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# Energy Transition, Human Development and Energy Justice in the Southern Countries

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**Abstract** Energy poverty deteriorates the human capital and the growth potential in the developing and emerging countries. We estimate the long-run effect of electricity access, modern renewable energy consumption, and traditional renewable energy consumption on human development (index). We use an AutoRegressive Distributed Lag/ARDL model based on pooled mean group estimation for a panel of 44 southern countries, representing three energy-poor regions of the world over the period 1990-2018. By distinguishing two groups of countries according to their level of HDI, we show that it exists a positive and significant relationship between electricity access and human development in countries with low and medium HDI and a positive effect of modern renewable energy on the level of human development in countries with higher HDI. In addition, the estimations reveal a significant negative effect of conventional renewable energy use on human development for the two countries groups.

**Keywords:** Energy justice, Energy Access, Electricity Access, Modern Renewable Energy, Traditional Renewable Energy, Human Development

*JEL Classifications: C23, I30, O10, Q40*

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# I. Introduction

The last decades have been marked by an acceleration of the globalization process, which has been accompanied by an increase in industrial production and the use of raw materials to meet the ever-increasing global demand for goods. Excessive consumption of non-renewable natural resources (whose stock is limited on a human scale), the deterioration of the environment or the imbalance of social development in the world, have become increasingly worrying for decision-makers in both rich and developing countries.

In addition to these challenges, the energy sector is facing three major transformations:

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climate change, security of supply and energy poverty. While the problems related to climate change (cf. IPCC reports) or to the security of energy supply are at the heart of the concerns of economists and policy makers alike, paradoxically energy poverty has received much less attention. Energy poverty is often defined as a household's difficulty in meeting its basic energy needs for housing or transport, due to inadequate resources or housing conditions. Another widely used definition considers a household to be in energy poverty when it spends more than 10% of its income on energy. Yet Energy poverty is a major problem in both emerging and developed countries. While in developed countries, energy poverty is mainly due to high-energy prices, which penalize low-income households, in emerging and developing countries it is the infrastructure that is lacking, which means that many households have no access to energy services and particularly to electricity.

Thus, addressing energy poverty is both about energy justice and about the socio-economic dimension. On one side, energy poverty is an energy justice issue. Energy justice is a growing field of study and practice that focuses on social justice in energy systems (McCauley, 2018). For example, the global energy system has revealed a range of inequalities that need to be addressed (Stern, et al., 2016). On other side, energy poverty is a social, economic, and health problem exacerbated by economic disruption, climate change, and technological advances. It can impair physical and mental health and lead to educational inequalities. This implies that energy poverty can affect people's well-being, or in other words human development. Energy underpins all development and its availability underpins the satisfaction of all basic human needs, access to affordable, reliable, and sustainable energy will be an essential condition for any form of development (IEA, 2014).

Among energy access sources available for emerging and developing countries, access to secondary energy in the form of electricity is an important marker for characterizing greater or lesser energy poverty. In a recent report (The Energy Progress Report, 2019) the IEA reminds us that nearly one billion people today live without access to electricity, while hundreds of millions more have insufficient or unreliable access. In addition, 95% of people without access to energy services live in Asia and Sub-Saharan Africa (SSA).

The aim of this article is therefore to study the impact of access to energy on human development in a panel of emerging and developing countries, and thus enrich an area of research that has been little investigated to date.

Since the publication of the first UNDP Report in 1990 (UNDP, 1990), the Human Development Index (HDI) has been an important alternative to the traditional unidimensional measure of development. In this perspective, this paper examines the long-term effects of energy access, on the HDI of 44 countries from the three most energy-poor regions of the world, namely Sub-Saharan Africa, South Asia and Latin America and the Caribbean. Access to energy will be measured alternatively by access to electricity, by modern renewable energy consumption and by traditional renewable energy consumption. The study will cover the period 1990-2018[1].

The remainder of this paper will be organized as follows. Section 2 provides a brief overview of the empirical literature on the relationship between energy consumption and human development. Section 3 describes the trend in electricity access and renewable energy development in the countries of the South. Section 4 illustrates the empirical methodology adopted to estimate the long-term effect of energy access on the human development index. The results are discussed in Section 5. Section 6 presents a robustness review. Section 7 concludes this work.

# II. Brief Overview of the Empirical Literature

We focus on the literature on the relationship between energy consumption and human development and complete by a brief overview of empirical research that addresses the contribution of energy access to development.

## A. Energy consumption and human development

The empirical literature has focused both on the total effect of energy consumption on human development, but also on the specific effects associated with the use of different forms of primary energy, particularly renewable energy and biomass.

Martinez and Ebenhack (2008) examined the relationship between Human Development Index (HDI) values and per capita energy consumption values for 120 nations. They show that there is a strong correlation between HDI values and energy consumption for the majority of the world's countries. These correlations reveal that considerable improvements in human development are possible for the world's poorest countries with a small increase in the level of energy access.

Furthermore, Ouedraogo (2013) examined the relationship between energy consumption and human development for 15 developing countries over the period 1988-2008 using a panel error correction model. He highlights a negative long-run relationship between energy consumption and human development such that a 1% increase in energy consumption per capita reduces the HDI by 0.8%. On the other hand, he finds a positive long-run relationship from electricity consumption to HDI. For their part, Nui et al. (2013) analyzed the causal relationship between electricity consumption and human development for a set of 50 countries classified into four groups according to income level, over the period 1990-2009. Five indices are used to report the level of human development: GDP per capita, consumption expenditure per capita, urbanization rate, life expectancy at birth, and adult literacy rate. Their results confirm the

1) Our study period is limited to 2018 due to the availability of data on traditional and modern renewable energy consumption in most developing and emerging countries.

existence of a long-term bidirectional causality between electricity consumption and the five indicators. Moreover, as a country's income increases, the contribution of electricity consumption to its level of human development increases. These results are also consistent with those of Martinez al. (2008) and Mazur (2011), confirming that any improvement in energy or electricity consumption can lead to significant improvements in human development levels.

On the other hand, Satrovic (2018) and Pîrlogea (2012), found a positive relationship between renewable energy consumption and human development. Conversely, Wang. Z et al. (2018), examining the relationship between renewable energy consumption, economic growth and human development index for the period 1990-2014 in Pakistan conclude that there is no effect of renewable energy consumption on human development. To the extent that human development can be used in place of concepts such as economic or socioeconomic development, Bello (2015) focuses on the link between renewable energy and socioeconomic development in Sub-Saharan African countries. He shows that renewable energy resources can contribute to socioeconomic activities when fully and appropriately exploited. Similarly, on a panel analysis of 21 African countries for the period 1990-2013, Ergun et al (2019) conclude that in countries with high HDI and GDP per capita, the proportion of renewable energy in their energy mix is lower.

