Trade Liberalization Policies and Renewable Energy Transition in Low and Middle-Income Countries? An Instrumental Variable Approach

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2019

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Abstract

A transition from the traditional dependence on use of non-renewable energy to the relatively environment-friendly renewable energy resources has been a key national agenda of governments across the globe. Keeping the environmental degradation and sustainable supply of energy into cognisance, it is pertinent to address the factors that possibly facilitate the renewable energy transitions worldwide. Against this backdrop, this paper aims to empirically analyse the compatibility of national trade liberalization policies with regards to promoting greater use of renewable energy across 71 low, lower-middle and upper-middle countries from South Asia, East Asia, Pacific, Central Asia, Latin America, Caribbean islands and Sub-Saharan Africa. Annual panel data between 2000 and 2017 is incorporated into the regression analyses using the Instrumental Variable Two-Stage Least Squares (IV-2SLS) and the Instrumental Variable Random Effects Generalized Least Squares (IV-RE-GLS) panel data estimators. The results indicate that greater openness to trade stimulates renewable energy consumption and also enhances the intensities of energy usage within the low and upper-middle income economies only. However, despite these upward pressures, trade openness does not guarantee higher shares of renewable energy use in the total energy consumption within these nations. Thus, the alignment of the trade liberalization policies in these countries with respect to attainment of the renewable energy transition can broadly be questioned. Furthermore, the results also indicate that trade liberalization within the lower middle-income countries is useful only in terms of enhancing the access to clean fuels and technology for cooking. The results, in a nutshell, imply that the impacts of trade liberalization on facilitation of renewable energy transition are large offset by other factors that trigger greater use of the non-renewable energy resources in these countries.

Keywords: renewable energy, non-renewable energy, renewable energy transition, instrumental variable
JEL Classifications: Q2, O13, P28, Q43, K32

1. Introduction

Moving away from the customary preconceived notion of capital and labor inputs being the key proponents of economic outputs, the vast importance of energy as one off the utmost important factors of production has been extensively acknowledged in the contemporary energy economics discourse. Thus, energy inputs have gradually augmented the traditional production functions to complement capital and labor (Murshed 2019a; Murshed 2018). However, despite some evidence of ambiguity with respect to certain country-specific examples, the role of energy in proliferating the output levels, in general, has been well documented in the existing literature (Asafu-Adjaye 2000; Aqeel and Butt 2001; Paul and Bhattacharya 2004; Odhiambo 2009; Bozoklu and Yilanci 2013; Ahmed and Azam 2016). The paramount significance of energy and its sustained supply, with respect to the socioeconomic development across the globe, have also been addressed in the United Nations' (UN's) 2030 Sustainable Development agenda (McCollum *et al.* 2017; Nilsson *et al.* 2018). Although energy employment, in a much broader sense, is often perceived to be a necessary condition to catalyze the rate of development within any economy, it does not entirely qualify as a sufficient one. This is because as much as the aggregate volume of energy used being a key macroeconomic determinant of development, its compositional shares in the total units of energy consumed are also believed to exhibit overarching associations with the ultimate development goals of the government. By compositional shares, energy economists usually emphasize on the relative shares of renewable and nonrenewable energy resources; and they often advocate in favor of a higher share of renewable energy in the total energy consumption bundle being a strong driver of sustainable development (Boyle 2004; Bugaje 2006).

In the past, when the supply of energy was relatively abundant, not much emphasis was given to the need for its conservation, which eventually attributed to the acute global energy crises at present (Cherp and Jewell 2011; Qureshi, Rasli and Zaman 2016; Ali *et al.* 2018; Zafar *et al.* 2018; Murshed 2019b). Moreover, the predominant reliance on combustion of nonrenewable fossil fuels as the primary sources of energy has further aggravated the scenario. Simultaneously, the use of such relatively less environment-friendly energy resources over the years has also triggered climate changes and, as a result, it chronically disrupted the global environmental harmony to a large extent (Marland and Rotty 1987; Raupach *et al.* 2007; Al-Mulali and Sab 2012; Shafiei and Salim 2014). Thus, environmental economists often advocate in favor of Renewable Energy Transition (RET) as a potential mechanism to not only ensure sustained supply of energy (Bugaje 2006; Armaroli and Balzani 2007; Balat 2010; Amin, Murshed and Jannat 2017; Kwan 2018) but to also put a hold on the persistent greenhouse emission-induced climate changes worldwide (Junfeng, Wang and Ohi 1997; Esen and Yuksel 2013; Raheem *et al.* 2016; Murshed 2018).

RET simply refers to a strategic approach to relieve the dependence on traditionally consumed nonrenewable energy resources to the contemporary renewable ones via gradually incorporating the renewable energy policies into the national energy policies. The seventh Sustainable Development Goal (SDG) of the UN, in particular, strives to enhance the shares of renewables in the total energy consumption profiles all across the globe (McCollum *et al.* 2017). The core significance of the RET can also be understood from the persistent surge in the overall demand for energy following rapid urbanization, industrialization and population growth across the globe (Giori *et al.* 2015). In this context, when the world is progressively running out of the nonrenewable energy resources and simultaneously deteriorating the global climate, incorporation of the renewables in the global energy mix could be the supply-side solution to increased energy demand (Turner 1999; Ramachandra and Shruthi 2007; Sambo 2008; Zhu *et al.* 2013). RET can also play a pivotal role in guaranteeing off-grid rural electrification when the national grids fail to ensure homogenous access to electricity within the economy (Kanase-Patil, Saini and Sharma 2010; Mainali and Silveira 2011; Bekele and Tadesse 2012; Sen and Bhattacharya 2014).

However, the major barriers impeding this smooth energy transitions, especially in the context of the low and middle income economies, comprise of the limited natural endowments, inadequate levels of skilled expertise and poor infrastructures necessary to cushion renewable energy adoption within these nations (Martinot *et al.* 2002; Reddy and Painuly 2004; Negro, Alkemade and Hekkert 2012). Thus, the need for international cooperation and globalization through international trade engagements and foreign financial flows are often asserted to be key to expedite the overall process of RET within these economies (Brander and Taylor 1998; Nepal and Jamasb 2012; Sbia, Shahbaz and Hamdi 2014; Shahbaz *et al.* 2015). Although, empirical evidence suggesting in favor of the adverse impacts of TL on environmental quality are subject to rigorous debates (Dean 2002; Shen 2008), it is believed that proper management of the TL policies could be exemplary in internalizing the associated environmental costs (Goldman 1992; Runge 1993; Lopez 1994; Perroni and Wigle 1994). For instance, deregulation of trade barriers tends to exert pressures on economic output levels, thus, aggravating the overall energy demand within the trade-liberalizing economies (Jacobsen 2000; Sadorsky 2011). However, if such a rise in demand for energy is met by greater employment of fossil fuels, then such actions would result in the total greenhouse emissions going up whereby the TL policies are ought to be scrutinized. Conversely, supplementing higher energy demands via greater supply and use of both indigenous and imported renewable energy resources can significantly off-set the associated environmental costs and thereby smoothen the RET at a global scale (Jebli and Youssef 2015).

Against this backdrop, this paper aims to empirically analyse the feasibility of Trade Liberalization (TL) policies on the overall RET across 71 low, lower-middle and upper-middle income countries from South Asia, East Asia, Pacific, Central Asia, Latin America, Caribbean islands and Sub-Saharan Africa. Although, the impacts of TL, via enhancements in the Trade Openness (OP) indices worldwide, on amplification of renewable energy use has been a well-discussed issue, measures to address the possibly endogeneity of the TO indices has received nominal consideration. This paper bridges this gap in literature by employing robust regression panel data estimators suitable for handling the endogeneity problem in the data. The novelty of this paper lies in its approach of not being confined to analyzing the prospects of renewable energy consumption only but it also sheds light on the impacts of enhanced TO on energy-use efficiencies within these economies as well. Thus, a comprehensive method of understanding the role of TL on overall energy sustainability via RET is put forward in this paper.

