# The Role of Education on Renewable Energy Use: Evidence From Poisson Pseudo Maximum Likelihood Estimations

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## Absract

*In this paper, the role of education level on the nonhydro renewable energy use is analyzed with regard to two different indicators. Theoretically, education level of a society is a key determinant of renewable energy demand and supply in that economy. In highly educated societies, enviromental awareness and social acceptance of renewable energy is expected to be high and so is renewable energy demand. On the supply side, it has been reported that higher levels of scientific knowledge and know-how facilitate innovation and diffusion of renewable energy technologies. In this study, these theoretical arguments are examined using a sample of 62 countries spanning the period of 1990-2014. To overcome exceed zero problem pseudo Poisson maximum likelihood technique is applied. The findings suggest that education level is positively related to renewable energy participation at the 1% level. Furthermore, the impact of higher levels of education is found to be stronger than the lower levels.*

***Keywords:***Renewable Energy, Education, Knowledge, PPML

***JEL:***O13, O15,I2, B23

## *1.Introduction*

Energy is seen as a critical foundation of economic development, industrialization, urbanization and national independence. Following the industrial revolution, energy demand has substantially increased and securing sustainable energy supply has become a priority of policy makers. Fossil fuels, which are advantageous in terms of cost and logistics,came to the fore in the first place and a fossil fuel based economy has formed. But due mainly to the negative environmental externalities of fossil fuels and energy security concerns, a significant trend towards increased utilization of renewable energy sources has risen in the past years. A global transition to renewable energy acquired dynamism through incentives, subsidies and technological developments especially since 90’s. New generation renewable energy sources like wind, solar, and geothermal are in the center of this dynamic transition and in the main focus of this study.

According to the year 2015 statistics, worldwide installed renewable energy capacity reached 1849 GW. 1064 GW of the total installed capacity consisted of hydroelectric power plants. Hydroelectricity is followed by wind energy with 433 GW capacity, solar PV with 227 GW capacity, bioenergy with 106 GW, geothermal energy with 13.2 GW, and solar CSV with 4.8 GW (REN21, 2016: 19). Despite lower gas and oil prices, deployment of renewable energies continued to surge in global markets in the last years. The global renewable industry grew by 8.3 % in 2015 and set a new historical record (REN21, 2016). The annual growth rate recorded in 2015 can be interpreted as that renewable are currently considered as a strong option over the conventional sources.

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Further to that, a large number of countries set ambiguous targets related to the renewable energy consumption. Therefore, growth in the renewable energy sector is expected to continue in the short and long run (REN21, 2016: 26-35, 161-176; IRENA, 2016: 1-4).

While reviewing the global deployment of nonhydro renewable energy, noteworthy regional differences can be seen. First and foremost, the research and development of nonhydro renewable energy technologies, primarily originate from developed countries. And therefore most of the global installed nonhdyro renewable energy capacity is located in these countries. Meanwhile, high technology nonhydro renewable energy systems have been diffusing to developing countries with time delays. For instance, global nonhydro renewable energy demand was 121.7 TWh in 1990 and about 87 percent of the total demand came from developed countries. Where as in 2015 total demand increased to 1612.5 TWh and the share of developed countries in total demand reduced to 67.5% (BP, 2016).

The observed trend of deployment asymmetries between developed and developing economies might be raised from both demand and supply side barriers. On the demand side, when environmental awareness is low and social acceptance is lacking in an economy, economic agents are possible not to be volunteered to pay more for expensive renewable energy sources. Or they might not want to have a wind farm near their residents due to visual and noise pollution allegations. Similarly, when human capital is not rich enough to adapt new ideas and technologies in an economy, it is very likely to continue using conventional sources instead of renewable energy. Also, it is predicted that income per capita, which is largely dependent of education level, has implications on demand of renewable energy (Aguirre and Ibikunle, 2014:377). The less educated individuals more likely to have lower income, and so is their renewable energy utilization reluctance. To sum up, these kind of demand decreasing factors are expected to be seen more in less educated economies.