Finally, if we look at biomass, it is an essential primary energy for many developing countries and its use poses many public health problems and is generally a drag on economic and social development. Birol (2007) and Kaygusuz (2011) have shown that inefficient use of traditional biomass negatively affects health, limits educational development, exacerbates local ecological damage, and can cause a vicious cycle of lack of economic and social development. Furthermore, for Kaygusuz (2011) particularly harmful effects affect the health of women who use traditional biomass as fuel for cooking and are therefore the most exposed and vulnerable to indoor air pollution. Furthermore, in their Millennium Development Goal (MDG) reports, Takada and Fracchia (2007) concluded that the use of traditional biomass fuels condemns many children to the daily chore of collecting firewood and other exhausting manual labor, which deprives them of school attendance and homework. Finally, the World Health Organization (2006) concludes that indoor lighting creates a better learning environment for students, especially by allowing them to study at night, and reduces the risk of visual impairment. Conversely, people exposed to indoor air pollution from biomass burning by conventional equipment are more likely to suffer from inflammatory diseases of the respiratory system as well as immune system disorders. Therefore, a modern energy supply can be expected to improve the quality of children's education and promote economic growth (Thiam (2011), Wang and Jiao (2005)).

## B. Energy access, renewable energy and human development

While the use of different energy sources can have beneficial effects on economic and social development, unfortunately not all developing countries have the same opportunities to access this energy. For example, access to secondary energy in the form of electricity is essential for generating employment, improving education levels and health status of the population, and ensuring sustainable development. While most empirical research has examined the effects of energy consumption on human development, the impact of energy accessibility remains poorly analyzed despite being fundamental to understanding energy poverty.

Gaye (2007) shows that access to electricity in Sub-Saharan Africa, the Caribbean, Latin America and South Asia is essential for improving basic services such as education, health, security, water and communication services. In this context, the link between electrification and the different determinants of the human development index can be decisive. Pereira et al (2010) assess the impact of rural electrification on energy poverty reduction in Brazil by analyzing 23,000 rural households or properties over the period 2000-2004. Their findings highlight that lack of electricity exacerbates poverty and may contribute to its persistence. Similarly, Pereira et al (2011) revisit the concept of the energy poverty line, attempting to refine its application to Brazilian social and economic realities. They analyze the effectiveness of the latest efforts in Brazil to expand access to electricity by applying an analytical framework using the Lorenz curve, the Gini coefficient and Sen's index. Among other things, this analysis reveals that rural electrification can lead to a significant reduction in energy poverty, and thus to an improvement in energy equity. Sapkota (2014) estimates the impacts of several infrastructure variables, including access to electricity, on the human development index and its three constituent indices, using panel data on 91 developing countries for the period 1995-2010. The dynamic GMM estimation leads to the conclusion that electricity access has significant and positive effects on the human development, education, and health indices. More recently, Acheampong et al (2021) showed on a panel of 79 countries in the Caribbean and Latin America, Sub-Saharan Africa and South Asia that access to electricity and clean energy improves human development.

As for the effects of energy poverty, González-Eguino (2015) notes that despite the emphasis on the issue of energy accessibility, there is a limited conceptual understanding of energy poverty in the human development pathway, especially in energy-poor regions of the world. Han Phoumin and Fukunari Kimura (2019) investigate the potential impact of energy poverty on the social well-being of the population in Cambodia using the latest data from the Cambodia Socio-Economic Survey 2015 (CSES 2015). The results suggest that the impacts of energy poverty on well-being are negative and statistically significant. Using survey data, Rafi et al (2021) investigate the effect of energy poverty on human capital development and show that an increase in energy poverty is associated with a decrease in human development performance.

Given the results available in the literature, the purpose of our work is to contribute to the debate on the relationship between energy access and human development in the case of developing and emerging countries. Our contribution is twofold. Firstly, we study the effects of energy accessibility on human development in 44 emerging and developing countries subdivided into two groups according to their level of human development and representing the world's three poorest energy regions. Secondly, our research also measures the impact of the use of traditional and modern renewable energies on human development of its countries.

To do so, we will analyze the long-term effect of traditional and modern renewable energy use on human development in a panel of 44 countries from the three poorest energy regions, over the period 1990-2018. The ARDL-PMG model is preferred for this purpose to estimate the long-run effect and the two-stage least squares (2SLS) approach to control for endogeneity. The effects of access to electricity and the use of renewable energies on human development in developing countries remains insufficiently studied to date.

## III. Electricity Access and Renewable Energy in Developing Countries

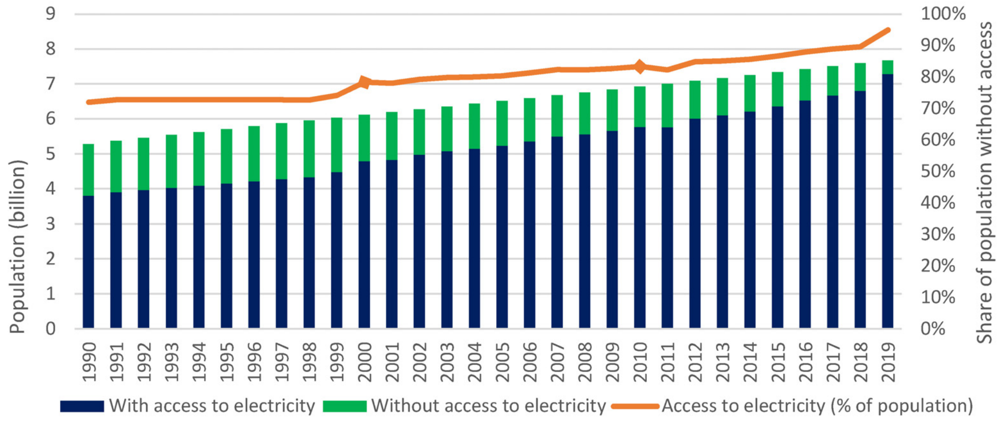
### A. Current status and trends in global energy access

In recent years, access to electricity has expanded rapidly through the accelerating deployment of affordable electrification options, particularly on- and off-grid solutions. Consequently, the proportion of people with access to electricity in the world has risen to over 94% in 2019 from 72% in 1990, providing access to over 1 billion people over the period. There were still 390 million people lacking access to electricity in 2019, compared to 1.48 billion in 1990 (Figure 1).

At the regional level, global progress in access to electricity since 2010 masks uneven levels of progress between the world's regions, prioritizing Sub-Saharan Africa (SSA). Both Latin America and the Caribbean (LAC) and East and Southeast Asia (SA) have moved closer to achieving universal access, reaching more than 98 percent electricity access in 2018. Over a 92 % of the population in Central and South Asia had access to electricity in 2018.

This expansion of the population gaining access to electricity was primarily due to electrification efforts in Central and South Asia, with an annual mean of 66 million people gained electricity access during 2010-2018. Regarding SSA, although electrification has exceeded demographic growth over 2016 to 2018, in recent years, electricity access growth has remained below demographic growth. This was manifested by an annual net increase of nearly 0.3 million people lacking access to electricity in the region during 2016-2018, mainly due to a slowing down in two major access-deficient African countries, notably the Democratic Republic of Congo (DRC) and Nigeria.

