	Full Panel	South Asian Panel	Southeast Asian Panel	African Panel	LAC Panel
Explanatory Variables	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
TO	0.380*	-0.223***	0.543*	0.776*	-0.0448
	(0.000)	(0.092)	(0.000)	(0.000)	(0.489)
FDI	1.75E-08*	0.001**	0.002*	0.006*	0.0003*
	(0.000)	(0.039)	(0.000)	(0.000)	(0.007)
REMIT	0.0001	-0.0001	0.001*	0.008*	-0.00002
	(0.544)	(0.614)	(0.000)	(0.002)	(0.936)
GDP	-1.851*	-2.971***	-3.226**	-0.464	0.152
	(0.000)	(0.066)	(0.011)	(0.282)	(0.773)
GDP^2	0.210	0.190	0.242	-0.010	0.092***
	(0.583)	(0.199)	(0.117)	(0.688)	(0.092)
Constant	30.566*	36.792*	-9.381***	-29.762*	75.409*
	(0.000)	(0.000)	(0.073)	(0.000)	(0.000)
R-squared	0.759	0.703	0.824	0.549	0.506

*Notes: The probability values are provided in the parentheses; *, ** and *** denote statistical significances at 1%, 5% and 10% levels, respectively; Optimal lag selection is based on Schwarz Information Criteria (SIC)*

Table 2 reports the estimated results from the 3SLS estimation of equation (ii). In line with the calculated results, it can be seen that TO is efficient in contributing to enhancement in efficiency of energy use. Inspection of the results reveals that a rise in the index of TO is found to be negatively affecting EI in all the five panel and subpanels which can be identified from the negative and statistically significant coefficients attached to TO. This implies that as TO is increased in an economy, less amount of energy is required on average to produce an output which is synonymous with a rise in the efficiency in the use of energy. A possible reason behind this could be the fact that the enhancement in openness to trade may be attributing to the inflow of technology which can be effective in reducing the amount of energy use per unit of output. Thus, these results corroborate to the remarks made by Nasreen and Anwar (2014) in context of Asian economies. In contrast, the inflow of FDI does generate adverse impacts on energy efficiency which can be distinguished from the positive and statistically significant estimated coefficients of FDI in almost all the cases, with the LAC subpanel being the only exception. A plausible reason behind inward FDI being ineffective in enhancing the efficiency in energy use might be the fact that the foreign investments are not inclined towards the power sector in particular whereby no significant impact on the energy efficiency can be expected. On the other hand, the inflow of REMIT across all the cases is found to be in line with contributing to improvement in the efficiency in energy use as perceived from the negative and statistically significant coefficients attached to REMIT, in most of the cases. Moreover, the results of the regression are not supportive in providing evidence regarding the non-linearity relationship between EI and GDP growth.

Table 2: The 3SLS Estimation Results in Context of Equation (ii)

Dependent Variable EI	Full Panel	South Asian Panel	Southeast Asian Panel	African Panel	LAC Panel
Explanatory Variables	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
TO	-0.012*	-0.046*	-0.005*	-0.617*	-0.002*
	(0.005)	(0.000)	(0.000)	(0.000)	(0.009)
FDI	1.26E-09*	0.0001*	0.00002*	0.001*	0.00001
	(0.000)	(0.000)	(0.009)	(0.000)	(0.199)
REMIT	-0.00004**	-0.00002	-0.0001*	-0.003*	-2.34E-06
	(0.013)	(0.308)	(0.000)	(0.000)	(0.918)
GDP	0.011	-0.268	-0.023	0.202***	-0.126*
	(0.823)	(0.125)	(0.569)	(0.056)	(0.001)
GDP^2	0.008	0.022	-0.00003	-0.001	0.003
	(0.139)	(0.167)	(0.995)	(0.982)	(0.395)
Constant	5.831*	6.733*	5.032*	10.310*	5.032*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R-squared	0.897	0.598	0.898	0.784	0.501

*Notes: The probability values are provided in the parentheses; *, ** and *** denote statistical significances at 1%, 5% and 10% levels, respectively; Optimal lag selection is based on Schwarz Information Criteria (SIC)Notes: Optimal lag selection is based on Schwarz Information Criteria (SIC)*