The following questions are particularly highlighted in this paper:

1. Does greater TO facilitate renewable energy consumption in low, lower-middle and upper-middle income countries?
2. Does TL complement the energy-efficiency enhancement public policies?
3. Is globalization fostering the overall RET across these countries?
4. Can TL help to attain the energy and environmental sustainability aspects of the SDGs?

The remainder of the paper is structured as follows. Section 2 highlights the stylized energy facts across the countries considered in this paper. The literature study, comprising of theoretical foundations and empirical findings, are outlined in section 3. Section 4 explains the methodology of research and also sheds light on the model and dataset used. Results from the empirical exercises are reported and discussed in section 5. Finally, section 6 provides the concluding remarks and clarifies the policy implications.

3. Literature Study

This particular section is subdivided into two subsection with the former shedding light on the conceptual framework linked to TO-RET nexus while the latter addresses the documented empirical findings in this regard.

3.1. Conceptual Framework

The rationale behind liberalizing trade barriers to facilitate RET within an economy can be understood from the theory postulated by Heckscher (1930) and Ohlin (1933). This theory took in cognizance the disparity in factor endowments and input costs across nations and hypothesized international trade flows to be determined by these relative factor abundance and scarcities. According to this theory, a country would be better-off specializing in production of goods and services in which it has a naturally bestowed comparative advantage in the form of indigenous factor endowments, while importing those products requiring inputs which cannot be sourced domestically. In the same vein, some countries are naturally deprived of renewable energy resources whereby the prospects of TL policies being implemented would ensure a pathway for renewable energy imports into these nations. Thus, this particular trade theory can be tapped to criticize the impositions of unnecessary trade barriers that impede renewable energy flows across nations.

Apart from the diffusion of renewable energy resource into the national energy mix being restrained by the factor endowment differentials across nations, a mismatch between the states of technological innovation and relative skill shortages can also play a pivotal role in delaying the overall process of RET. Thus, the prime importance of TL in resolving this issue can be perceived from the 'Learning by Doing' model of growth by Arrow (1962). This particular growth model can be tapped to explicate how liberalizing trade is likely to catalyze technological spillovers, particularly from the developed to the less developed and emerging economies, ultimately aiding these technology-deprived economies in upgrading their poor renewable energy infrastructures. Thus, greater openness to trade is believed to be critically important in this regard since trade inflows would ideally go on to mitigate the technological disparities bottlenecking RET within these economies.

The impacts of TL on RET from the perspective of environmental sustainability can also be analysed in the context of the Environmental Kuznets Curve (EKC) hypothesis. This hypothesis was developed from the theory of an inverted-U shaped association between growth and inequality by Kuznets (1955). Similarly, the EKC hypothesis refers to an inverted-U shaped association between growth and environmental quality which ideally sums up to assert that although economic growth, presumably caused via greater involvements in trade engagements, would lead to a rise in emissions from combustion of traditional fossil fuels, ultimately reduces the emission intensities beyond a threshold level of growth. Thus, the EKC hypothesis can demonstrate the cyclical impact of TL policies attributing to RET over the long run, taking the scale, composition and technique effects of TL into consideration. The scale effect can be viewed in the form of a rise in the level of emissions following a rise in the energy demand during the initial stages of growth. However, with time, further liberalization of trade restrictions is expected to trigger a shift from use of nonrenewable to relatively environment-friendly green energy options to bridge the escalated energy demand. This is termed as the technique effect which ultimately justifies the use of TL policies in facilitating the RET process along the economic growth cycle.

3.2. Empirical Findings

Liberalization of trade barriers to induce greater bilateral and multilateral exchange of goods and services, as documented in the existing literature, has been referred to as a key policy tool to promote the diffusion of renewable energy resources in the global energy mix (Owen 2006; Mezher, Dawelbait and Abbas 2012; Karatayev *et al.* 2016). While some economist voice in favor of TL having a negative impact on the environment (Managi 2004; McCarney and Adamowicz 2005; Managi, Hibiki, and Tsurumi 2009), many studies have concluded the unnecessary trade regulations to be a barrier to the flows of technical expertise and renewable energy resources; particularly into the low and middle income economies that are obliged to use the traditional nonrenewable energy resources following the associated constraints (Painuly 2001; Verbruggen *et al.* 2010; Yaqoot, Diwan and Kandpal 2016). The common reasoning put forward in the latter studies, refuting to the conclusions made in the former ones, was the fact that the trade-off between international trade and environmental degradation can largely be accounted if the environmental costs are internalized whereby TL can be expected to lead to greater use of renewable energy in contrast to imposing further pressure on the demands for nonrenewable energy resources. Thus, reduction in tariffs and other trade barriers on renewable energy imports in particular are often perceived to be pertinent in facilitating RET (Hashim and Ho 2011; Omri and Nguyen 2014).

The role of TL policies in governing the overall RET across the world is a more or less accepted phenomenon in the existing literature (do Valle Costa, Rovere and Assmann 2008; Pollitt 2012). Improper use of trade barriers have been identified as the key factors restricting renewable energy diffusion within the national energy mix across the globe. Omri and Nguyen (2014) argued liberal trading strategies to contribute to renewable energy use within 64 high, middle and low income countries. The regression estimates from the GMM panel regression analysis showed that a 1% growth increase in trade openness contributed to 0.25% and 0.19% growths in renewable energy consumption, on average, in the middle and low income economies, respectively. In another study on Nigeria, Saibu and Omuji (2016) referred trade openness to account for greater renewable energy demand for production of electricity in the country. However, the authors also found economic growth to undermine renewable energy adoption whereby the marginal impact of growth on the Nigerian economy was found to reduce renewable energy adoption by 2.76% *ceteris paribus*. Sohag *et al.* (2015) mentioned trade openness to be a crucial macroeconomic policy tool to facilitate the technological inflows necessary for boosting renewable energy consumption in the Asian economies. Similarly, trade barriers were also opined by Coelho (2005 February) to be inappropriate in assisting the transition from fossil fuels to biofuels usage within the developing countries. In contrast to the aforementioned positive findings, Pfeiffer and Mulder (2013) referred trade openness to condemn RET within the developing economies in particular.

In a study by Shahbaz *et al.* (2014), the authors analysed the impacts of openness to trade on energy consumption across 91 high, middle and low income nations. Relevant panel data from 1980 to 2010 was used to run panel unit roots, maximum likelihood-based panel cointegration and homogenous and heterogeneous causality and non-causality and pooled mean group regression analyses. The bivariate econometric model used in the study expressed per capita energy consumption as a function of real trade openness per capita. The results suggested that only in the high income countries, liberalization of the trade barriers promoted energy consumption initially before reaching a threshold after which the nature of the association gets reversed. In contrast, opposite interlinkage between trade openness and energy consumption were found in the context of the low and middle income countries considered in this paper. In addition, bidirectional causal associations were also found for all the panels while the heterogeneous causality analysis showed that a unidirectional causal association stemmed from trade openness to energy consumption. Some major drawbacks of this study could be interpreted in terms of the author's not providing emphasis on the disaggregated form of energy consumption, whereby the heterogeneous impact of exogenous shocks to trade openness on renewable and nonrenewable energy consumptions could not be understood. Moreover, the region-specific impacts on energy consumption trends were also not taken into consideration which could have generated key policy implications as a whole.