On the supply side, the most critical factors are the efficient management of technological diffusion, the financial development stage, and the quality of human capital. When an economy is resourceful in terms of skills and finance, then it would be more possible to develop renewable energy systems, to benefit from scale economics via domestic renewable energy industry, and to provide innovations to increase productivity of these technologies. On the other hand, unskilled and low-educated human capital might turn out to be a destructive human resource shortage in the nonhydro renewable energy sector and might become the main barrier in that country. Therefore, the common supposition in the field is that as knowledge increases in a society, nonhydro renewable energy sector grows as well. Despite the strong theoretical relationship between renewable energy use and education, only a few studies can be found in the literature on this relationship. Most of the scarce literature related to our research question is qualitative and theoretical. The empirical evidence is even rather more sparse than the theoretical ones and to the best of our knowledge, none of them directly focuses on this relationship. Majority of empirical studies is on the determinants of renewable energy deployment and they only shortly address education level's impact on renewable energy consumption. Therefore, it can be said that there is a research gap. This research aims to contribute this research gap and to draw long-term political implications. Apart from this contribution, this study has some other strengths. As renewables have no long history in many countries, the excess zero value problem occurs in large data sets. Instead of reducing the data set, Poisson pseudo-maximum likelihood (PPML) estimator is applied to deal with this challenge. As an another strength, a wide range of possible factors that might have influence on renewable energy deployment is being controlled in specifications. Last but not least, different from previous studies a nonlinear relationship between education and income per capita is examined, and the findings compared to the environmental Kuznets curve hypothesis. The remainder of this paper is organized into 5 major sections. The following section presents a theoretical framework required for a deep scientific understanding of the subject. Subsequently, section three provides a brief review of previous studies. And then the description of the data and research methodology is followed by the estimation results. Finally, conclusions and policy suggestions are given in the section six.

## *2. Theoretical Framework*

Drivers of renewable energy deployment can be classified into 3 groups based on the literature: socioeconomic factors, political factors, and other country specific factors. Political factors comprises geopolitical risks, government's vision for renewable energy, national energy policies, international treaties and commitments. Socioeconomic factors group is being a wider group.

It covers the effects of social preferences and economic variables on the use of renewable energy. Education, income, carbon intensity, energy prices, energy needs, and demographic qualifications fall within the socioeconomic factors group.

Country specific factors group involves the factors, which cannot fit in any other groups, like renewable energy potential and continuous commitment to renewable energy adoption (Margues et al., 2010:6878-6880; Aguirre and Ibikunle, 2014:375; Mehrara et al., 2015:98). Interwoven with many of these factors, education level can be classified in the socioeconomic factors group. Education, which is a basic human right, is increasingly regarded as a factor directly related to economic development, employment, income inequality, and personal income. But relating education to the use of renewable energy refers to a more recent past, to the beginning of the 21st century.

Since human capital theory explicitly focuses on education level, in some studies education level is considered under the concept of human capital (Zhao et al., 2013:889; Mehrara et al,. 2015:102). Education enhances the abilities of learning, coordination and innovation, adaptation to new circumstances and tasks, the probability of adoption of new technologies, self-reliance on economic matters, and productivity (Lawrence et al., 1991:2). Hence, individuals with a good education are more likely to have advanced production skills, higher income, lower unemployment risk, and a differentiated consumption pattern. Higher income and awareness leads to higher luxury good demand like leisure time and clean environment (Dunn and Mutti, 2004:245). Demand for clean but expensive renewable energy is considered within this purview. It should have to be noted that due to technological developments, renewable energy costs have been decreasing dramatically and already become competitive in many plants. But it is not possible to generalize it to world wide yet.

Income channel is not the only mechanism that affects renewable energy demand while education level rises in a society. Reviewing the definition of education process might be a good starting point for explaining another channel. Education shortly can be defined as a set of tool for receiving, understanding, processing the data. As long as an individual is evolving in terms of these skills, then it is claimed that this person would be aware of the challenges and provide solutions on time. From this point of view, education is a kind of prerequisite for evaluating the risks of global warming and climate change, fighting against them and adapting to new environmental conditions (Lutz et al., 2014:1061).

According to some authors, the role of education in environmental policies is not well acknowledged and education should be at the core of national-international energy policies (Hsu, 2016:4-5,23; Stern, 2006:8). Hsu (2006) names fossil-fuel dependent societies as the societies with the wrong kind of human capital. And the author claims that wrong kind of human capital would behave like fossil-fuel lobby and would lead to a political economy in favor of hydrocarbon sources. On the other side, societies with qualified human capital and higher environmental awareness is defined as societies with the right kind of human capital by the author. In countries endowed with the right kind of human capital, demand of clean technologies is expected to be high (Hsu, 2006:1). The idea of knowledge and awareness towards environment will increase renewable energy demand is being emphasized also in many different studies (Furchtgott-Roth, 2012; Pfeiffer and Mulder, 2013; Aguirre ve Ibikunle, 2014; Margues et al., 2010).

As for renewable energy supply and education of a society relationship, two crucial aspect attract attention: a) technology development and innovation capability b) technological diffusion. Technological invention and innovation, from a broad perspective, is the insurance of the sustainability of today's modern, energy-intensive lifestyle. In addition, knowledge and know-how gained from research and development activities are considered as physical capital and be termed knowledge capital in economic growth literature (Yeldan, 2012:50).Besides, many different problems, global warming and climate change is widely accepted as a threat to human life. And since nearly 3/4 of harmful atmospheric greenhouse emissions originates from energy extraction and use, renewable energy related research and development has become increasingly important (Newell, 2011;Fischer and Newell, 2008; Acemoğlu et al., 2012; Johnstone et al., 2010). As it can be seen, research and development activities and innovations are being foregrounded in order to acquire the knowledge and know-how required by the renewable energy sector. As in Hsu (2006) stated that only in economies which are resourceful in terms of knowledge and skill, it is possible to keep up with technological developments and create innovations (Hsu, 2006). It is considered that qualifications of human capital are directly connected to the education process they received and the structure of education investments in that economy (Mondal et al., 2016:1122-1123). It is expected that in economies, where knowledge level and environmental awareness rises through education, the number of non-governmental organizations operating in the renewable energy field are expected to be increased as well (Viardot, 2013).