The 3SLS estimations of equation (iii) are reported in table 3. An inspection of the reported results unearths that enhancement in openness to trade does not lead to corresponding enhancement in consumption of renewable energy resources as perceived from the negative and statistically significant estimated coefficients attached to TO in cases of all the five panel and subpanels. Thus, these results are similar to the conclusions made by Seker and Cetin (2015) who have advocated in favor of a positive relationship between TO and carbon emissions which can be interpreted as a negative association between TO and REC as well. In contrast, the results reported in table 3 reveals that, unlike TO, the inflow of FDI increases the total consumption of renewable energy resources in the context of all the subpanels in this paper since the corresponding slope coefficients attached to REC are positive and statistically significant at 1% and 5% levels of significance. This is pretty much in line with the highlights in the paper by Doytch and Narayan (2016) whereby the authors clearly emphasized on the importance of FDI inflows in the service sector in determining renewable energy transition in the economy. Likewise, FDI, the inflow of REMIT is also found to be contributing to the overall consumption of renewable energy in the economy. This is evident from the fact that the estimated coefficients attached to REC in cases of all the five panel and subpanels are positive and statistically significant as well. Another important finding here is the fact that only in the case of the South Asian subpanel, an inverted-U shaped non-linear relationship between REC and GDP growth can be seen, whereby the threshold level of GDP growth rate is calculated to be 4.39%.

Table 3: The 3SLS Estimation Results in Context of Equation (Iii)

Dependent Variable REC	Full Panel	South Asian Panel	Southeast Asian Panel	African Panel	LAC Panel
Explanatory Variables	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
TO	-7172.28*	-44987.2*	-17391.81*	-3548.29*	-5195.06*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI	0.00001	83.416**	20.574*	74.593*	42.573*
	(0.793)	(0.044)	(0.009)	(0.000)	(0.000)
REMIT	97.541*	80.019*	70.634*	26.284*	33.359*
	(0.000)	(0.001)	(0.000)	(0.208)	(0.000)
GDP	30527.71**	-449134.1***	-40838.81	11341.12*	4950.627
	(0.025)	(0.085)	(0.451)	(0.001)	(0.623)
GDP^2	-944.68	51184.85**	7514.726	-605.895	-624.005
	(0.365)	(0.033)	(0.252)	(0.104)	(0.551)
Constant	589689.2*	3209334*	3048745*	329862.9*	456694.8
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R-squared	0.562	0.894	0.824	0.844	0.509

*Notes: The probability values are provided in the parentheses; *, ** and *** denote statistical significances at 1%, 5% and 10% levels, respectively; Optimal lag selection is based on Schwarz Information Criteria (SIC)Notes: Optimal lag selection is based on Schwarz Information Criteria (SIC)*

Table 4 presents the estimated results following the 3SLS estimation of equation (iv). In line with the results reported in table 3, it is found that a rise in the TO indices, in context of all the panel and subpanels, reduces the share of renewable energy consumption in total energy consumption, as supported by the negative and statistically significant slope coefficients attached to TO. A similar negative relationship is also found between REMIT and RES implying that a rise in the inflow of REMIT triggers a greater rise in the consumption of non-renewable energy resources as compared to that of the renewable energy resources. Moreover, the results once again highlight the effectiveness of inward FDI in increasing the share of renewable energy consumption in total energy consumption. The estimated coefficients attached to FDI in context of all the five panel and subpanels are found to be positive and statistically significant as well. An important finding from the results reported in table 4 is that economic growth encourages the use of non-renewable energy and undermines renewable energy consumption, leading to a fall in the overall RES. This finding is in line with the remarks of Doytch and Narayan (2016).

Table 4: The 3SLS Estimation Results in Context of Equation (iv)

Dependent Variable RES	Full Panel	South Asian Panel	Southeast Asian Panel	African Panel	LAC Panel
Explanatory Variables	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
TO	-0.341*	-0.255*	-0.261*	-0.794*	-0.076**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.045)
FDI	1.10E-08*	0.0001**	0.0003*	0.005*	0.0001**
	(0.000)	(0.071)	(0.000)	(0.000)	(0.084)
REMIT	-0.001*	-0.002**	-0.0003*	-0.014*	-0.001*
	(0.000)	(0.046)	(0.007)	(0.000)	(0.000)
GDP	-1.161*	-0.635	-0.681	-0.711***	-0.162
	(0.001)	(0.531)	(0.351)	(0.065)	(0.703)
GDP^2	-0.007	0.068	-0.075	-0.008	-0.102**
	(0.811)	(0.464)	(0.394)	(0.737)	(0.021)
Constant	66.828*	43.441*	56.675*	119.795*	32.576*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R-squared	0.681	0.552	0.670	0.609	0.543