Linking sustainable development to renewable energy use, Ahmed, Shahbaz and Kyophilavong (2016) analyzed the trade openness-energy-emissions nexus in the context of Brazil, India, China and South Africa. The authors resorted to using the Granger causality test and estimated the long run marginal impacts of enhancements in trade openness on total energy consumptions, emission and growth using panel data from 1970 to 2013. As per the estimates, a unidirectional causal association stemming from trade openness to energy use and emissions suggested that TL policies put pressure on the overall energy demand in these economies, largely attributing to greater volumes of emission. However, the negative sign of the estimated coefficient attached to trade openness suggested that trade openness reduces emissions in the long run which was also supported by the inverted-U shaped nonlinearity between growth and emissions in these countries. Thus, the authors concluded that although liberalizing trade may initially account for higher consumption of fossil fuels and greater volumes of greenhouse emissions, the relationships would be reversed in the long run through substantial increase in renewable energy consumptions and adoption of energy-efficient technologies.

The nexus between international trade and the consumption of both renewable and nonrenewable energy has also been evaluated in terms of the trends in the emissions following the relaxation of the trade barriers. Policies aimed at liberalizing trade are said to be welfare-enhancing, from the environmental sustainability perspective, if the intensity of the post-trade emissions are mitigated which can be interpreted as a relative rise in the use of the environment-friendly renewable energy resources (Frankel and Rose 2005). In a study by Zhang, Liu and Bae (2017), the impact of trade openness on carbon emissions was examined in the context of newly industrialized economies. The authors specifically focused their econometrics analyses on understanding the validity of the Environmental Kuznet Curve (EKC) hypothesis and made conclusions based on the manner in which trade openness affected carbon dioxide emissions within those nations. The results from the regression analyses portrayed the marginal impact of a 1% rise in trade openness accounting for a 0.2% decline in carbon dioxide emissions. Moreover, it was also seen that more than 70% of the emissions were driven by combustion of fossil fuels which signaled towards a tendency within the industrialized economies to adopt renewable energy. Similar negative association between TL and carbon emissions was also found by Shahbaz *et al.* (2013) for Indonesia while Dogan and Seker (2016) also made similar remarks in the context of the European Union. In contrast to the findings of the aforementioned studies, several other studies have also referred TL to stimulate both fossil fuel consumptions and carbon dioxide emissions (Farhani, Shahbaz and Arouri 2013; Kasman and Duman 2015).

4. Econometric Model and Data Attributes

This paper modifies the bivariate regression model used by Shahbaz *et al.* (2014) in which the authors expressed energy consumption as a function of trade openness. However, although the focus of the authors was on the causality analyses, it is anticipated that the model could be subject to an omitted variable bias. Thus, the model used in this paper augments Shahbaz *et al.'s* model (2014) to control for key macroeconomic variables as well. Moreover, since the aim of this paper is to understand the dynamics of trade openness with respect to stimulating the RET, the outcome variables used were chosen in line with the targets mentioned in SDG 7 (McCollum *et al.* 2017). The functional forms of the regression models considered in this paper include

$$REC_{it} = \partial_1 + \partial_2 OPEN_{it} + \beta_j X_{j,it} + \varepsilon_{it} \quad (1)$$

$$RES_{it} = \partial_1 + \partial_2 OPEN_{it} + \beta_j X_{j,it} + \varepsilon_{it} \quad (2)$$

$$E\_INT_{it} = \partial_1 + \partial_2 OPEN_{it} + \beta_j X_{j,it} + \varepsilon_{it} \quad (3)$$

$$ACFT_{it} = \partial_1 + \partial_2 OPEN_{it} + \beta_j X_{j,it} + \varepsilon_{it} \quad (3)$$

where the subscripts *i* and *t* refer to the cross-sectional unit and time period respectively. The four outcome variables include renewable energy consumption (REC), renewable energy share (RES), intensity of energy use (E_INT) and access to clean fuel and technology for cooking (ACFT). Although the consideration of REC and RES being self-explanatory from the perspective of the goal of evaluating the trends in renewable energy adoption following liberalization of trade barriers, the inclusion of E_INT and ACFT are motivated by the targets of doubling the global energy-use efficiencies and substantially enhancing the share of clean fuel in the world energy-mix by 2030, respectively, as mentioned under the broad target of achieving SDG7 by 2030 (McCollum *et al.* 2017). Equation (2) would specifically address the RET phenomenon following the relaxation of trade barriers. All these four outcome variables are separately regressed as function of the main regressor of interest Trade Openness (OPEN) and other control variables. All the variables are expressed in their natural logarithms to evaluate the corresponding elasticities.

The variable X_j denotes a set of key control variables influencing the outcome variables in the aforementioned regression models. It is pertinent to control for Access to Electricity (ATE) since it has been empirically acknowledged that the demand for primary energy resources, irrespective of it being renewable or nonrenewable in nature, is driven by the inadequate ATE (Rabah 2005; Suberu *et al.* 2013). Moreover, the less developed economies are also burdened by their persistent low rates of rural electrification whereby the prospects of renewable energy use to ensure off-grid power generation are immense (Nandi and Ghosh 2010; Mohammed, Mustafa and Bashir 2014). This paper also controls for Carbon-dioxide (CO_2) emissions, used as a proxy for greenhouse emissions, following the rich literature which advocates RET to be governed by the environmental threats engulfing high emission intensities generated from the combustion of fossil fuels (Sadorsky 2009; Apergis *et al.* 2010; Salim and Rafiq 2012; Apergis and Payne 2014). Price of crude oil (OIL_PR) is included in the models to account for the price elasticity of substitution between renewable and nonrenewable energy whereby economies are better-off switching to alternative renewable energy resources following the volatile behavior of world oil prices (Toth and Rogner 2006; Sadorsky 2009).

Globalization, through trade and financial liberalization, is also presumed to play a critical role in facilitating RET. Thus, inflow of foreign currencies in the forms of Foreign Direct Investments (FDI), Official Development Assistances (ODA) and Foreign Remittances (REMIT) are included in the regression models to control of financial liberalization within the economies. Inflow of FDI into the less developed economies are thought to lay a foundation for spillover of international skills and expertise that are essential in bridging the relative skill deficiencies hampering the adoption of clean energy technologies in the relatively deprived developing economies (Lee 2013; Amri 2016). Similarly, ODA can be effective in developing the poor energy infrastructures and eventually go on to catering the overall process of RET (Hancock 2015; Michalena and Hills 2018). Furthermore, the regression models are also controlled for economic development, proxied by the Real Gross Domestic Product (RGDP) of the concerned nations (Chang, Huang and Lee 2009; Apergis and Payne 2010; Apergis and Payne 2011). In addition, a squared term of RGDP ($RGDP^2$) is included to analyse the possible non-linear associations and also to shed light on the possible scale and technique effects of TL policies coming into effect. Finally, Domestic Inflation (INF), proxied by the consumer price indices, is taken into account to control for the renewable energy purchasing power aspect of the consumers (Chang, Huang and Lee 2009; Malik *et al.* 2014).

This paper tapped annual data of the aforementioned variables between 2000 and 2017 in the context of 12 Low Income Countries (LIC), 28 Lower Middle-Income Countries (LMIC) and 31 Upper Middle-Income Countries (UMIC) from South Asia, East Asia, Pacific, Central Asia, Latin America, Caribbean Islands and Sub-Saharan Africa. Table 1 (see appendix) reports the names of the countries and their classifications in terms of their respective income groups. The units of measurement and the sources of the dataset used in this paper are provided in Table 2 (see appendix).

5. Methodology

Prior to the regression analyses, this paper performs the Harris-Tzavalis (1999) panel unit root test and applies the Pedroni (2004) residual-based cointegration techniques. The Instrumental Variable Two-Stages Least Squares (IV-2SLS) panel regression estimator is chosen as the preferred regression tool following the problem of endogeneity in the regression models, whereby the use of Ordinary Least Squares (OLS) estimator is inappropriate. The OLS models are tested for endogeneity using the Wooldridge (1991) test for autocorrelation in panel data.