This kind of organizations not only provide demand supportive activities, but they also help to reduce human resources problem of the sector.The other major aspect is technological diffusion process. If the breakthroughs of some developing countries like China and India in last years left aside, it is seen that renewable energy technologies are almost entirely sourced from developed countries.

It is stated that the underlying reason of this situation is developed countries are the countries rich in well-educated human capital and financial resources (Dechezleprete et al., 2011; Popp et al., 2011). However the number of renewable energy technology developer countries is limited on a global scale. So that technological diffusion process gains significance and it would be helpful to give some details about technological diffusion.As is known, newly developed technologies may not be competitive at first stage (and this goes for renewable energy technologies) and cannot replace the conventional ones immediately. In other words, new technologies usually accepted as complementary in the beginning. It takes some time to grow into a substitute (Pfeiffer and Mulder, 2013; Gruebler et al., 1999).

At early stages of the life cycle, technology importer countries would largely become dependent on foreign markets and trying to cope with some financial problems. Also expertise, productivity of the capital and profitability would remain low at early periods. These undesired factors would make new investments less attractive. At this point, the most vital factor would be the speed of learning by doing. If learning happens quickly, then one might expect fast increases in productivity and profitability (Arrow, 1962; Parente, 1994; Pfeiffer and Mulder, 2013). To sum up, the development of global renewable energy sector largely depends on the efficient management of technological diffusion. On the other hand, efficiency of technological diffusion heavily depends on the existence of well educated human capital.

Another dimension of the subject is the competitiveness of the economies. Owing to the knowledge intensive nature of renewable energy sector, leading renewable energy technology exporter countries are able to keep the first-mover advantage for relatively longer time than any other labor or capital intensive industry. Because many times it is not possible to keep the competitiveness in renewable industry only by using cheap labor without not adequate knowledge and skill endowment (Markandya et al., 2016:8). And being innovative is clearly a significant factor in to continue to be a market leader in the field and have all benefits associated.

The human resource shortage problem, renewable energy industry is facing in the developing countries, is cannot be reduced to the first stages of technological diffusion and insufficient expertise. Because the shortage of technical workforce responsible for operation&maintenance activities and the shortage of executives who might lead the domestic renewable energy industry are considered the main barriers worldwide (Hassett and Borgerson, 2009; Seetharamana et al., 2016:1371;REN21, 2017:108). The shortage about specialized technical labor also causes technical dependence on developed countries and cutting down the foreign exchange savings sector providing to the economy.

## *3. Literature Review*

Using patent data Popp et al. (2011) aims to reveal the effect of knowledge on renewable energy investments in OECD countries. The study covers solar, wind, geothermal, waste, bioenergy sources and 1990-2004 period. Established results show that increased knowledge has a robust positive, yet weak, influence on wind, waste and bioenergy investments. On the contrary, the research fails to report statistically significant results for solar and geothermal type of energies.

As mentioned in the previous section, while developed countries have been heavily investing in non-hydro renewable energy sources since 90’s, developing countries started to follow them with a time lag. Due to country-specific reasons, most of the developing countries are still behind the developed countries. Kinab and Elkhoury (2012) discusses the barriers to renewable energy adoption in Lebanon, which is 98 percent dependent on foreign energy sources and definitely one of the lagging countries in the renewable energy field. Identified main barriers are all knowledge related and summarized as follows: a) having no reliable data on the wind, solar and water potential of the country b) insufficient government incentives and institutional infrastructure c) high cost of renewable energy d) the shortage of well educated labor d) lack of social environmental awareness.

Pfeiffer and Mulder (2013) explore the drivers of technological diffusion of renewable energy across 108 developing countries.Estimates show that secondary schooling enrollment ratio is positively related to renewable energy diffusion.

The reason behind this finding is explained by education's bolstering effect on learning by doing, innovation and adaptation to new challenges.Similarly Zhao et al. (2013) estimates that secondary schooling ratio is in positive relationship with non-hydro renewable energy consumption.Viardot (2013) approaches the issue from a different point. The author explores the cooperatives, which are established to promote renewable energy use and has become increasingly widespread in Canada, Germany, Denmark, USA, and England.