**Figure 1.** World energy access trend for the period 1990-2019

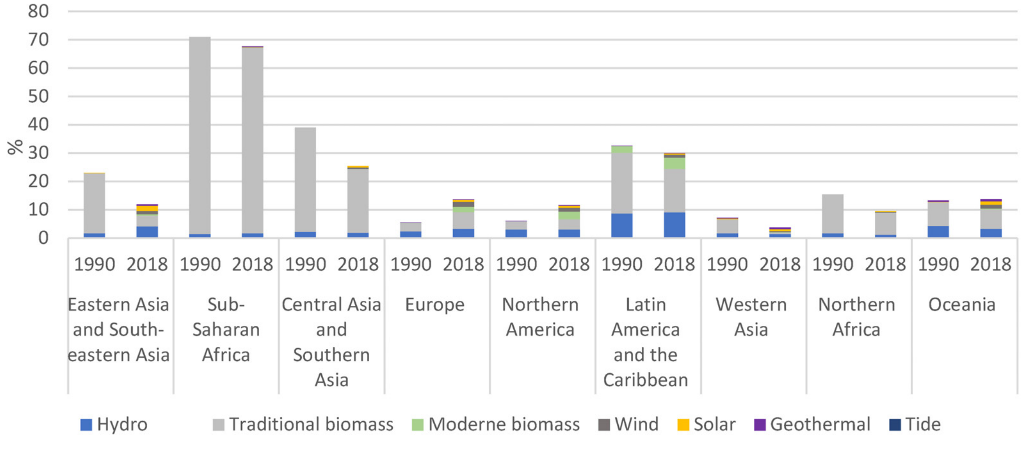



(Source) WDI data

## B. The place of renewable energies in the world energy mix

During recent years, while the renewables market has been relatively stable, many developing and emerging economies have continued to expand their renewable energy deployment. This has contributed to greater accessibility to energy for households in isolated regions of these economies.

**Figure 2.** Share of renewable energy consumption by technology 1990-2018




(Source) IEA, et al., 2020

According to the IRNA statistics report (IRENA, 2021), renewable energies have seen unprecedented growth over the past decade. The share of renewable energy in the total final energy consumption (TFEC), including biomass, has increased from 16.5% to 18.1% over the period between 1990 and 2018, (Figure 2). This increase has been marked, on the one hand, by a decline of the share of traditional renewable energy, from 9.9% in 1990 to 7.56% in 2018, and on the other hand by an increase of the share of modern renewables from 6.6% in 1990 to 10.6% in 2018.

Regionally, in 2018, SSA had the largest share of renewables in its total energy mix, with traditional biomass uses accounting for over 85% of that share. Excluding traditional biomass sources, LAC had the largest share of modern renewables in the TFEC. Europe and North America together account for 43% of the annual increase in modern renewable energy uses. This is due to the consumption of bioenergy for heat, good hydroelectricity generation conditions in Europe, and growing contributions from wind and solar photovoltaics. Although biomass in its traditional form is, in principle, renewable, policy makers should encourage the use and adoption of more efficient technologies for heating and cooking. Therefore, in order to achieve the 7th SDG and to ensure affordable, reliable and sustainable energy access, the adoption of modern renewable energy and the transition to a more efficient use of biomass must be accelerated.

# IV. Empirical Methodology

## A. The sample

According to Ritchie and Roser (2020), about 591 million of Sub-Saharan Africa's total population, 255 million of South Asia's total population, and 14 million of Latin America and the Caribbean's total population lack access to electricity. In order to contribute to the empirical literature, the aim of this research is to investigate the effect of energy access, i.e. electricity access and renewable energy consumption on human development in those three poorest energy regions. To this end, our research uses data sets covering 1990 to 2018 to investigate the effect of electricity access, traditional and modern renewable energy consumption on human development for a panel of 44 countries, subdivided into two groups according to their human development levels. To do this, we retain the thresholds used in the UNDP report (2019), which classifies countries according to their level of development into 4 categories (see Table 1). We have chosen here to group countries with low and medium human development level in the group 1 and countries with high and very high development level in the group 2.

We note that half of the second group are countries now classified as emerging.

**Table 1.** *Sample Presentation Period: 1990-2018*

| Group of countries | Level of development | List of countries |
|---|---|---|
| 1st Group<br><br>28 countries | Low Human Development<br>$0 \leq HDI \leq 0.549$ | Burundi, Central African Republic, Ivory Coast, Democratic Republic of Congo, Guinea, Haiti, Malawi, Mali, Mozambique, Papua New Guinea, Senegal, Sudan |
| | Medium Human Development<br>$0.550 \leq HDI \leq 0.698$ | Bangladesh, Egypt, El Salvador, Gabon, Ghana, Guatemala, Guyana, Honduras, India, Kenya, Morocco, Nicaragua, Rwanda, Uganda, Zambia, Zimbabwe. |
| 2nd group<br><br>16 countries | High Human Development<br>$0.699 \leq HDI \leq 0.799$ | Bolivia, Brazil, China, Ecuador, Indonesia, Mauritius, Paraguay, Peru, Philippines, South Africa, Sri Lanka, and Vietnam. |
| | Very high Human Development<br>$0.8 \leq HDI \leq 1$ | Argentina, Costa Rica, Turkey, Uruguay. |
| Total number of countries: 44 | | |

*Note.* Baseline year 2018 (see UNDP, 2019)

## B. The model

In order to meet the main objective of our study, we have distinguished two complementary approaches. The first approach attempts to examine the effect of electricity access on the HDI without qualitatively distinguishing between types of electricity generation sources. (See eq (1)). The second approach focuses on the impact of the use of renewable energy on the human development in the southern countries, distinguishing between the two categories of renewable energy, namely traditional and modern. Our economic models are as follows:

$$HDI_{it} = F\ (EA_{it},\ X_{it}) \tag{1}$$

$$HDI_{it} = F\ (TREC_{it},\ MREC_{it},\ X_{it}) \tag{2}$$

Where HDI represents the human development index, EA the access rate to electricity, TREC the share of traditional renewable energy consumption, MREC the share of modern renewable energy consumption, and X the control variables.

As lack of access to energy services affects and degrades human health, restricts educational and development possibilities, and can reduce people's potential to escape poverty. This leads us to suggest that any improvement in the accessibility of electricity can have a positive effect on human development levels. In other words, the expected sign for the impact of access to electricity on the HDI is positive and significant ($\frac{\partial\ HDI}{\partial\ EA} > 0$). This positive effect should be observed on the components of the index, i.e. health, education and life standard.

It has long been recognized that increased energy consumption contributes directly to improved human development. However, it is not clear that the consumption of renewable energies, traditional or modern, has the same positive effect on human development. In contrast to the literature that has supported the idea that the use of traditional renewables (biomass, etc.) has a positive effect on human development, we believe that they will have a negative impact on development because their use is the source of polluting particle emissions, and their collection affects biodiversity. This implies that the expected sign of traditional renewable energy consumption would be negative and that it would deteriorate the human development indicators ($\frac{\partial HDI}{\partial TREC} < 0$), through the impact on its components. Moreover, considering their characteristics as modern and clean, the expected sign of the impact of modern renewables on the HDI is positive ($\frac{\partial HDI}{\partial MREC} > 0$), which implies that the use of modern renewable energies improves human development indicators, through its components.

In our study, we have chosen a hybrid HDI developed by the United Nations Development Program (UNDP) in 2010 (Gidwitz et al. 2010)[2] that modifies both the calculation method and the choice of indicators. In effect, the HDI is calculated as an average of three indicators: a health indicator measured by life expectancy at birth, a standard-of-living indicator apprehended by GDP per capita (PPP) and an indicator of educational attainment/access to knowledge approximated by literacy rate (2/3) and school enrolment rate (1/3). Beyond the choice of geometric rather than arithmetic mean, the UNDP corrects two indicators. For education, the average length of schooling replaces the literacy rate, and the gross enrolment ratio is reformulated as expected duration of schooling. Standard of living is no longer measured by GDP per capita, but by Gross National Income (GNI) per capita. This choice is particularly important for developing countries that can benefit from substantial remittances from abroad, but also from development aid, which leads to a much higher GNI than GDP.