The IV-2SLS estimation technique is applied to analyze structural equations that suffer from the problem of endogeneity. It is basically an alternative to the OLS estimation technique which under endogeneity issues can no longer produce unbiased estimates. Endogeneity problem in panel data is likely to occur following the presence of correlation between the error term and the explanatory variable/s. Under such circumstance, the OLS estimation assumption of the error terms independence of the regressor/s is violated whereby its efficiency to produce unbiased estimates is marginalized. Thus, the IV-2SLS estimation technique accounts for a solution to the endogeneity problem in the models via the incorporation of instruments (Angrist and Imbens 1995; Benda and Corwyn 1997). The choice of the instruments is crucial to determine the outcome of the regression estimates. The instruments are used to modify the problematic endogenous regressor, TO in the context of this paper, being correlated with the error term, should in general be an exogenous variable that can directly affect TO and indirectly influence the four renewable energy outcome variables of the regression models.

The IV-2SLS estimation process basically involves two stages. In the first stage, the instruments are used to transform the endogenous regressor/s, OPEN in the context of this paper, to estimate its predicted value. All the four regression models considered in this paper can be combined and written as:

$$Y_{k,it} = \beta_1 + \beta_2 OPEN_{it} + \beta_j X_{j,it} + \varepsilon_{it} \qquad (5)$$

where Y is the *k* set of the outcome variables (*k=1,…,4*) in four core regression models considered in this paper. OPEN is referred to as the endogenous regressor following its correlation with the error term (ε). In order to instrument OPEN, the Real Exchange Rate (RER), Terms of Trade (TOT) and Tariffs levied on imports (TAR) are used as the IVs. All the three IVs conform to the perquisites of their inclusion into the models whereby these variables are found to be correlated to endogenous variable [i.e. corr (OPEN, RER), corr (OPEN, TOT) and corr (OPEN, TAR) are not equal to zero] and are also independent of the error terms [i.e. corr (RER, ε) = corr (TOT, ε) = corr (TAR, ε) = 0]. In the first stage, OPEN is regressed on the IVs and other regressors to estimate the predicted value P(OPEN) and the regression output can be given as follows:

$$P(OPEN)_{it} = \rho_1 + \rho_2 RER_{it} + \rho_3 TOT_{it} + \rho_4 TAR_{it} + \beta_j X_{j,it} + \varepsilon_{it} \qquad (6)$$

In the second stage, the endogenous variable gets replaced by its predicted value, obtained in the first stage, in equation (5) and is regressed using the OLS estimator. The second stage regression model can be written as:

$$Y_{k,it} = \delta_1 + \delta_2 P(OPEN)_{it} + \beta_j X_{j,it} + \varepsilon_{it} \qquad (7)$$

For robustness check, the Instrumental Variable Random Effects Generalized Least Squares (IV-RE-GLS) panel data regression technique is also employed in this paper.

6. Empirical Results

The **Harris-Tzavalis** (1999) unit root results, reported in table 3, shows that all the variables and the IVs are stationary at their first differences, I(1). This implies that all these variables are mean reverting and therefore the possibility of the regressions being spurious is nullified.

Table 1: Harris-Tzavalis Unit Root Tests Results

Panel	LIC		LMIC		UMIC	
Variable	**Level**	**1st Diff.**	**Level**	**1st Diff.**	**Level**	**1st Diff.**
lnREC	0.78	0.31*	0.76	0.18*	0.65	0.04*
lnRES	0.47	-0.09*	0.61	-0.07**	0.57	-0.03*
lnE_INT	0.68	0.10*	0.66	0.08*	0.64	-0.05*
lnACFT	1.41	0.89**	0.71	0.42*	0.86	0.59**
lnOPEN	0.48	-0.09*	0.63	-0.02*	0.49	-0.04*
lnATE	0.02	-0.021*	0.02	-0.43*	0.34	-0.04*
$lnCO_2$	0.45	-0.19*	0.39	-0.22*	0.69	0.00*
lnOIL_PR	0.70	0.10*	0.70	0.10*	0.70	0.10*
lnNODA	0.49	0.29*	0.02	-0.41*	0.50	-0.18*
lnFDI	0.80	-0.25*	0.32	0.07*	0.53	-0.03*
lnREMIT	0.99	0.31*	1.62	0.35*	0.62	0.12*
lnRGDP	0.78	0.46**	0.51	0.33*	0.50	0.41*
$lnRGDP^2$	0.79	0.59*	0.40	0.21*	0.34	0.30*
lnINF	0.82	0.37*	0.43	0.11*	0.44	-0.09*
lnRER	0.50	0.56*	-0.10	-0.45*	-0.26	0.87*
lnTOT	-0.14	-0.08*	0.64	-0.12*	0.73	0.07*
lnTAR	0.50	-0.50	0.53	-0.19*	0.41	-0.35*

*Notes: The rho-statistics are estimated considering trends; * & ** denote statistical significance at 1% and 5% significance levels.*

Results from the Pedroni (2004) residual-based cointegration test are outlined in Table 4. According to the statistical significances of the estimated statistics, for each of the regression models, it can be inferred that all the variables in the respective regression models move together in the long run.

Table 4: The Pedroni (2004) Cointegration Test Results

Panel	LIC				LMIC				UMIC			
Model	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Statistics												
Within Dimension												
Panel v	-1.19**	2.88*	-2.36*	19.79*	-2.40*	-3.52*	-2.98*	4.05*	-5.23*	-5.30*	-3.17*	6.48*
Panel rho	4.84*	4.54*	5.10*	6.13*	7.11*	7.03*	6.78*	7.09*	7.84*	7.33*	6.08*	5.86*
Panel PP	-1.73*	-4.00*	-0.31	5.32*	-2.59*	-3.30*	-3.46*	0.33	-5.40*	-7.63*	-8.82*	-6.95*
Panel ADF	1.34**	4.51*	6.14*	9.21*	7.38*	5.55*	10.34*	12.52*	6.55*	10.41*	12.97*	10.09*
Between Dimension												
Group rho	6.12*	5.86*	6.29*	6.19*	8.70*	8.71*	8.71*	8.69*	9.72*	9.42*	8.16*	7.69*
Group PP	-1.15	-3.48*	0.04	3.52	-6.08*	-5.16*	-4.51*	1.16	-7.43*	-7.82*	-9.70*	-8.90*
Group ADF	2.97*	6.45*	8.80*	8.98*	11.48*	8.86*	10.38*	14.32*	8.94*	11.07*	13.12*	13.03*
Obvs.	216	216	216	216	504	504	504	504	558	558	558	558

*Notes: The null hypothesis is that the variables are cointegrated. A time trend is considered. The optimal lag selection is based on the Bayesian Information Criterion. * and ** denote statistical significance at 1% and 5 %, respectively.*

As far as the impacts of TL on renewable energy consumption are concerned, the regression results in the context model (1) are reported in Table 5. The findings indicate that lessening trade barriers are effective in inducing greater consumption of renewable energy resources only in the context of the panel of LIC while TL policies are found to dampen renewable energy consumption within the panels of LMIC and UMIC. The IV-2SLS estimates of the elasticities suggest that a 1% rise in OPEN increases REC in the LIC by about 7.49% on average, ceteris paribus while it decreases REC by 1.14% and 0.4% on average for the LMIC and UMIC. A particular reason behind this heterogeneous impact of TL on REC could be interpreted as a possibility that the propensity of incorporation of renewable energy in the national energy mix is comparatively higher in the LIC whereas countries belonging to higher income groups are better-off delaying the transition from non-renewable to renewable energy uses. This presumption can be backed by the signs of the estimated coefficients attached to RGDP and $RGDP^2$ for all the three panels. In the context of the LIC, the association between economic development and consumption of renewable energy is found to be linear as both the coefficients display positive signs. In contrast, non-linear U-shaped associations are found for the LMIC and UMIC. Thus, these findings imply that adoption of REC in the LMIC and UMIC is subject to time lags. Furthermore, the regression results also show that inflows of ODA, FDI and REMIT are also key attributes of REC in the LIC while, on the other hand, REC in the LMIC and UMIC is positively influenced by ODA inflows only.