*Notes: The probability values are provided in the parentheses; *, ** and *** denote statistical significances at 1%, 5% and 10% levels, respectively; Optimal lag selection is based on Schwarz Information Criteria (SIC).*

Panel unit root tests and cointegration followed the regression analyses and their corresponding results are reported in table 7 and table 8 in the appendix. According to the estimated results, it is found that all the variables considered in this paper are stationary in their first difference form and there are also long-run cointegrating equations in the models. Thus, the long run causal analyses using the Granger causality test was then performed.

The long-run causality results in light of the Granger causality estimations are reported in table 5. From the table, it can be interpreted that in context of the full panel, a unidirectional long-run causal association is found to be running from TO to ACFT only in the cases of the African and LAC subpanels. In addition, another unidirectional causality is found from FDI to ACFT in the context of the African subpanel while for the Southeast Asian subpanel the direction of causality gets reversed. Moreover, inward REMIT is also found to influence ACFT in the long run in the Southeast Asian and the LAC subpanels. Finally, economic growth is found to exhibit a unidirectional causal association running to ACFT only in the case of the South Asian and the LAC subpanels.

The results also show evidence of a unidirectional causality running from TO to EI in context of the LAC subpanel only. In addition, a bidirectional causal association between FDI and EI is also found in the context of the South Asian subpanel, further emphasizing the significance of boosting inward FDI as a means to achieving greater efficiency in the use of energy resources. A unidirectional causal association stemming from REMIT to EI is also ascertained in context of the South Asian subpanel. The paramount importance of inward FDI generation with relevance to escalating renewable energy consumption is further brought to the limelight through the Granger causality results found in this paper. From table 5, it can be deduced that except for the African subpanel, there exists a bidirectional causality between FDI and REC in the other four panel and subpanels,

providing support to the effective role of FDI in triggering renewable energy transition within an economy. Finally, the Granger causality results in this paper depict a unidirectional causality running from RES to REMIT only in the context of the African panel.

Therefore, it can be assumed, in light of the statistical evidence found in this paper, that the effects of the regressors in the simultaneous equations model do affect the dependent variables, however, trends in the causal directions with respect to the variables portray ambiguity with respect to the panel or regional subpanels.

Table 5: The Granger Causality Test Results (Lag=2)

Panel/Subpanel	Full	South Asia	Southeast Asia	Africa	LAC
Null Hypothesis	**F-Stat.**	**F-Stat.**	**F-Stat.**	**F-Stat.**	**F-Stat.**
Equation (i)					
TO does not Granger cause ACFT	0.056	1.738	1.505	2.974***	3.910**
ACFT does not Granger cause TO	0.073	0.645	0.378	1.299	1.237
FDI does not Granger cause ACFT	0.388	0.345	0.224	2.746***	1.338
ACFT does not Granger cause FDI	0.777	0.162	4.335**	1.522	0.166
REMIT does not Granger cause ACFT	0.021	0.385	5.003**	0.009	2.807***
ACFT does not Granger cause REMIT	0.328	0.207	1.726	0.177	0.058
GDP does not Granger cause ACFT	0.074	4.696**	0.070	1.955	8.858*
ACFT does not Granger cause GDP	6.019*	1.062	0.486	1.828	0.284
Equation (ii)					
TO does not Granger cause EI	0.187	1.239	0.989	0.54.	2.415***
EI does not Granger cause TO	3.839**	0.551	1.395	0.813	1.976
FDI does not Granger cause EI	0.518	3.360**	0.322	1.316	0.225
EI does not Granger cause FDI	0.118	5.625*	0.430	2.368***	0.081
REMIT does not Granger cause EI	0.296	4.762**	0.140	0.033	0.035
EI does not Granger cause REMIT	0.250	1.627	0.187	9.147*	0.105
GDP does not Granger cause EI	1.472	2.412	0.900	2.544***	0.653
EI does not Granger cause GDP	5.829*	0.165	1.377	16.363*	3.041***
Equation (iii)					
TO does not Granger cause REC	0.386	0.352	1.159	0.457	0.068
REC does not Granger cause TO	0.425	1.541	0.198	1.201	1.143
FDI does not Granger cause REC	19.454*	7.796*	8.209*	0.044	44.992*
REC does not Granger cause FDI	14.399*	7.901*	2.567**	1.496	11.984*
REMIT does not Granger cause REC	7.127*	2.895***	0.319	2.204	0.177
REC does not Granger cause REMIT	7.867*	6.703*	0.041	0.259	0.340
GDP does not Granger cause REC	0.705	1.441	0.507	0.613	0.696
REC does not Granger cause GDP	1.191	2.095	0.729	1.006	0.034
Equation (iv)					
TO does not Granger cause RES	0.185	0.424	2.224	0.819	0.271
RES does not Granger cause TO	0.323	1.791	0.434	1.140	1.432
FDI does not Granger cause RES	0.201	1.442	1.191	0.075	0.175
RES does not Granger cause FDI	0.085	0.085	0.649	0.139	0.316
REMIT does not Granger cause RES	0.996	0.921	0.895	0.466	0.028
RES does not Granger cause REMIT	0.203	0.653	0.301	2.990**	0.113
GDP does not Granger cause RES	1.026	0.652	0.862	0.980	0.192
RES does not Granger cause GDP	6.148*	1.893	0.2901	2.021	0.080