Based on their experiences, the cooperative officials determined the main barriers to renewable energy adoption like follows: a) free rider problem b) high costs of renewable energy d) not owning a feasible location to produce energy from renewable sources. This study also investigates the ways to circumvent the barriers. Interviewed officials stated that they are mostly taking the advantage of creating a reliable financial environment, reducing the uncertainties, making easier to change the lifestyles of individuals. What is more to the point, interviewed officers claimed that for all these purposes educational communication is mainly used. So this study can be considered as another study confirming increased education positively affects renewable energy deployment.

Mehrara et al. (2015) explores the key drivers of renewable energy demand in the Economic Cooperation Organization (ECO) countries. As a regressor tertiary school enrollment ratio is used. Statistically significant results show that education is positively related to renewable energy consumption in ECO countries. In addition, the tertiary school enrollment ratio is happened to be one of by far the most robust one among the 19 auxiliary regressors.

Gabriel et al. (2016) investigates the enterpreneur's perception of challenges that affect the renewable energy sector in 28 developing countries. To this end, they have conducted two staged study by using country level secondary data and by using primary data obtained from sector entrepreneurs. As a starting point, the most common barriers chosen depending on the literature and discussed with the entrepreneurs. Findings show that due to lack of qualified education, unskilled labor is one of the main problems. It is asserted that entrepreneurs are trying to sort this issue out by training the labor in business. Furthermore, lack of knowledge and understanding of renewable energy technologies is suggested a main cause of insufficient renewable energy demand.

Following a different methodology from the previous studies Seetharamana et al. (2016), compares the internal and external factors that might affect the renewable energy deployment. Based on supply-chain model, the authours identifies the external factors as lack of social awareness, environmental concerns, and technological innovation deficiencies. On the other side, internal factors are listed as follows: talent shortage, performance instabilities, unstructured process, and unaligned strategies. This research emphasized the importance of developing knowledge management process and sharing information to deal with talent shortage and lack of social acceptance.

## *4. Data and Methodology*

The number of cross-sections, determined by the data availability, is 62 and listed in Appendix A. Used annual time series spans 1990 to 2014; hence, it can be said that data set captures the significant developments (technological or political) in renewable energy adoption. Our data set is unbalanced and compiled based on open sources: the International Energy Agency, the World Development Indicators of the World Bank, and the British Petroleum Statistical Review of World Energy. Summary statistics of the data are provided in Appendix B. To assess the effects of school enrollment ratio's on renewable energy adoption, regression equations are specified as follows.

$$RE_{it} = \alpha + \beta X_{it} + \delta SEC_{it} + u_{it} + w_{it} \qquad (1)$$

$$RE_{it} = \alpha + \beta X_{it} + \delta TER_{it} + u_{it} + w_{it} \qquad (2)$$

where $RE_{it}$ is denotes the electricity generation from non-hydro renewable energy sources as a share of total electricity generation in country i at year t. $SEC_{it}$ is secondary school enrollment (gross) variable. $TER_{it}$ is tertiary school enrollment (gross) variable in country i at year t. $X_{it}$ represents the vector of control variables. $\alpha$ is the constant. $\beta$ is the vector of coefficients of control variables. $\delta$ is the coefficient of education variables. $w_i$ is country fixed effects to reflect heterogeneity between cross-sections. $u_{it}$ is the random error term. As is seen in Equation (1) and (2), secondary school enrollment ratio (SEC) and tertiary school enrollment ratio (TER) are chosen as indicators of education level of an economy.

But the correlation between them is 0.6205 and using them together in the same regression might lead to multicollinearity problem. So we prefer to regress them separately. Since renewable energy deployment has many drivers, a large set of control variables is incorporated into models.

$$X_{it} = GDP_{it} + GDP_{it}^2 + EC_{it} + CO2_{it-3} + Kyoto_{it} + TO_{it} + Oil_{it} + Coal_{it} + Gas_{it} + OPrice_{it} + Hydro_{it-3} + Nuc_{it-3} \quad (3)$$

In Equation 3 income is represented by GDP per capita (constant 2010 1000 US$) As a strength of this study, the income effect on renewable energy is modeled in non-linear form like in environmental Kuznets Curve hypothesis. EC denotes annual electricity consumption growth and $CO_2$ is the per capita carbon dioxide emissions (metric tons). Kyoto is a dummy variable and reflects the status of ratification to Kyoto Protocol. Trade openness (TO) is measured by the sum of exports and imports as a share of GDP. Oil, Coal, and Gas denote the megaton oil production per million capita, the megaton oil equivalent of coal production per million capita, and the megaton oil equivalent of gas production per million capita respectively. To capture substitution effect, crude oil prices (US$ per barrel constant at 2015) are used. Data is taken from the British Petroleum Statistical Review of World Energy. For not to cause a multicollinearity problem, gas or coal prices are not added. Hydro and Nuc represent the share of hydro and nuclear energy sources in electricity production respectively. Hydro and nuclear energy sources are seen as the other environment friendly energy types. So it is anticipated that higher shares of hydro and nuclear in electricity generation will lead to countries being less like to invest in renewable sources. To control for this possible impact Hydro and Nuc variables are included into the equations. Finally, following similar approaches seen in Popp et al. (2011) and Zhao et al. (2013) to avoid potential endogeneity problems lagged forms of carbon dioxide emissions, share hydro and nuclear energies in the electricity generation are used in models. Other variables are used in levels based on the previous literature.