The list of variables is shown in Table 2.

**Table 2.** *Presentation of Variables and Data Sources*

| Variable | Definition | Measure | Data source |
|---|---|---|---|
| HDI | Hybrid Human Development Index | Index | PNUD |
| EA | Access to electricity | % Of population | SE4ALL |
| TREC | Traditional renewable energy consumption | % Of renewable energy consumption | EIA |
| MREC | Modern renewable energy consumption | % Of renewable energy consumption | EIA |
| PX | The oil price | $US/Brent | Bp Stat |
| INDAV | Industry, value add | constant 2010 $US | WDI |
| ICT | ICT goods imports | % Total goods imports | WDI |

To measure the effect of energy access on human development, we used the electricity access rate, which is defined as the share of the population that has access to electricity, hereafter

2) See Goujon and Hoarau (2015) for a detailed analysis and an adaptation of this index to small island states.

referred to as EA. However, traditional and modern renewable energy consumption, referred to as TREC and MREC, is captured from the database of the International Energy Agency (IEA). All variables used are in natural logarithm, except HDI (Ouedraogo, 2013). We further examine whether information and communication technology (ICT), industry value added (INDVA), and oil price (PX, proxy of the energy price), mediate the role of energy access and both types of renewable energy consumption on human development for the aggregate panel. Initially, we had retained a wider range of control variables, but the estimates and data availability led us to eliminate them. The remittances variable was not included because the data were incomplete for all the countries and periods selected. We would have had to reduce the sample size and modify the estimation of an unbalanced panel model. Similarly, the introduction of a natural resource rent variable has not produced relevant results. We can assume that a large part of the rent effect is captured by the oil price. Finally, the non-significance of the FDI variable can be explained by the inclusion of value added in industry.

## C. Methodology and unit root tests

Based on the recently developed dynamic panel data method, we will refer to the work of Pesaran et al. (1999). We build two basic empirical models to evaluate the long-run relationship between the level of human development, access to energy, and traditional and modern renewable energy consumption in ARDL (1, 1, 1, 1). Our econometric models are presented as follows:

$$HDI_{it} = \mu_i + \lambda_i HDI_{i,t-1} + \delta_{1i} \mathrm{Ln} EA_{i,t-j} + \delta_{2i} \mathrm{Ln} X_{i,t-j} + \epsilon_{it} \quad (3)$$

$$HDI_{it} = \mu_i + \lambda_i HDI_{i,t-1} + \delta'_{1i} \mathrm{Ln}\, TREC_{i,t-j} + \delta'_{2i} \mathrm{Ln} MREC_{i,t-j} + \delta'_{3i} \mathrm{Ln} X_{i,t-j} + \epsilon_{it} \quad (4)$$

Where HDI, LnEA, LnTREC, LnMREC, and LnX denote respectively the human development index, and respectively the logarithms of electricity access, traditional renewable energy consumption, modern renewable energy consumption and of the control variables, i.e. oil price, ICT, and industry value added. $\varepsilon_{it}$ is the error term. The index i refers to the countries and t denotes the year.

According to Pesaran et al. (2001), the error correction model (ECM) can be specified as follows:

$$\Delta HDI_{it} = \phi_i \left( HDI_{i,t-1} - \theta'_i V_{it} \right) + \sum_{j=1}^{p-1} \lambda'_{ij} \Delta HDI_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{ij} \Delta V_{i,t-j} + \mu_i + \epsilon_{it} \quad (5)$$

where V represents the vectors of explanatory variables of interest and other control variables. $\phi_i$ is the speed of adjustment parameter. We expect $\phi_i$ to be negative. If it exists, this implies that there is a long-run equilibrium relationship (cointegration relationship).

To estimate the Eq. (5) we used three distinct estimators, namely the Pooled Mean Group (PMG) model proposed by (Pesaran, et al., 1999) the Mean Group (MG) estimator of (Pesaran, 1995), and the Dynamic Fixed Effects (DFE) estimator introduced by (Pesaran, 1995). These three estimators are calculated using the maximum likelihood and considering the long-run equilibrium and the heterogeneity of the dynamic adjustment process[3].

To assess which of the three models is most appropriate, we use the Hausman test, which checks if there's a statistically significant difference between the estimators. The null hypothesis of the Hausman test is that the differences between the PMG and MG or PMG and DFE estimators are not significant. If the null hypothesis is accepted, the PMG model should be more appropriate.

Although this approach remains relevant, whatever the order of integration of the variables, whether they are integrated at the order I (1) or mutually integrated at the order I (0) and I (1), it is still necessary to verify that none of our series is integrated at the order I (2), otherwise, this technique cannot be applied. To achieve this, we check a set of unit root tests, namely the tests of Levin, et al., (2002), Im, et al., (2003), Breitung, (2000), and Hadri, (2000) are used in this study. The LLC and Breitung panel unit root tests are both estimated under the null hypothesis that suggests the presence of a unit root. In contrast, the Hadri test is based on the null hypothesis that all series are stationary. The Pesaran test is a second-generation test that runs a t-test statistic in the presence of a cross-sectional dependence based on a null hypothesis that suggests that all series are non-stationary.

Our results suggest that no series, for both groups of countries, are integrated of order 2 I(2). At the end of the first step, and based on all the results of the tests applied to the different groups, we can conclude that most of the variables are integrated in the order I (1) while the rest are in I (0) (See Table 3).

**Table 3.** *Unit Root Tests*

| Group 1 | LLC | | IPS | | Breitung | | Hadri | |
|---|---|---|---|---|---|---|---|---|
| | Level | Δ | Level | Δ | Level | Δ | Level | Δ |
| IDH | -1.2293 | -4.678*** | 4.7235 | -6.8226*** | 17.8667 | -7.0117*** | 90.908*** | 15.99*** |
| LnEA | -6.1641*** | -9.8470*** | -0.7805 | -22.338*** | 7.5837 | -6.4554*** | 64.892*** | 1.5507* |
| LnTREC | 3.2701 | -10.098*** | 6.4603 | -12.748*** | 7.3966 | -10.986*** | 74.977*** | -0.5217 |
| LnMREC | -1.8193** | -11.256*** | 0.7745 | -13.318*** | 0.3249 | -14.917*** | 72.263*** | -2.7102 |
| LnPX | -1.1887 | -13.597*** | -1.6161* | -15.43*** | -1.221 | -13.231*** | 74.261*** | -1.9938 |
| LnINDAV | -6.6832*** | -18.340*** | -6.147*** | -20.005*** | -2.285** | -12.081*** | 26.307*** | -3.3123 |
| LnICT | -2.707*** | -11.853*** | -2.894*** | -17.865*** | -1.722** | -19.240*** | 55.005*** | -3.2171 |

3) We can refer to Samargandi et al. (2015) or Blackburne and Frank (2007) for a discussion of these estimators and their main characteristics.