*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).*

6. Conclusions

Energy inadequacy has been a grueling problem across the LDCs in particular whereby their development strategies are often left being characterized by unattained goals. For instance, unreliable supply of electric power has often been referred to as a key obstruction attributing to the impediment of the national output levels in the panel of countries considered in this paper. Moreover, failure to ensure self-sufficiency in energy generation is also a major area to ponder on. Hence, the urgency for achieving energy sufficiency in these economies is of greater emphasis following the fact that most of these countries belong to the group of LDCs and some are on the verge of graduating in the near future. Furthermore, the over-dependence on use of non-renewable energy resources in these economies has also aggravated the energy deficits which strongly call for rapid renewable energy transitions in line with the SDG7 of the United Nations. Thus, the aim of this paper was to empirically investigate how TO, particularly facilitating the inflow of international funds, across South Asia, Southeast Asia, Africa, Latin America and the Caribbean Islands, could ultimately lead towards renewable energy transition in the aforementioned regions.

In accordance with the estimated results, it can be concluded that a rise in the TO index, overall, is not in line with the energy goals set by the UN's 2030 Sustainable Development Agenda. The results found in this paper revealed that enhancing openness to trade, within the panel or subpanel of the countries considered, reducesACFT, lowers down the REC and also contributes to a reduction in the RES. However, an encouraging point to note here is the fact that rising openness to trade does enhance energy use efficiency which has been mentioned as a part of SDG 7. Thus, it is important for the governments and the policymakers to understand the gravity of the problem engulfing the adverse contribution of TO with regard to reducing ACFT, REC and RES. A possible explanation to such results could be the fact that the benefits of enhancement in TO indices facilitate the trade of non-energy goods and services in particular whereby its effect on the energy sector is not as desired from the broader perspective of the SDG7 attainment by 2030.

In contrast, the inflow of FDI is found to be pretty much in line with the attainment of the most of the targets enlisted under the SDG7. In light of the statistical evidence provided in this paper, the inflow of FDI is found to be associated with enhancing ACFT, increasing the total REC and boosting the RES as well. However, a concerning fact remains since inward FDI is found to curtail energy use efficiency within the economy which partially hampers the attainment of the overall energy sustainability goal. The regression results in this regard are more or less coinciding to the Granger causality results, providing robustness, to some extent, to the findings. Based on these estimated findings, it can be concluded with authority that the stress on boosting FDI inflows, as mentioned under the SDG7, is indeed a credible strategy to achieving energy sustainability across the regions considered in this paper. In addition, the inflow of REMIT is also found to stimulate a rise in the overall consumption of renewable energy. However, a paradoxical finding is also encountered since rising levels of REMIT is also found to lower the RES. A possible understanding of this phenomenon could be the fact that inward REMIT stimulates the overall consumption of energy resources; but the growth in the volume of non-renewable energy, following a hike in the level of funds remitted, outpaces the volume of REC growth

whereby the RES goes down. Hence, it is pertinent to identify the possible factors attributing to a relatively higher growth in consumption of non-renewable energy and simultaneously adopt policies to facilitate further use of renewable energy in the economy.