In Figure 1. the histogram of the dependent variable is given. The histogram shows that a larger number of observations piled up at zero; 21.8% of the total RE observations has a zero value.

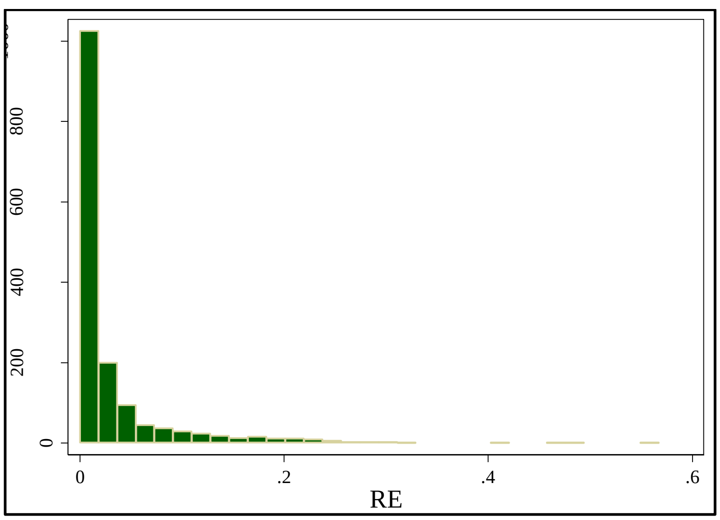


**Figure 1.** Histogram of the non-hydro renewable energy share

As emphasized in Helpman et al. (2008) and Santos Silva and Tenreyro (2006), this kind of distribution would lead to biased results in ordinary least squares estimation methodology. Additionally, the data set is unbalanced. So, according to the characteristics of the sample, fixed effect Poisson pseudo-maximum likelihood estimation technique, which can deal with missing data, exceed zero problem and cross-country heterogeneity, is applied. Besides Poisson pseudo-maximum likelihood estimation (PPML) is robust in case of heteroskedastic error terms and for any kind of data distribution. In literature, Poisson estimators usually known for count-data applications. But it is proven that fixed effect PPML is convenient in many situations if the dependent variable is strictly positive (Manning and Mullahy, 2001; Wooldridge, 2002:676). Also Santos Silva and Tenreyro (2006, 2011) presented a simulation which clearly shows that PPML performs well compared to other estimators. After these breakthrough studies, many researchers choose to use PPML for many different purposes. For instance Fournier et al. (2015), Groba and Cao (2014), Koźluk and Timiliotis (2016), Iwata et al. (2015), Felbermayr and Gröschl (2011), and Zhao

et al. (2014) are among them. For detailed information about this technique, see Wooldridge (2002), Deniz (2005), and Winkelman (2008). Scatter plots of the share of non-hydro renewable energy sources in electricity consumption against secondary school enrollment and tertiary school enrolment are given in Figure 2.
In both plots, a weak positive relationship between school enrollment ratios and renewable energy can be seen. Yet having a clear understanding is not possible at this stage.

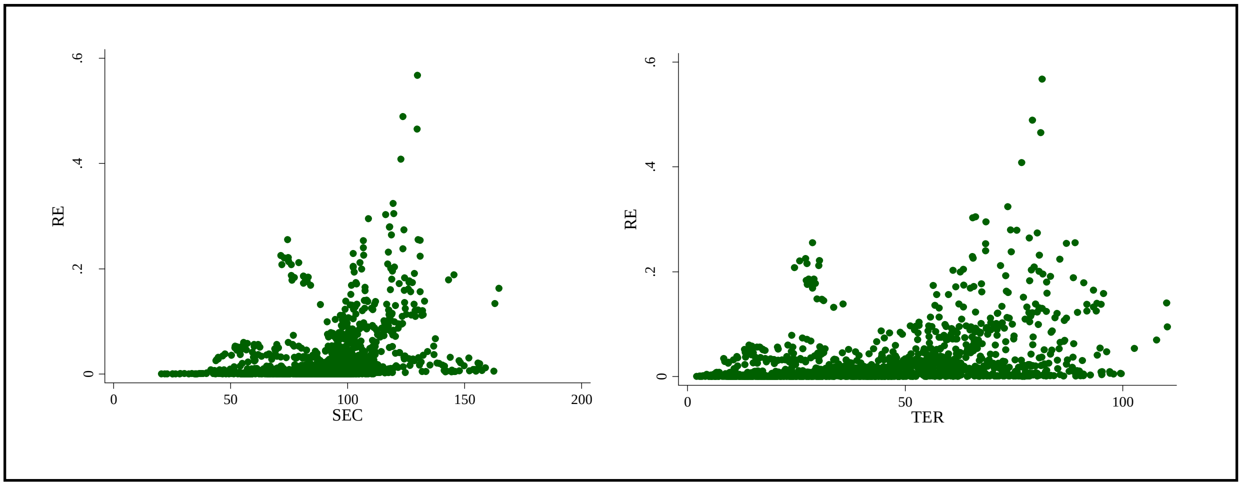


**Figure 2. Scatter plot of secondary school enrollment and tertiary school enrollment against the share of non-hydro renewable energy sources**