**Table 3.** *Continued*

| Group 2 | LLC | | IPS | | Breitung | | Hadri | |
|---|---|---|---|---|---|---|---|---|
| | Level | Δ | Level | Δ | Level | Δ | Level | Δ |
| IDH | -3.9794*** | -4.8832*** | 1.5037 | -6.0574*** | 13.2891 | -11.177*** | 68.989*** | 4.579*** |
| LnEA | -6.1662*** | -6.9641*** | -1.4920* | -12.914*** | 6.9542 | -7.9504*** | 64.581*** | -3.1225 |
| LnTREC | 4.0276 | -3.8187*** | 6.5015 | -5.8247*** | 9.2974 | -7.9205*** | 58.877*** | 5.384*** |
| LnMREC | 0.0039 | -10.342*** | 1.0965 | 1.0965*** | 2.5315 | -10.534*** | 47.998*** | 1.7209** |
| LnPX | -0.8986 | -10.278*** | 1.6500 | -11.639*** | -1.2216 | -10.002*** | 56.136*** | -1.5072 |
| LnINDAV | -1.4781* | -6.2005*** | -2.2394** | -10.497*** | -4.68*** | -5.9171*** | 16.624*** | -1.9474 |
| LnICT | -2.2111** | -8.5963*** | 0.6397 | -9.6270*** | -0.5297 | -14.488*** | 51.206*** | -1.8993 |

***, **, * indicate respectively the significance level of 1%, 5% and 10%.

Finally, the ARDL approach eliminates endogeneity problem by including lag length for all exogenous and endogenous variables (Pesaran, et al., 1999).

# V. Long-term Relationships Estimates

As mentioned before, the PMG estimator is our basic estimation approach. Moreover, we will also report our estimates using the MG and DFE estimators to objectively compare the different results. To examine the robustness of our estimates, we use Hausman tests. In addition, when comparing PMG and MG, the Hausman test suggests for a significant p-value at the level of 5% the rejection of the null hypothesis, which implies that the results of the MG estimator are preferable to those of the PMG estimator.

The findings of our study will be discussed in the following by a group of countries according to their level of human development. First, we study the impact of access to energy and the use of modern and traditional renewable energies on the human development index in the first group and then in the second group of countries. As discussed above, we check the difference between the three estimators based on the Hausman test.

## A. Group of countries with low and medium HDI

Table 4 shows the results of the ARDL model for countries with low and medium levels of human development. Estimates [1]-[3] show the results for using EA as an explanatory variable. Estimators [4]-[6] show the results for TREC and MREC as explanatory variables.

For the first group, with a p-value greater than 5%, the test suggests that DFE is a more appropriate estimator than PMG and MG for the first model, while it suggests that the PMG estimator is the most appropriate than MG and DFE for the second model in the first group (See Table 4).

**Table 4.** *ARDL Model Estimates for the First Group of Countries*

| VARIABLES | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | (1)<br>PMG | (2)<br>MG | (3)<br>DFE | (4)<br>PMG | (5)<br>MG | (6)<br>DFE |
| Long-run | | | | | | |
| LnEA | 0.0241**<br>(0.00976) | 0.239<br>(0.151) | 0.0416***<br>(0.00526) | | | |
| LnTREC | | | | -0.112**<br>(0.0515) | -0.0208<br>(0.369) | 0.183***<br>(0.0621) |
| LnMREC | | | | 0.0178<br>(0.0166) | 0.172<br>(0.124) | 0.0348*<br>(0.0194) |
| LnINDVA | 0.0107***<br>(0.00311) | 0.00400<br>(0.00610) | 0.00389<br>(0.00333) | 0.00724**<br>(0.00327) | -0.00308<br>(0.00934) | 0.0103<br>(0.00732) |
| LnICT | 0.00758***<br>(0.00215) | 0.000732<br>(0.00214) | 0.00504**<br>(0.00221) | 0.0150***<br>(0.00261) | -0.00183<br>(0.00694) | 0.0138***<br>(0.00483) |
| LnPX | 0.119***<br>(0.0101) | -0.00726<br>(0.0508) | 0.0620***<br>(0.00784) | 0.121***<br>(0.00965) | 0.0580*<br>(0.0299) | 0.112***<br>(0.0192) |
| Short-run | | | | | | |
| ECT | -0.0228***<br>(0.00792) | -0.0793***<br>(0.0117) | -0.0574***<br>(0.00658) | -0.0166**<br>(0.00748) | -0.109***<br>(0.0285) | -0.0286***<br>(0.00568) |
| D.LnEA | -0.00239<br>(0.00327) | -0.00544<br>(0.00580) | -0.000271<br>(0.000454) | | | |
| D.LnTREC | | | | -0.00902<br>(0.00840) | -0.0129<br>(0.0204) | -0.00260<br>(0.00278) |
| D.LnMREC | | | | 0.00460 | -0.000203 | -0.000192 |
| D.LnINDVA | 0.000512<br>(0.000489) | 0.000165<br>(0.000300) | 4.50e-05<br>(0.000219) | 0.000382<br>(0.000362) | 0.000792**<br>(0.000378) | -7.35e-05<br>(0.000224) |
| D.LnICT | 2.97e-05<br>(0.000193) | -9.57e-05<br>(0.000181) | 2.07e-05<br>(0.000165) | 0.000273<br>(0.000330) | -5.54e-05<br>(0.000244) | -1.01e-05<br>(0.000169) |
| D.LnPX | 5.10e-05<br>(0.00104) | -0.00153<br>(0.00105) | -0.000551<br>(0.000869) | 0.000626<br>(0.00116) | -0.000435<br>(0.00133) | 0.000174<br>(0.000876) |
| Constant | 0.00317**<br>(0.00125) | -0.0113<br>(0.0269) | 0.0112***<br>(0.00196) | 0.0125***<br>(0.00261) | 0.0626<br>(0.115) | -0.0159***<br>(0.00614) |
| Hausman | 33.72*** | | 1.0000 | 6.61 | | |
| Number of countries | 28 | 28 | 28 | 28 | 28 | 28 |
| Number of time periods | 28 | 28 | 28 | 28 | 28 | 28 |
| Observations | 784 | 784 | 784 | 784 | 784 | 784 |

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

In the Table 4, the results of the estimation [3] show that access to energy has a positive and significant long-term effect on the level of human development in countries with low and medium HDI. Furthermore, the results of model [4] suggest that the use of traditional renewable energy has a negative and statistically significant effect on the human development index. Moreover, the speed of adjustment coefficients for the two estimates [3] and [4] are negative and significant at conventional levels, supporting the long-run association between energy access, traditional renewable energy consumption, and the HDI.

The results from the estimation [3] in Table 4, suggest that every increase of one unit, in the long term, in access to electricity is associated with an increase of 0.04 points in the level of human development. This implies that access to electricity improves human development and is crucial for improving people's well-being. The results from the estimation [4] of Table 4, allows us to assume that an increase in the share traditional renewable energies (biomass) leads to decreases of 0.11 points in the level of human development in developing countries. Also, the results from the estimation [4] reveals that the use of modern renewable energy has a positive but non-significant effect on the level of Human development for the first group of our samples. This non-significant effect can be explained by both the cost and the capacity of these countries to invest and promote modern renewable energy

## B. Group of countries with high HDI

As for the first group of developing countries, we will try to examine the impact of access to energy estimations [1]-[3], and the use of modern and traditional renewable energies, estimations [4]-[6], on the human development index for countries with high level of human development (see Table 5). Furthermore, as part of the sensitivity analysis to specify the best results provided by the different estimators for the group of developed countries, the results of the Hausman test suggest that the results of the DFE estimator are preferable to the PMG and MG estimates for the two models (See Table 5).