Data constraint was a major limitation faced in this paper which restrained this paper from the incorporation of crucial regressors in the simultaneous equations model. In such a case, there can be a possible omitted variable bias in the model. Moreover, limited availability of disaggregated data has also prevented the use of robust methodologies which could have aggravated the robustness of the conclusions. As part of the future scope of the study, this paper can be extended by including more countries adding to the size of the panel which can help in comparing region-specific associations between TO and trends in renewable energy transition.

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Appendix

Table 6: List of the Countries Considered in This Paper

South Asia	Africa		LAC	
Bangladesh				
India	Cameroon	Botswana		
Pakistan	Ghana	Namibia	Argentina	Jamaica
Sri Lanka	Kenya	Niger	Brazil	Mexico
Southeast Asia	Madagascar	Senegal	Chile	Paraguay
Indonesia	Malawi	Sierra Leone	Costa Rica	Panama
Malaysia	Mali	Sudan	Ecuador	Peru
Philippines	Mauritius	Tanzania	El Salvador	Uruguay
Thailand	Mozambique	Uganda	Haiti	Venezuela, RB

Table 7: Panel Unit Root Test Results at 1st Difference, I (1)

	Levin, Lin and Chu	Im, Pesaran and Shin	Breitung	Maddala and Wu		
Variable	**t-stat**	**W-stat.**	**t-stat.**	**ADF--Fisher Chi-Square Stat.**	**PP-Fisher Chi-Square Stat.**	**Decision on Stationarity**
ACFT	-5.922*	-5.603*	-7.931*	45.968*	92.103*	Stationary
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
EI	-5.453*	-3.965*	-1.099	32.487*	52.856*	Stationary
	(0.000)	(0.000)	(0.136)	(0.000)	(0.000)	
REC	-4.752*	-5.327*	-1.138	40.450*	52.222*	Stationary
	(0.000)	(0.000)	(0.128)	(0.000)	(0.000)	
RES	-5.515*	-4.033*	-2.548*	32.079*	50.104*	Stationary
	(0.000)	(0.000)	(0.005)	(0.000)	(0.000)	
OPEN	-6.137*	-3.189*	-2.738*	27.721*	53.049*	Stationary
	(0.000)	(0.001)	(0.003)	(0.002)	(0.000)	
FDI	-4.475*	-2.732*	-2.868*	24.499*	41.248*	Stationary
	(0.000)	(0.003)	(0.002)	(0.006)	(0.000)	
REMIT	-5.350*	-2.629*	-2.842*	23.405*	32.684*	Stationary
	(0.000)	(0.004)	(0.002)	(0.009)	(0.000)	
GDP	-6.697*	-4.788*	-2.878*	37.879*	65.444*	Stationary
	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	
GDP^2	-3.908*	-3.315*	-3.770*	28.045*	53.896*	Stationary
	(0.000)	(0.001)	(0.000)	(0.002)	(0.000)	

*Notes: Considering trend and intercepts. The probability values are given in the parenthesis. *, **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).*

Table 8: Kao Residual Cointegration Test Results

Equation	Full	South Asia	Southeast Asia	Africa	LAC
	Panel ADF stat.	**Panel ADF stat.**	**Panel ADF stat.**	**Panel ADF stat.**	**Panel ADF stat.**
(i)	1.384***	1.307***	-4.580*	2.373**	2.544*
	(0.083)	(0.096)	(0.000)	(0.035)	(0.006)
(ii)	1.558**	-1.302***	-2.489*	-3.266*	-2.072**
	(0.029)	(0.096)	(0.006)	(0.001)	(0.015)
(iii)	-3.053*	-1.968**	-3.302*	3.581*	-5.713*
	(0.001)	(0.026)	(0.001)	(0.001)	(0.000)
(iv)	1.925**	-1.967**	-1.903**	-3.215*	4.709*
	(0.027)	(0.025)	(0.029)	(0.001)	(0.002)

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