Prior to estimations, the sample is also checked for outliers. In the literature different approaches can be seen related to outliers. First one of the reviewed approaches claim that data should be taken as it is. Without a robust theoretical or rational reason, leaving the outliers out of the sample would lead to sample selection bias and/or ethical problems ( Liu et al., 2002, Aguinis et al., 2013; Pollet and van der Meish, 2016; Orr et al., 1991). The other approaches suggest that outliers might have an undue influence on the parameter estimations. So if this is the case, then one of the following options should be applied: a) transforming the outliers b) implementing an outlier robust estimator c) removing outliers from the data d) conducting two separate estimation (one with whole data, the other one with outlier free data) and reporting outcomes comparatively (Obydenkova and Salahodjaev, 2017:185; Luzzati and Orsini, 2009:294; Kelly, 2011:5612-5613; Rolls et al., 1999:867, Cook and Tang, 2010:76).In this analysis, firstly statistical tests were carried out in order to reveal possible outliers and their influence on the estimations. None of the computed Cook's distance statistics are greater than 1; even not greater than the weak cut-off value (4/(n-k-1)). So it is concluded that there is not any significant outlier issue in the data. For threshold values, see Cook (1977) and Fox (2009).

### *5. Results and Discussion*

**Table 1. presents the estimation results obtained with fixed effect PPML.**

| **Table1. Regression results** | | | |
|---|---|---|---|
| | Model I | | Model II |
| Tahminci | PPML | | PPML |
| SEC | 0,0100519*** | | |
| | [0,0037297] | | |
| TER | | | 0,0210999*** |
| | | | [0,0065815] |
| GDP | 0,170665*** | | 0,114466* |
| | [0,0633493] | | [0,0653248] |
| GDP² | -0,0014442*** | | -0,0011766** |
| | [0,0004953] | | [0,0005641] |
| EC | -0,6417919*** | | -0,5665837** |

| | | | |
|---|---|---|---|
| | [0,2382967 ] | | [0,2238881] |
| CO2 | -0,1573547*** | | -0,1401252** |
| | [0,0459548] | | [0,0571744] |
| Kyoto | 0,1632936 | | 0,1322081 |
| | [0,1342878 ] | | [0,1172614] |
| TO | 0,0147729*** | | 0,0159279*** |
| | [0,0032272] | | [0,0032576] |
| Oprice | 0,0064024*** | | 0,0044985*** |
| | [0,0014736] | | [0,0014766 ] |
| Oil | -0,0299483 | | -0,0502605 |
| | [0,0505615] | | [0,0488764 ] |
| Gas | 0,0889838 | | 0,0857373 |
| | [0,0505615] | | [0,0845533] |
| Coal | -0,0409647 | | 0,0710077 |
| | [0,2889534] | | [0,2236367] |
| Hydro | 0,0057203 | | 0,0121417 |
| | [0,0097051] | | [0,0113411] |
| Nuc | -0,0153601*** | | -0,0184723*** |
| | [0,0054525] | | [0,0052994] |
| Constant | | | |
| Cross section fixed effects | + | | + |
| Log likelihood | -88,54916 | | -84,64021 |
| Observation | 1248 | | 1202 |
| Pseudo $R^2$ | 0,21 | | 0,22 |

Notes: The numbers in the paranthesis indicate robust standart errors.
***, ** and * represents significance at 1%, 5 % and 10% level respectively.

According to the results, statistically significant variables are secondary school enrollment ratio, tertiary school enrollment GDP, $GDP^2$, electricity consumption growth, carbon dioxide emission per capita, trade openness and oil price. Both secondary school enrollment and tertiary school enrollment ratio coefficients are positive and significant above the 1% level. Estimated positive relation outcome is in accordance with the theoretical literature and previous studies like Zhao et al. (2014) and Aguirre and Ibikunle (2013). Based on these results, it can be stated that increased schooling improves knowledge stock of the society, qualities of the human capital and social awareness towards the environment. So as a consequence of these developments, adoption of renewable energy rises as well. On the other side, it is estimated that the impact of tertiary school enrollment is stronger than the secondary school enrollment's. This result is well expected since renewable energy technologies are defined as skilled-biased-technological change (Rennings et al., 2004:385; Raitano et al., 2017:118). As a new developing technology, renewable energy technologies require highly educated human capital to boost the industry. Besides on the demand side, increased academic education might enhance the likelihood of having the skills needed for being aware of environmental risks for an individual.