Along with the impacts on REC, the changes in the RES following implementation of TL policies are also crucial in making conclusions regarding the prospects of RET. Table 6 reports the regression results in the context of model (2). The IV-2SLS estimates show that liberal trade arrangements not only induce greater consumption of renewable energy resources in the LIC, such flexible trade barriers are also key to enhancing the overall share of renewable energy in the total energy consumption in these countries. It is found that a 1% increase in OPEN accounts for a 0.24% rise in the RES on average, ceteris paribus. In contrast, a negative association between OPEN and RES is witnessed in the context of the LMIC since the marginal impact of OPEN, for the nations belonging to this group, is estimated to be a 0.19% decline in the RES, on average ceteris paribus. This is an alarming finding for the development prospects of the LMIC since a negative OPEN-RES nexus implies that TL policies trigger consumption of nonrenewable energy resources in these economies, thus jeopardizing their environmental sustainability targets. However, despite OPEN and REC found to be inversely correlated for the panel of UMIC, it is seen that TL actually elevates the RES of total energy consumption in these economies. This interesting finding denotes that liberal trade arrangements tend to reduce nonrenewable energy consumption more than the reduction in the REC in the UMIC which, to some extent, marginalizes the overall adverse impacts of TL on REC. Apart from OPEN, RES in the LIC and UMIC are also found to be positively influenced by REMIT and NODA respectively.

The regression results in the context of model (3) are tabulated in Table 7. The IV-2SLS estimates for all the three panels show that TL policies are aligned with energy efficiency enhancement goals of the concerned economies. This is evident from the fact that the coefficients attached to OPEN are found to be positive and statistically significant as well. Thus, a 1% rise in OPEN is seen to curb E_INT within the LIC, LMIC and UMIC panels by 0.12%, 0.01% and 0.41% respectively, on average, ceteris paribus. However, a concerning finding was in the form of FDI inflows being ineffective in reducing the intensity of energy use which tend to contradict to the GDG targets of enhancing FDI flows to ensure dissemination of technical expertise in particular. A plausible explanation behind this finding could be the fact that the FDI could be directed at relatively energy-intensive industries.

Finally, Table 8 outlines the regression results in the context of model (4). The IV-2SLS estimates show that TL policies enhance clean cooking fuel access only for the countries included in the LMIC panel while reducing the access for the LIC and UMIC. The estimated coefficient suggest that the marginal impact of a 1% rise in OPEN, on average, increases ACFT by 0.41% in the LMIC panel but it reduces ACFT by 0.37% and 0.21% respectively for the LIC and UMIC panels, ceteris paribus. These key findings can be justified by the assumption that the energy infrastructure within the LMIC are relatively more suited to clean cooking fuel adoption, following a drop in the trade barriers, which unfortunately is not the case in the context of the other two panels. Other than the TL, the findings also point out towards the importance of attracting FDIs into all the three income groups as perceived from the positive and statistically significant estimates of the coefficients attached to FDI. A 1% rise in total FDI inflows into the LIC, LMIC and UMIC is found to boost ACFT by 0.7%, 0.97% and 0.14% on average, holding all else equal, respectively.

For robustness check, this paper also uses the IV-RE-GLS panel data estimator and the estimated coefficients are found to exhibit same signs as the signs of the coefficients estimated using the IV-2SLS estimator.

Table 5: The regression results in the context of model (1)

Dependent Variable: Renewable Energy Consumption (lnREC)															
Panel	Low Income Countries					Lower-Middle Income Countries					Upper-Middle Income Countries				
Estimator	OLS	IV-2SLS		IV-RE-GLS		OLS	IV-2SLS		IV-RE-GLS		OLS	IV- 2SLS		IV-RE-GLS	
Stage		(1)	(2)	(1)	(2)		(1)	(2)	(1)	(2)		(1)	(2)	(1)	(2)
Regressors															
lnOPEN	2.55		7.49*		4.50*	-0.13		-1.14*		-0.09**	0.00		-0.4**		-0.16*
	(2.14)		(2.60)		(1.02)	(1.17)		(0.02)		(0.30)	(0.85)		(0.20)		(0.01)
lnATE	-3.32*	0.27**	-4.49*	0.38***	-2.02**	-1.27*	-0.14	-1.27*	-0.44**	-0.91*	-0.20*	-0.19*	-0.29*	-0.20	0.05
	(0.66)	(0.13)	(1.07)	(0.21)	(1.01)	(0.10)	(0.09)	(0.10)	(0.23)	(0.27)	(0.05)	(0.07)	(0.08)	(0.40)	(0.20)
$lnCO_2$	-276.5*	75.75*	-661.6*	40.39*	-50.97*	-5.31*	3.33***	-5.30*	2.40	0.33	-12.8*	27.67*	-1.54	-7.10*	-0.02
	(73.43)	(7.43)	(212.61)	(12.57)	(24.12)	(1.86)	(1.82)	(1.88)	(1.97)	(1.77)	(2.64)	(3.36)	(5.54)	(-1.04)	(0.21)
lnOIL_PR	1.28	0.57	18.44	5.83	13.39	9.66*	-0.74	9.62*	4.09**	6.71*	4.01	12.24*	-1.04	3.13	-1.17
	(23.11)	(2.84)	(27.89)	(3.64)	(14.21)	(3.82)	(3.70)	(3.79)	(2.00)	(2.51)	(3.37)	(3.59)	(3.50)	(3.12)	(1.42)
lnNODA	-1.51	0.24	4.13**	0.68*	2.53*	1.37*	2.82*	1.38**	-2.17**	1.41	2.43*	-1.81**	1.69**	-1.91	0.15
	(1.29)	(0.26)	(1.07)	(0.22)	(0.97)	(0.53)	(0.76)	(0.70)	(0.94)	(1.24)	(0.79)	(0.68)	(0.80)	(1.94)	(0.62)
lnFDI	0.41	1.30*	6.45***	0.96*	4.54**	1.37	2.27*	0.01	0.49*	0.45	-0.06	0.47**	0.16	0.80*	0.11
	(1.90)	(0.13)	(3.07)	(0.18)	(2.10)	(1.31)	(0.44)	(0.58)	(0.17)	(0.34)	(1.67)	(0.19)	(0.25)	(0.11)	(0.24)
lnREMIT	3.23***	-1.28*	8.20**	-1.47*	3.88**	0.47**	1.53*	0.47	1.40*	1.08**	-0.29	-0.64*	0.35	0.47	-0.60**
	(1.84)	(0.37)	(3.45)	(0.39)	(1.85)	(0.25)	(0.24)	(0.36)	(0.28)	0.62)	(0.17)	(0.23)	(0.24)	(0.88)	(0.25)
lnRGDP	20.55*	-5.32*	43.93*	-1.60	37.05**	1.36*	-0.16	-1.36*	0.72	-1.75**	-0.15*	-0.10	-0.15*	0.03	-0.04
	(7.42)	(0.75)	(15.24)	(3.07)	(18.15)	(0.33)	(0.30)	(0.33)	(0.50)	(0.71)	(0.05)	(0.07)	(0.05)	(0.17)	(0.00)
$lnRGDP^2$	-0.41	0.15*	1.04**	0.05	1.23**	-0.02	0.01***	0.02*	-0.00	0.01**	0.00**	0.00	0.00*	-0.00	0.00
	(0.28)	(0.03)	(0.02)	(0.09)	(0.49)	(0.13)	(0.00)	(0.005)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lnINF	0.46**	0.01	-0.40	-0.07	-0.25	0.004	0.05	0.01	0.04	-0.16	-0.11*	-0.05	-0.17*	0.06	-0.35*
	(0.22)	(0.13)	(0.22)	(0.02)	(0.24)	(0.08)	(0.08)	(0.08)	(0.05)	(0.18)	(0.04)	(0.05)	(0.06)	(0.05)	(0.04)
lnRER		0.00**		0.00*			0.10*		0.00*			0.00*		0.00**	
		(0.00)		(0.00)			(0.00)		(0.00)			(0.00)		(0.00)	
lnTOT		-0.16*		0.11**			0.12*		0.05*			-0.31*		0.17*	
		(0.04)		(0.06)			(0.04)		(0.01)			(0.04)		(0.05)	
lnTAR		-1.014*		1.00*			-1.57*		-1.11**			-0.42		0.16*	
		(0.01)		(0.01)			(0.40)		(0.52)			(0.34)		(0.05)	
Const.	185.5***	68.29*	-123.9*		96.90	190.8*	52.3**	191.1*		180.9*	78.8*	75.80*	99.5*		43.92*
	(107.08)	(30.01)	(99.49)		(130.32)	(17.7)	(20.30)	(19.56)		(34.41)	(10.4)	(14.33)	(16.2)		(14.09)
R^2/Adj. R^2	0.57	0.61	0.46		0.46	0.52	0.49	0.52		0.40	0.61	0.39	0.51		0.29
F-Stat. +	27.64*					42.29*					90.92*				
Wald chi^2			111.63*		4058.7*			612.9*		106.6*			70.1*		22.8**
Wald Chi				229.1*					1066*					15304*	
Obvs.	216	216	216	216	216	504	504	504	504	504	558	558	558	558	558