The results of the estimation [3] in Table 5 indicate that electricity access has a non-significant long-term effect on the HDI. This could mean that access to electricity is irrelevant to improving long-term human development in high-HDI countries. But it is also possible that the dependence of electricity production on the price of oil masks the impact of the variable access to electricity. This is what the estimation results would suggest, since oil price is the only variable with a statistically significant coefficient. However, the results suggest that access to electricity significantly improves the HDI in the short run. Looking at the results of the estimation [6] for the 2nd group. The DFE estimator suggests that the use of modern renewable energies has a positive and significant effect on the development index. In contrast, the use of traditional renewable energies such as traditional biomass will have a negative and significant effect on the long-term human development level in developed countries. Moreover, the correction term is negative and significant at the 1% level, supporting the long-term association between renewable energy consumption and the human development index in developed countries.

**Table 5.** *ARDL Model Estimates for the Second Group of Countries*

| VARIABLES | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | (1)<br>M1-PMG | (2)<br>M1-MG | (3)<br>M1-DFE | (4)<br>M1-PMG | (5)<br>M2-MG | (6)<br>M2-DFE |
| Long-run | | | | | | |
| LnEA | 0.111<br>(0.0754) | 1.007<br>(0.655) | -0.0161<br>(0.0903) | | | |
| LnTREC | | | | -0.182<br>(0.385) | -0.328<br>(0.306) | -0.0258**<br>(0.0125) |
| LnMREC | | | | 0.888<br>(2.254) | 0.253<br>(0.233) | 0.0333***<br>(0.0116) |
| LnINDVA | -0.00367<br>(0.00555) | 0.0321<br>(0.0197) | 0.00532<br>(0.00768) | -0.0151<br>(0.0586) | -0.0140<br>(0.0138) | 0.00512<br>(0.00549) |
| LnICT | 0.0152***<br>(0.00327) | -0.000524<br>(0.00526) | 0.00175<br>(0.00491) | 0.155<br>(0.366) | 0.0452<br>(0.0466) | 0.000542<br>(0.00359) |
| LnPX | 0.0531***<br>(0.0106) | 0.117<br>(0.119) | 0.0557***<br>(0.0171) | 0.341<br>(0.749) | 0.0924<br>(0.0787) | 0.0429***<br>(0.0120) |
| Short-run | | | | | | |
| ECT | -0.00655<br>(0.00898) | -0.152***<br>(0.0314) | -0.0355***<br>(0.00788) | -4.32e-05<br>(0.00116) | -0.164***<br>(0.0478) | -0.0493***<br>(0.00914) |
| D.LnEA | 0.0156<br>(0.0378) | -0.00479<br>(0.0783) | 0.0113*<br>(0.00649) | | | |
| D.LnTREC | | | | -0.00610<br>(0.00633) | -0.00519<br>(0.0122) | 0.00210<br>(0.00204) |
| D.LnMREC | | | | -0.0123**<br>(0.00519) | -0.00786<br>(0.00549) | -0.00182<br>(0.00149) |
| D.LnINDVA | -0.000394<br>(0.000251) | -0.00168*<br>(0.00101) | -0.000239<br>(0.000287) | -0.000430<br>(0.000287) | -0.000183<br>(0.00126) | -0.000253<br>(0.000284) |
| D.LnICT | -0.000147<br>(0.000188) | -0.000447<br>(0.000294) | 3.16e-05<br>(0.000226) | -7.62e-05<br>(0.000173) | -1.37e-05<br>(0.000228) | 1.73e-05<br>(0.000225) |
| D.LnPX | -0.000289<br>(0.000921) | -0.000756<br>(0.00111) | -0.000862<br>(0.000886) | 0.000194<br>(0.00100) | -0.00213<br>(0.00140) | -0.000931<br>(0.000884) |
| Constant | 0.00504***<br>(0.000665) | -0.451<br>(0.404) | 0.0244*<br>(0.0129) | 0.00546<br>(0.00386) | 0.0665<br>(0.108) | 0.0295***<br>(0.00664) |
| Hausman | 154.03*** | | 1.0000 | 22.90*** | | 1.0000 |
| Number of countries | 16 | 16 | 16 | 16 | 16 | 16 |
| Number of time periods | 28 | 28 | 28 | 28 | 28 | 28 |
| Observations | 448 | 448 | 448 | 448 | 448 | 448 |

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

## C. Syntheses

To resume, our results imply that access to electricity improves human development and is crucial for improving people's well-being[4]. This allows us to deduce that improved access to electricity leads to long-term improvements in certain aspects of development, namely income, education, and health in developing countries. The availability of reliable, affordable and clean energy improves the quality of life of the population and encourages productivity. The lighting indoors can create a better learning environment for students to complete their homework during the daytime and reduce the risk of visual impairment. Also access to electricity can ensures better medical facilities for maternal care and a reliable power supply in clinics and health centers allows for the sterilization and refrigeration of vaccines.

In addition, the negative effect of traditional renewable energy on the human development index in both groups of countries can be explained by the idea that the inefficient use of traditional renewable energy can affect health, limits educational development and exacerbates local ecological damage. First, people who are exposed to the indoor air pollution from the combustion of biomass using conventional equipment are more susceptible to suffer from inflammatory diseases of the respiratory system as well as immune system disorders. Second, the use of traditional biomass fuels forces many young children into the daily chore of firewood collection and other exhausting handwork, depriving them of school and completing their homework. Finally, the land use change effects and carbon leakage due to biomass usage increase carbon emissions and that it also addresses concerns about food security, the depletion of natural resources, the deforestation, the degradation of land and the loss of biodiversity. [Bilgili, et al., (2017) and Müller, et al., (2015)]. Additionally, we can consider that any increase in oil prices encourages an increase in the use of renewables, which in turn positively affects human development,

However, the effect of modern renewable energy consumption on human development appears positively significant for the 2$^{nd}$ group of countries with high HDI. This implies that any increase in modern renewable energy consumption is associated with an improvement in the degree of development of these countries. This can be justified by the important potential of these countries to exploit modern renewable energies such as solar and wind energy (see Figure 2). In contrast to the results for the second group, the lack of a relationship between modern renewable energy consumption and human development for the first group of countries with low and medium HDI can be explained both by their inability to promote modern renewable energy and the cost of investing in it[5].

To refine these results, we estimated the model by replacing the HDI with the three

4) New estimates have been made by constituting the groups according to natural resource endowments. The groups no longer have the same constitution and we show that access to electricity has a positive and significant impact on both groups of countries, whatever their natural resource endowments.

5) We tested the same model on two groups now differentiated based on natural resource endowment. We considered net natural resource-importing countries (at most 50% of total exports, average 2006-2010) as countries poor in non-renewable natural resources. On the other hand, we considered net natural resource exporting countries (at least 50% of total exports, average 2006-2010) as countries rich in non-renewable natural resources (Acikgoz,B et al 2016 ;IMF, 2012 ; Michele and Venables, 2012). The results of the new estimations show that the relationship between the HDI Hybrid and access to electricity has changed. It has become statistically significant for the majority of countries of the second group of our main study (cf. Table A in Appendix 2).

component indices representing education (EDU), the GNI per capita and the life expectancy at birth (LEB). The results are presented in Appendix 1. These estimates show that access to electricity has a positive effect on all HDI components for both groups of countries.