According to the estimates of GDP per capita, which is considered as one of the most important indicators of economic development, non-linear relationship is confirmed at 5% significance level.Linear and non-linear terms of GDP per capita show the existence of an inverted-U shaped relationship between income and non-hydro renewable energy. This estimate suggests that as countries economically evolve, (initially zero) non-hydro renewable energy sources share increases as well until a certain income threshold.

At this stage financial opportunity, technological progress and social awareness towards environment would rise along with the economic development. The renewable energy sector would grow in line with these developments. But since the share of renewable sources in total is still too low, we would expect that environmental degradation will continue but at a decreasing rate at this stage. Then after a certain income threshold, test results for the sample offers that the share of renewable energy in total energy sources will decrease with the income per capita. This outcome may be interpreted by the desire for diversity, renewable energy potential constraints, energy system security and balance costs of the system.

For instance, in very high income case, economic activities volume would be too large to depend on only non-hydro renewables. Also, many other interactions not mentioned here may lead to this relationship. But more importantly revealed inverse U-type relationship between economic development and renewable energy adoption can be associated with N shaped Environmental Kuznets curve.

As explained in many studies, N shaped Kuznets curve implies that environmental degradation increases at the first stage, but then falls after the transitory period degradation starts to increase again in the final stage (Atasoy, 2017:733; Pal and Mitra, 2017:2; Dinda, 2004:441). So it can be said that obtained inverted-U type relationship between renewable energy adoption and economic development corresponds to second and third stages of the N shaped EKC. And lastly, one can also expect that it is highly possible to obtain an inverted-N shaped curve for non-hydro renewable energy and income when analyzing a longer time horizon than this study.

Estimation results suggest that carbon dioxide emissions are not positively associated with renewable energy development for the countries in our sample. The negative effect of $CO_2$ emissions on the dependent variable is robust between models and statistically significant at the 1% level. These findings are in line with Zhao et al. (2013), Pfeiffer and Mulder (2013), Marques and Fuinhas (2011), Marques et al. (2010).So, for the sample, it can be said that either environmental awareness is low or despite high awareness, environmental issues are not a decisive factor in energy policies. If low awareness is the case, then environmental education activities might be useful. Also, it is very possible that increasing carbon dioxide emissions bring out energy policies in favor of renewables. But, on the other hand, increased residential and transportational fossil fuel use may compensate renewable source's environment friendly impacts. Under this circumstance carbon emissions and renewable energy use in electricity generation rise together. Another possible explanation comes from Whitmarsh (2009). The author addresses the asymmetric behaviors of individuals related to environmental issues in England. Her findings shows that individuals volunteer to recycle home waste and improve their home's energy efficiency, but resist to pay more for electricity or to change transportation habits. As a last note, due to high upfront costs of renewable sources, many carbon intensive economies prefer to deploy natural gas and slow down the adoption of renewable energy.

Another expected finding is statistically significant at the 1% level and the negative effect of electricity consumption annual growth rate on renewable energy deployment. This result is in alignment with the findings of Marques et al. (2010), Popp et al. (2011), Marques and Fuinhas (2011), Zhao et al. (2013), Pfeiffer and Mulder (2013). Negative impact implies that as electricity demand accelerates, policy makers tend to meet the energy deficit from non-renewable sources since they are cheaper for now.

The findings confirm the theoretically anticipated positive impact of trade openness on the share of renewable energy sources in total. Estimations are significant at the 1% level in both specifications. This result is in accordance with the Omri and Nguyen (2014) and Omri et al. (2015). As expected, increased trade openness enhances technological diffusion and stimulates learning-by-doing. The result given in Table 1. shows that the oil price is positively related to the renewable energy adoption. This finding implies that oil and renewable energy are substitutes. However, the relationship is very weak, Omri and Nguyen (2014), Salim and Rafiq (2012) also documented weak effect of oil prices on renewable energy adoption. On the other side, the share of nuclear energy in electricity generation has a significant, but negative impact on non-hydro renewable energy adoption. This finding is in accordance with Popp et al. (2011), Aguirre and Ibikunle (2013). And this finding suggests that nuclear energy is seen a strong substitute of non-hydro renewable energy because it is an emission-free source and helps to fight global warming. Finally, the coefficients of domestic production of conventional sources (natural gas, oil, and coal), participation of hydro power in electricity generation and ratification of the Kyoto protocol are not found to be statistically significant.

## *6. Conclusion*

In this paper, the effect of education on non-hydro renewable energy is investigated. Education level is measured by secondary school and tertiary school enrollment rates. The dataset covers 62 countries and the period of 1990-2014. Overall, the empirical evidence suggests that education has a significant and positive impact on non-hydro renewable energy deployment. This finding is robust across model specifications. Furthermore tertiary school enrollment rate is found to have a stronger impact on the non-hydro renewable energy. Hence it can be said that increased levels of education will lead to more non-hydro renewable energy demand and help to diminish problems related to non-hydro renewable energy supply.