*Notes: The robust standard errors are reported within the parentheses. *,**, and *** denote statistical significance at 1%, 5% & 10% levels. + denotes the F-Statistic of the Wooldridge (1991) Test for Autocorrelation in Panel Data.*

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

Dependent Variable: Renewable Energy Share (lnRES)															
Panel	**Low Income Countries**					**Lower-Middle Income Countries**					**Upper-Middle Income Countries**				
Estimator	**OLS**	**IV-2SLS**		**IV-RE-GLS**		**OLS**	**IV-2SLS**		**IV-RE-GLS**		**OLS**	**IV- 2SLS**		**IV-RE-GLS**	
Stage		**(1)**	**(2)**	**(1)**	**(2)**		**(1)**	**(2)**	**(1)**	**(2)**		**(1)**	**(2)**	**(1)**	**(2)**
Regressors															
lnOPEN	0.10		0.24**		0.05	-0.09		-0.19*		-0.20**	-0.01		0.09*		0.19**
	(0.15)		(0.013)		(0.05)	(0.19)		(0.01)		(0.08)	(0.02)		(0.00)		(0.09)
lnATE	-0.31*	0.27**	-0.34*	0.38**	0.10***	-0.52*	-0.14	-0.52*	-0.44**	-0.43*	-0.18*	-0.19	-0.19*	-0.20	-0.17**
	(0.06)	(0.13)	(0.06)	(0.21)	(0.06)	(0.03)	(0.09)	(0.03)	(0.22)	(0.06)	(0.04)	(0.72)	(0.05)	(0.40)	(0.07)
$lnCO_2$	-39.46*	75.74*	-50.54*	40.39*	-21.63*	-11.5*	3.33**	-11.53*	2.40	-1.42	-23.6*	27.66*	-21.5*	-7.10*	-5.64***
	(6.78)	(7.42)	(17.78)	(13.57)	(6.44)	(1.39)	(1.52)	(1.38)	(1.97)	(0.88)	(1.59)	(3.36)	(2.95)	(2.22)	(3.27)
lnOIL_PR	0.82	0.57	1.31**	5.83	0.41	-1.51	-0.74	1.45	4.10	-0.60	4.46*	12.24*	3.82**	3.13	0.23
	(1.98)	(2.84)	(0.66)	(3.64)	(0.82)	(1.43)	(3.70)	(1.43)	(2.89)	(1.28)	(1.58)	(3.59)	(1.93)	(3.13)	(1.00)
lnNODA	0.03	0.24	-0.04	0.68*	0.28	0.20	2.82*	-0.23*	-2.17**	-0.44**	1.91*	-1.8***	1.77*	-1.91	0.56
	(0.14)	(0.26)	(0.16)	(0.22)	(0.17)	(1.99)	(0.76)	(0.08)	(0.94)	(0.19)	(0.63)	(0.98)	(0.62)	(1.94)	(0.40)
lnFDI	0.09	1.30*	-0.10	0.96*	-0.05	-0.01	2.28*	0.02	0.49*	0.09	0.03	0.47**	0.08	0.78*	0.12
	(0.09)	(0.13)	(0.30)	(0.18)	(0.05)	(0.14)	(0.44)	(0.24)	(0.17)	(0.14)	(0.10)	(0.19)	(0.13)	(0.11)	(0.13)
lnREMIT	0.27***	-1.28*	0.41***	-1.47*	0.24**	-0.28*	1.53*	-0.26**	1.40*	0.10	0.39**	-0.64*	-0.40**	0.47	-0.08
	(0.16)	(0.37)	(0.23)	(0.39)	(0.11)	(0.09)	(0.24)	(0.12)	(0.28)	(0.14)	(0.16)	(0.23)	(0.16)	(0.88)	(0.18)
lnRGDP	0.08	-5.32*	0.76*	1.60	2.02*	0.43*	-0.16	0.42*	0.72	0.22	-0.16*	-0.10	-0.16*	0.02	-0.02
	(0.69)	(0.75)	(0.14)	(3.07)	(0.52)	(0.13)	(0.30)	(0.13)	(0.50)	(0.26)	(0.04)	(0.07)	(0.04)	(0.17)	(0.04)
$lnRGDP^2$	0.02	0.15*	0.00	-0.05	0.07*	-0.01*	0.01***	-0.01*	-0.00	-0.00	0.00	0.00	0.00**	-0.00	0.00
	(0.02)	(0.03)	(0.00)*	(0.09)	(0.02)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.34)	(0.00)	(0.00)	(0.00)	(0.00)
lnINF	0.01	0.01	0.02	-0.07*	0.02*	0.00	0.05	0.00	0.03	0.05*	-0.12	-0.05	-0.14*	0.06	0.13*
	(0.10)	(0.02)	(0.01)	(0.02)	(0.00)	(0.03)	(0.08)	(0.34)	()0.05	(0.02)	(0.13)	(0.05)	(0.04)	(0.05)	(0.01)
lnRER		0.00**		0.00*			0.00*		0.00*			0.00*		0.00**	
		(0.00)		(0.00)			(0.00)		(0.00)			(0.00)		(0.00)	
lnTOT		-0.16*		-0.01*			0.12*		-0.01			-0.31*		-0.04*	
		(0.04)		(0.00)			(0.04)		(0.01)			(0.03)		(0.00)	
lnTAR		-0.114*		-0.02*			-0.77*		0.01			-0.42*		0.03	
		(0.01)		(0.00)			(0.13)		(0.02)			(0.08)		(0.08)	
Const.	90.52*	68.29*	81.61*		79.13*	104.1*	52.25*	104.6*		94.20*	84.8*	75.80*	89.1*		61.68*
	(9.50)	(10.51)	(17.12)		(7.32)	(6.43)	(20.30)	(7.23)		(8.57)	(7.80)	(14.33)	(9.74)		(11.84)
R^2/Adj. R^2	0.52	0.62	0.50		0.51	0.76	0.34	0.76		0.36	0.34	0.21	0.32		0.31
F-Stat. +	10.50*					47.35*					86.99*				
Wald chi^2			404.9*		8034.2*			1961.8*		156.8*			411.1*		22.8**
Wald Chi				23046*										15304*	
Obvs.	216	216	216	216	216	504	504	504	504	504	558	558	558	558	558