Modern renewable energy consumption has a positive and significant effect on life expectancy in both groups, while the effect on GNI is positive for the richest countries and negative for the poorest. Conversely, it has no impact on the level of education in any country. These two opposing effects on Group 1 components, and the fact that this variable has no effect on education, may explain why we can't find effect on HDI.

Finally, the traditional renewable energy consumption variable has a negative effect on income and education in the poorest/1st group countries, and on all three components of HDI in the richest/2nd group countries.

# VI. Endogeneity and Robustness Check

The issue of the endogeneity of energy access to the human development index may pose a threat to the identification of the causal effect in our case. Potential origins of endogeneity may be related to omitted variables, simultaneity, or measurement errors. The endogeneity bias problem can be addressed by different methods. Besides, concentrating on the dynamic panel models, the GMM-difference estimator of Arellano and Bond (1991) and the GMM system estimator of Arellano and Bover (1995) are consistent solutions dealing with endogeneity. Moreover, they are valuable when the sample has a large number of countries compared to the time period, which is not the case in our paper. Therefore, to ensure that our results are robust to endogeneity, we generally use the Instrumental Variable (IV) approach, as the main estimation technique.

To use the IV approach to handle endogeneity requires that appropriate instruments must be available to identify the model. In addition, the instruments must be significantly correlated with the endogenous variable. They must satisfy the orthogonality condition and be adequately excluded from the model so that the impact of the instrument on the dependent variable is indirect. However, identifying adequate instruments that can satisfy simultaneously these requirements is still in many cases difficult and constitutes a serious problem for using IV estimators for the majority of applied studies [Baum et al (2012) ; Stock, et al (2002)]. In order to overcome these limitations, this study used Lewbel's (2012) two-step least squares (2SLS) technique which is applicable in cases where sources of identification, such as adequate external instruments, are unavailable or weak. Lewbel's approach is useful for identifying structural parameters in models containing an endogenous or imperfectly measured regressor when conventional identification information is unavailable. The Lewbel's 2SLS include internally constructed instruments based on heteroskedasticity. The internal instruments of the equation are produced from the residuals from the auxiliary equation, multiplied by each exogenous variable included in a mean-centered form.

One advantage of Lewbel's 2SLS approach is that it doesn't depend on satisfying any standard exclusion restrictions. Application of Lewbel's 2SLS in the absence of external instruments generates estimates that closely approximate to those generated by practical external instruments (Lewbel, 2012).

To complete, we also check the robustness of results by applying the Driscoll-Kraay estimation technique. The estimation of Driscoll & Kraay (1998), is based on a non-parametric estimator of the covariance matrix of the time series, and presupposes that the error structure is heteroskedastic, auto-correlated up to a certain lag, and possibly cross-panel correlated. In addition, according to Hoechle (2007), the nonparametric Driscoll-Kraay estimator generates robust findings under cross-sectional and time dependence. Using the Driscoll-Kraay estimation technique, it is also able to handle missing datasets and can be used with both balanced and unbalanced panels.

Findings from the Lewbel 2SLS and Driscoll-Kraay estimators, presented in Table 6, are coherent with the ARDL-PMG results in terms of signs. Nevertheless, the statistical levels and significance are slightly different. As an example, the findings for the 1st group in our aggregate panel suggest that while access to electricity significantly improves the HDI, traditional renewable energy consumption significantly enhances the HDI and modern renewables use has an non-

**Table 6.** *Lewbel (2SLS) and Driscoll-Kraay Results*

| VARIABLES | Lewbel | | | | Driscoll-Kraay | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st group | | | | 2nd group | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | Lewbel | | Driscoll-Kraay | | Lewbel | | Driscoll-Kraay | |
| LnEA | 0.0123*** | | 0.0246*** | | 0.0807* | | 0.121*** | |
| | (0.00219) | | (0.00711) | | (0.0451) | | (0.0314) | |
| LnTREC | | -0.0804** | | -0.0428* | | -0.0363** | | -0.0416*** |
| | | (0.0313) | | (0.0216) | | (0.0141) | | (0.00403) |
| LnMREC | | 0.0316 | | 0.00299 | | 0.0184*** | | 0.0193*** |
| | | (0.0218) | | (0.00379) | | (0.00526) | | (0.00356) |
| LnPX | 0.0595*** | 0.0529*** | 0.0544*** | 0.0594*** | 0.0318*** | 0.0261*** | 0.0293*** | 0.0246*** |
| | (0.00262) | (0.00519) | (0.00655) | (0.00575) | (0.00417) | (0.00486) | (0.00743) | (0.00582) |
| LnICT | 0.00426*** | 0.00346*** | 0.00316 | 0.00461** | 0.00863*** | 0.00675*** | 0.00810** | 0.00638*** |
| | (0.000710) | (0.00108) | (0.00210) | (0.00220) | (0.00109) | (0.00124) | (0.00318) | (0.00193) |
| LnINDVA | 0.000981 | -0.00225 | 0.000251 | 0.000627 | 0.000739 | 0.00137 | 0.000370 | 0.00129 |
| | (0.00104) | (0.00223) | (0.00148) | (0.00129) | (0.00151) | (0.00126) | (0.00125) | (0.00116) |
| Constant | | | 0.193*** | 0.401*** | | | 0.0123 | 0.621*** |
| | | | (0.0223) | (0.0886) | | | (0.127) | (0.0248) |
| Observations | 812 | 812 | 812 | 812 | 464 | 464 | 464 | 464 |
| R-squared | 0.723 | 0.617 | 0.7471 | 0.6658 | 0.722 | 0.801 | 0.7247 | 0.8021 |
| Number of groups | 28 | 28 | 28 | 28 | 16 | 16 | 16 | 16 |

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

significant effect on human development. Similarly, for the 2nd group in our aggregate sample, evidence implies that if access to electricity improves the HDI significantly. These results are consistent with the model's estimates when HDI is replaced by each of its components (cf. Appendix 1).The use of traditional renewable energy significantly reduces the HDI, while the use of modern renewable energy sources has a positive impact on human development. These findings are robust to alternative econometric estimation strategies, Lewbel 2sls and Driscoll-Kraay estimators.

## VII. Conclusion

Accessibility to energy services is a fundamental requirement for stimulating human development in all countries. In contrast, the lack of knowledge on energy and human development, particularly that which focuses on the energy-poor areas, makes it essential to conduct additional empirical investigations. Given that most empirical studies that exist have primarily explored the effect of energy consumption on human development while ignoring energy accessibility, which is critical to understanding energy poverty, our paper contributes to the literature in the following ways. First, the study of the effect of energy accessibility on human development in 44 countries subdivided into two groups by their level of human development and representing the three poorest energy regions of the world. This will constitute one of the contributions of this research, as these areas ideally represent global energy poverty. Second, our study also explores the impact of traditional and modern renewables consumption on human development.