*Notes: The robust standard errors are reported within the parentheses. *,**, and *** denote statistical significance at 1%, 5% & 10% levels. + denotes the F-Statistic of the Wooldridge (1991) Test for Autocorrelation in Panel Data.*

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

Dependent Variable: Energy Intensity (lnE_INT)															
Panel	**Low Income Countries**					**Lower-Middle Income Countries**					**Upper-Middle Income Countries**				
Estimator	**OLS**	**IV-2SLS**		**IV-RE-GLS**		**OLS**	**IV-2SLS**		**IV-RE-GLS**		**OLS**	**IV- 2SLS**		**IV-RE-GLS**	
Stage		**(1)**	**(2)**	**(1)**	**(2)**		**(1)**	**(2)**	**(1)**	**(2)**		**(1)**	**(2)**	**(1)**	**(2)**
Regressors															
lnOPEN	-0.03		-0.12*		-0.02**	-0.00		-0.01**		-0.01*	-0.01		-.041**		-0.00*
	(0.10)		(0.04)		(0.01)	(0.00)		(0.00)		(0.00)	(0.21)		(0.02)		(0.00)
lnATE	0.05*	0.27**	0.07*	0.38***	0.02**	0.05*	-0.14	0.05*	-0.44**	0.72*	0.01***	-0.19*	0.02*	-0.20	0.05*
	(0.01)	(0.13)	(0.02)	(0.21)	(0.01)	(0.01)	(0.09)	(0.01)	(0.22)	(0.03)	(0.01)	(0.07)	(0.01)	(0.40)	(0.02)
lnCO$_2$	0.48	75.74*	7.54**	40.39*	-0.31	-2.47*	3.33***	-2.44*	2.40	-0.71	-5.88*	27.68*	-7.26*	-7.10	-5.95*
	(0.73)	(7.43)	(3.05)	(13.57)	(0.61)	(0.25)	(1.82)	(0.24)	(1.97)	(0.28)	(0.25)	(3.36)	(0.46)	(10.25)	(0.54)
lnOIL_PR	0.32	0.56	0.01	5.83***	0.26***	1.51*	-0.74	1.54*	4.10	1.27*	1.54*	12.24*	1.18*	3.13	1.13*
	(0.27)	(2.84)	(0.38)	(3.01)	(0.16)	(0.33)	(3.70)	(0.34)	(2.87)	(0.42)	(0.24)	(3.59)	(0.34)	(3.13)	(0.28)
lnNODA	-0.03	0.24	-0.01	0.68*	-0.05	-0.18	2.82*	-0.17*	2.40	-0.03	0.02	-1.81***	0.11	-1.91	-0.08
	(0.02)	(0.26)	(0.03)	(0.22)	(0.21)	(0.40)	(0.76)	(0.05)	(1.97)	(0.07)	(0.08)	(0.98)	(0.10)	(1.94)	(0.16)
lnFDI	0.02	1.30*	0.14**	0.95*	0.04**	-0.01	2.28*	-0.02	4.10	-0.03	0.01	0.47**	-0.02	0.80*	-0.01
	(0.02)	(0.13)	(0.03)	(0.18)	(0.01)	(0.02)	(0.44)	(0.04)	(2.87)	(0.03)	(0.01)	(0.19)	(0.02)	(0.11)	(0.03)
lnREMIT	-0.01	-1.28*	-0.10***	-1.47*	0.02**	-0.09*	1.53*	-0.08*	-2.17**	-0.01	-0.10*	-0.64*	-0.09*	0.47	-0.12**
	(0.02)	(0.37)	(0.05)	(0.39)	(0.00)	(0.02)	(0.24)	(0.02)	(0.94)	(0.04)	(0.02)	(0.23)	(0.03)	(0.88)	(0.05)
lnRGDP	-0.08	-5.32*	-0.50**	1.60	-0.34*	-0.02	-0.16	-0.02	0.49*	-0.12*	0.01	-0.10	0.01	0.03	-0.02
	(0.09)	(0.75)	(0.21)	(3.07)	(0.11)	(0.03)	(0.30)	(0.03)	(0.17)	(0.04)	(0.01)	(0.07)	(0.01)	(0.17)	(0.01)
lnRGDP^2	-0.00	0.15*	0.01***	-0.05	0.01*	0.00	0.01***	0.00		0.00**	-0.00**	0.00	-0.00	-0.00	0.00
	(0.00)	(0.03)	(0.01)	(0.09)	(0.00)	(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lnINF	-0.01*	0.01	-0.00***	-0.07*	0.00	-0.01	0.05	-0.01		-0.01	-0.02*	-0.05	-0.01**	0.06	-0.00
	(0.00)	(0.02)	(0.00)	(0.02)	(0.00)	(0.01)	(0.08)	(0.01)		(0.01)	(0.01)	(0.05)	(0.01)	(0.05)	(0.01)
lnRER		-0.00**		0.00*			0.00*		0.00*			0.00*		0.00**	
		(0.00)		(0.00)			(0.00)		(0.00)			(0.00)		(0.00)	
lnTOT		0.16*		-0.00*			0.12*		-0.01*			-0.31*		-0.23*	
		(0.04)		(0.00)			(0.04)		(0.00)			(0.04)		(0.05)	
lnTAR		-0.01		-0.02*			-0.57*		0.01			-0.42		0.21	
		(0.00)		(0.00)			(0.04)		(0.23)			(0.34)		(0.52)	
Const.	3.55*	68.29*	9.22*		4.84*	1.54	52.25**	1.78		0.13	6.49*	75.80*	3.53**		5.16**
	(1.28)	(10.50)	(2.94)		(1.11)	(1.48)	(20.30)	(1.51)		(2.32)	(2.07)	(14.33)	(1.55)		(2.32)
R^2/Adj. R^2	0.42	0.62	0.41		0.63	0.38	0.34	0.43		0.48	0.59	0.41	0.41		0.56
F-Stat. +	26.27*					45.77*					47.02*				
Wald chi^2			127.97*		2668.7*			298.40*		240.4			300.4*		281.1*
Wald Chi				23022*					10664*					15304*	
Obvs.	216	216	216	216	216	504	504	504	504	504	558	558	558	558	558

*Notes: The robust standard errors are reported within the parentheses. *,**, and *** denote statistical significance at 1%, 5% & 10% levels. + denotes the F-Statistic of the Wooldridge (1991) Test for Autocorrelation in Panel Data.*

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

Dependent Variable: Access to Clean Fuel and Technology (lnACFT)															
Panel	**Low Income Countries**					**Lower-Middle Income Countries**					**Upper-Middle Income Countries**				
Estimator	**OLS**	**IV-2SLS**		**IV-RE-GLS**		**OLS**	**IV-2SLS**		**IV-RE-GLS**		**OLS**	**IV- 2SLS**		**IV-RE-GLS**	
Stage		**(1)**	**(2)**	**(1)**	**(2)**		**(1)**	**(2)**	**(1)**	**(2)**		**(1)**	**(2)**	**(1)**	**(2)**
Regressors															
lnOPEN	0.03		-0.37*		-0.07*	0.08		0.41*		0.33*	0.02		-0.21*		-0.07**
	(0.05)		(0.15)		(0.01)	(0.12)		(0.15)		(0.10)	(0.02)		(0.04)		(0.34)
lnATE	0.54*	0.27**	0.64*	0.38***	0.01	0.55*	-0.14	0.58*	-0.44**	0.51*	0.78*	-0.19*	0.73*	-0.20	0.71*
	(0.05)	(0.13)	(0.07)	(0.21)	(0.10)	(0.04)	(0.09)	(0.05)	(0.22)	(0.09)	(0.04)	(0.07)	(0.04)	(0.43)	(0.18)
$lnCO_2$	-5.82	75.74*	25.77**	40.39*	-3.50*	7.52*	3.33***	6.33*	2.39	-0.54	0.40	27.68*	6.72*	-7.10*	-9.70*
	(5.33)	(7.43)	(12.81)	(13.57)	(0.01)	(1.06)	(1.82)	(1.20)	(1.97)	(1.92)	(1.32)	(3.36)	(1.80)	(2.11)	(1.92)
lnOIL_PR	-0.98	0.57	-2.38	5.83	-0.61	1.90	-0.74	0.27	4.09**	0.37	2.69***	12.24*	4.35*	3.13	1.32***
	(1.49)	(2.84)	(1.96)	(3.64)	(1.45)	(1.67)	(3.70)	(2.12)	(2.01)	(1.21)	(1.39)	(3.59)	(1.54)	(3.12)	(0.70)
lnNODA	-0.66*	0.24	-0.44***	0.68*	-0.13*	-0.51**	2.82*	-1.38**	-2.17**	-0.41	-4.83*	-1.81***	-5.25*	-1.91	-2.00*
	(0.25)	(0.26)	(0.26)	(0.22)	(0.01)	(0.24)	(0.76)	(0.56)	(0.94)	(0.36)	(0.74)	(0.98)	(0.80)	(1.94)	(0.60)
lnFDI	0.13	1.30*	0.70*	0.96*	0.109*	-0.18	2.28*	0.97**	0.49*	0.20*	0.01	0.47**	0.14***	0.80*	0.03
	(0.11)	(0.13)	(0.34)	(0.18)	(0.03)	(0.12)	(0.44)	(0.43)	(0.17)	(0.07)	(0.08)	(0.19)	(0.08)	(0.11)	(0.11)
lnREMIT	0.52*	-1.28*	0.11	-1.47*	0.62	0.83*	1.53*	0.42*	1.40*	0.04*	-0.17	-0.64*	-0.20	0.47	-0.52***
	(0.12)	(0.37)	(0.23)	(0.39)	(0.30)	(0.14)	(0.24)	(0.06)	(0.28)	(0.00)	(0.17)	(0.23)	(0.18)	(0.88)	(0.27)
lnRGDP	1.22**	-5.32*	-0.69	1.60	-0.69	-0.77*	-0.16	-0.72*	0.72	-0.46***	0.08**	-0.10	0.08**	0.03	-0.07***
	(0.52)	(0.75)	(0.83)	(3.77)	(1.11)	(0.18)	(0.30)	(0.20)	(0.50)	(0.27)	(0.03)	(0.07)	(0.04)	(0.17)	(0.04)
$lnRGDP^2$	-0.01	0.15*	0.04	-0.05	0.23	0.01*	0.01***	0.01***	-0.00	0.00	-0.00*	0.00	-0.00*	-0.00	0.00***
	(0.02)	(0.03)	(0.03)	(0.09)	(0.33)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lnINF	0.00	0.01	0.01***	-0.07*	0.01	0.15*	0.05	0.13**	0.03	0.02	0.12*	-0.05	0.09*	0.56*	-0.01
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.06)	(0.08)	(0.06)	(0.05)	(0.04)	(0.03)	(0.05)	(0.03)	(0.06)	(0.01)
lnRER		0.00**		0.00*			0.00*		0.00*			0.00*		0.00**	
		(0.04)		(0.00)			(0.00)		(0.00)			(0.00)		(0.00)	
lnTOT		-0.16*		-0.00*			0.12*		0.05			-0.31*		-0.06*	
		(0.04)		(0.00)			(0.04)		(0.04)			(0.04)		(0.01)	
lnTAR		-0.01		-0.41*			-0.57		-1.11**			-0.42*		0.05	
		(0.01)		(0.00)			(0.40)		(0.52)			(0.02)		(0.12)	
Const.	-10.70	68.29*	14.70		10.62	-17.21*	52.25*	-29.60*		-18.57*	-8.65	75.80*	4.88		11.97*
	(7.89)	(10.51)	(13.53)		(10.02)	(7.53)	(20.30)	(10.50)		(2.89)	(7.18)	(14.32)	(8.84)		(2.21)
Adj. R^2	0.80	0.62	0.69		0.49	0.69	0.35	0.54		0.49	0.50	0.30	0.43		0.67
F- Stat. +	137.14*					26.10*					159.10*				
Wald Chi^2			589.94*		88455*			1105.9*		73.43*			607.9*		317.42*
Wald Chi				22867*					10664*					15304*	
Obvs.	216	216	216	216	216	504	504	504	504	504	558	558	558	558	558

*Notes: The robust standard errors are reported within the parentheses. *,**, and *** denote statistical significance at 1%, 5% & 10% levels. + denotes the F-Statistic of the Wooldridge (1991) Test for Autocorrelation in Panel Data.*

6. Conclusions

Globalization through liberal trade and financial arrangements seem to be a common global macroeconomic tool to attain development. However, disaggregation of the development process into socioeconomic and environmental development, in a sustainable manner, calls for efficient management of the liberalization strategies. In particular, TL policies are welfare enhancing only if the associated costs can be internalized. For instance, from the perspective of energy and environmental sustainability, enhancing openness to trade should ideally induce RET which not would be exemplary in curbing the greenhouse emission intensities but would also supplement the non-renewable energy resources in matching the persistent growth in demand for energy. Against this backdrop, this paper aimed at analyzing the dynamics of REC behavior in the low, lover middle and upper middle income countries.

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Appendix

Table 1: List of the 71 countries considered in this paper

Low Income (12)	Lower Middle Income (28)	Upper Middle Income (31)
Benin	Angola	Albania
Democratic Republic of Congo	Bangladesh	Armenia
Ethiopia	Bolivia	Azerbaijan
Haiti	Cambodia	Belarus
Niger	Cameroon	Bosnia and Herzegovina
Mozambique	Republic of Congo	Botswana
Nepal	Cote d' Ivoire	Brazil
Senegal	El Salvador	Bulgaria
Tajikistan	Georgia	Columbia
Tanzania	Ghana	Costa Rica
Togo	Honduras	Dominican Republic
Zimbabwe	India	Ecuador
	Indonesia	Gabon
	Kenya	Guatemala
	Kyrgyz Republic	Jamaica
	Moldova	Kazakhstan
	Mongolia	Macedonia
	Myanmar	Malaysia
	Nicaragua	Mauritius
	Nigeria	Mexico
	Pakistan	Montenegro
	Philippines	Namibia
	Sri Lanka	Paraguay
	Sudan	Peru
	Ukraine	Romania
	Uzbekistan	Serbia
	Vietnam	South Africa
	Zambia	Suriname
		Thailand
		Turkey
		Venezuela

Table 2: Description and Source of the Dataset

Variable	Units	Source
REC	kg of oil equivalent	World Development Indicator (2018)
RES	percentage	
E_INT	kg of oil equivalent per $1,000 GDP	
ACFT	percentage of population	
OPEN	percentage of GDP	
ATE	percentage of population	
CO_2	kg per US$ of GDP	
NODA	million US$	
FDI	million US$	
REMIT	million US$	
RGDP	million US$	
$RGDP^2$	million $US\$^2$	
INF	percentage	
RER	local currency unit per US$	
TOT	Index	
TAR	percentage	
OIL_PR	US $	BP Statistical Review of World Energy