In this study, we used the ARDL approach based on Pesaran and Shin (1999) to evaluate the effect of energy access and renewable energy consumption on human development, which admits a mix of variables I(0) and I(1). Second, this approach overcomes the problem of endogeneity by including the lag length for both exogenous and endogenous variables (Pesaran, et al., 1999).

The main finding of this study supports the idea that while sustainable energy offers low- or zero-carbon alternatives, having a just global energy system implies rebalancing the three aspects of accessibility, affordability and durability.

In general, we can draw from the results of our study that accessibility to energy services is crucial for social and economic development in developing countries. However, to ensure access to these services, it is important to move towards the deployment of new, modern, and clean renewable technologies. For, even if the use of traditional renewable technologies, namely traditional biomass, as in the case of countries with low and medium aggregate development levels, will have a positive effect in the short term, their negative impacts in the long term, on the level of development are worrying.

In light of these findings, while sustainable energy policies in the three poorest regions in terms of energy access are undoubtedly guiding worldwide efforts to achieve Goal 7 of the SDGs, it is apparent that the policymakers today need to take into consideration how their current and future energy investments will enable solutions to access to clean, modern, and sustainable energy services. On the other hand, the increasing carbon emissions cannot be ignored. Hence, the adoption of modern renewable energy and the transition to more energy-efficient uses of biomass must be accelerated.

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# Appendix 1

This appendix presents the results of econometric estimates (OLS) of the impact of variables measuring access to energy on each of the HDI components (Table A1), plus a summary table showing the effects of energy access variables on HDI and its components (Table A2). For this summary, for the model with HDI we give priority to the results obtained with the robustness tests.

**Table A1.** *Effect of Energy Access on HDI Components*

Group 1

| | LEB_Index | EDU_Index | GNI_index | LEB_Index | EDU_Index | GNI_index |
|---|---|---|---|---|---|---|
| LnEA | 0.030*** | 0.021*** | 0.008*** | | | |
| | (0.002) | (0.001) | (0.001) | | | |
| LnTREC | | | | -0.012 | -0.060*** | -0.065*** |
| | | | | (0.011) | (0.007) | (0.006) |
| LnMREC | | | | 0.016*** | -0.003 | -0.014*** |
| | | | | (0.005) | (0.003) | (0.003) |
| Control var. | Yes | Yes | Yes | Yes | Yes | Yes |
| Fixed effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | 0.306*** | 0.095*** | 0.345*** | 0.368*** | 0.385*** | 0.655*** |
| | (0.012) | (0.009) | (0.009) | (0.049) | (0.034) | (0.030) |
| Observations | 812 | 812 | 812 | 812 | 812 | 812 |

Group 2

| | LEB_Index | EDU_Index | GNI_index | LEB_Index | EDU_Index | GNI_index |
|---|---|---|---|---|---|---|
| LnEA | 0.116*** | 0.126*** | 0.114*** | | | |
| | (0.016) | (0.023) | (0.023) | | | |
| LnTREC | | | | -0.030*** | -0.047*** | -0.052*** |
| | | | | (0.003) | (0.004) | (0.004) |
| LnMREC | | | | 0.017*** | 0.019*** | 0.024*** |
| | | | | (0.003) | (0.004) | (0.004) |
| Control var. | Yes | Yes | Yes | Yes | Yes | Yes |
| Fixed effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | 0.179*** | -0.116 | 0.004 | 0.730*** | 0.531*** | 0.610*** |
| | (0.068) | (0.098) | (0.096) | (0.016) | (0.023) | (0.021) |
| Observations | 464 | 464 | 464 | 464 | 464 | 464 |

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table A2.** *Summary of the Effects of Access to Energy on HDI and Its Components*

| | Group 1 | | | Group 2 | | |
|---|---|---|---|---|---|---|
| Variables | | HDI | | | HDI | |
| EA | | + | | | + | |
| TREC | | - | | | - | |
| MREC | | NS$^{\psi}$ | | | + | |
| | Education | Life expectancy | GNI per capita | Education | Life expectancy | GNI per capita |
| EA | + | + | + | + | + | + |
| TREC | - | NS$^{\psi}$ | - | - | - | - |
| MREC | NS$^{\psi}$ | + | - | + | + | + |

$^{\psi}$ NS for not significant

# Appendix 2

This appendix presents the results of econometric estimates for two groups of countries distinguished according to whether or not they are endowed with non-renewable natural resources.

**Table A3.** *ARDL Model Estimates for the Groups of Countries Based on Natural Resource Endowment*

| VARIABLES | Rich in Non-Renewable Natural Ressources | | | Poor in Non-Renewable Natural Ressources | | |
|---|---|---|---|---|---|---|
| | (1) PMG | (2) MG | (3) DFE | (4) PMG | (5) MG | (6) DFE |
| LnEA | 0.133***<br>(0.0256) | 0.154*<br>(0.0838) | 0.0399***<br>(0.00732) | 0.0288***<br>(0.00779) | 0.672<br>(0.411) | 0.0610***<br>(0.00741) |
| LnINDVA | -0.0151***<br>(0.00553) | 0.0127<br>(0.0141) | 0.00164<br>(0.00464) | 0.0147***<br>(0.00314) | 0.00773<br>(0.0104) | 0.00900**<br>(0.00372) |
| LnICT | 0.00788**<br>(0.00366) | 0.00177<br>(0.00225) | 0.00323<br>(0.00314) | 0.00709***<br>(0.00180) | -0.000981<br>(0.00407) | 0.00382*<br>(0.00222) |
| LnPX | 0.0972***<br>(0.0160) | 0.000552<br>(0.0376) | 0.0577***<br>(0.0102) | 0.0976***<br>(0.00815) | 0.0844<br>(0.0674) | 0.0541***<br>(0.00808) |
| ECT | -0.0127*<br>(0.00769) | -0.0943***<br>(0.0204) | -0.0461***<br>(0.00781) | -0.0237**<br>(0.00968) | -0.106***<br>(0.0189) | -0.0606***<br>(0.00677) |
| D.LnEA | -0.000546<br>(0.00414) | -0.00589<br>(0.00663) | -0.000178<br>(0.000514) | 0.0238<br>(0.0297) | -0.00856<br>(0.0466) | -0.00109<br>(0.000676) |
| D.LnINDVA | -0.000117<br>(0.000312) | -0.00117<br>(0.00127) | -2.33e-05<br>(0.000227) | 0.000365<br>(0.000479) | -5.68e-05<br>(0.000485) | -0.000189<br>(0.000265) |
| D.LnICT | 0.000167<br>(0.000240) | -0.000136<br>(0.000269) | 0.000233<br>(0.000195) | -0.000125<br>(0.000166) | -0.000217<br>(0.000157) | -0.000105<br>(0.000180) |
| D.LnPX | 0.000735<br>(0.000878) | -0.000324<br>(0.000893) | 0.000168<br>(0.000930) | -0.000703<br>(0.00102) | -0.00187*<br>(0.00114) | -0.00121<br>(0.000859) |
| Constant | 0.00316<br>(0.00207) | -0.0208<br>(0.0228) | 0.0123***<br>(0.00236) | 0.00438***<br>(0.00111) | -0.257<br>(0.241) | 0.0121***<br>(0.00273) |
| Hausman | 4.32 | | | 12.71** | | 1,00 |
| Observations | 476 | 476 | 476 | 756 | 756 | 756 |

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1