As another significant contribution to the field, income and renewable energy adoption is examined whether there is a quadratic relationship between them. Our findings confirm an inverse-U shaped association. Beside the implications of this result argued above, it is also possible to obtain an N shaped curve for a longer period of time than this study.

The obtained results indicate that trade openness is positively linked with non-hydro renewable energy deployment. High levels of trade will make easier to technological diffusion of renewable technologies, which is vital factor especially in developing countries. Likewise, oil prices are positively related to non-hydro renewable adoption. This evidence implies that oil and non-hydro renewable sources are substitutes, yet the impact is weak. On the other side, $CO_2$ per capita emission levels are negatively linked with non-hydro renewable energy participation. This finding suggests that environmental awareness is not a decisive factor in the energy policies of the countries in our sample and cheaper sources are mostly preferred over non-hydro renewable energy sources. Or behavioral asymmetries mentioned above, might lead to negative linkage. If any of these is the case, one might expect to benefit from environmental education activities. Similarly, the need for additional electricity is negatively linked with non-hydro renewable energy participation. This finding may be relevant to the cost structure of competing energy sources. It is commonly stated that policy makers tend to choose cheaper energy sources. Unexpectedly, the estimates can not identify a statistically significant relationship between ratification of Kyoto protocol and dependent variable. Likewise, the findings cannot depict a statistically significant lobby effect of domestic coal, oil and natural gas industries. Empirical investigations of this research have strong policy implications. Increased knowledge in an economy will help human capital to gain required skills and awareness towards clean environmental issues. Hence, in order to properly fight to climate change, energy policy makers should see education as a tool to boost non-hydro renewable energy deployment. Especially higher levels of education would be a useful tool to reduce the problems non-hydro renewable industry facing in many countries.

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### **Appendix A**

Algeria, Argentina, Austria, Australia, Azerbaijan, Bangladesh, Belarus, Belgium, Brazil, Bulgaria, Canada,Chile, China, Colombia, Czech Republic, Denmark, Egypt, Equator, France, Finland, Germany, Greece, Hungary,India, Indonesia, Iran, Ireland, Israel, Italy,Japan,Kazakhstan, Kuwait,Lithuania,Malaysia, Mexico,Netherlands, New Zealand, Norway, Pakistan, Peru, Philipppines, Poland, Qatar,Romania, Russia, Saudi Arabia, Slovakia, South Africa, South Korea, Spain, Sweeden, Switzerland, Thailand, Trinidad and Tobago, Turkey, Ukraine, UAE, UK,USA,UzbekistanVenezuela.

## Appendix B

**Table B** Summary Statistics of The Data

| Variable | Observation | Mean | Std Deviation | Min | Max |
|---|---|---|---|---|---|
| RE | 1550 | 0.029 | 0.055 | 0.000 | 0.567 |
| SEC | 1319 | 92.547 | 21.865 | 2.040 | 164.812 |
| TER | 1275 | 44.247 | 23.593 | 2.135 | 110.263 |
| GDP | 1527 | 20.987 | 20.092 | 0.400 | 91.594 |
| TO | 1527 | 71.971 | 36.776 | 13.753 | 220.407 |
| EC | 1550 | 0.031 | 0.067 | -0.626 | 0.566 |
| $CO_2$ | 1498 | 8.356 | 8.402 | 0.121 | 70.985 |
| Oprice | 1550 | 56.513 | 32.429 | 18.490 | 117.229 |
| Coal | 1547 | 0.496 | 1.320 | 0.000 | 12.244 |
| Oil | 1547 | 3.608 | 10.718 | 0.000 | 68.285 |
| Gas | 1547 | 1.896 | 6.525 | 0.000 | 76.068 |
| Hydro | 1529 | 21.021 | 25.759 | 0.000 | 99.623 |
| Nuc | 1529 | 11.985 | 19.607 | 0.000 | 87.986 |

## References

Acemoglu, D., Aghion, P., Bursztyn, L., and Hemous, D. (2012). The Environment And Directed Technical Change. *American Economic Review,* 102, 131-166.

Aguinis, H., Gottfredson, R.K., and H. Joo. (2013). Best-Practice Recommendations for Defining, Identifying, and Handling Outliers. *Organizational Research Methods*, 16(2), 270-301

Aguirre, M., and Ibikunle, G. (2014). Determinants of renewable energy growth: a global sample analysis. *Energy Policy,* 69, 374-384.

Arrow, K.J. (1962). The economic implications of learning by doing. *Review of Economic Studies*, 29, 155-173

Atasoy, B.S. (2017). Testing the environmental Kuznets curve hypothesis across the U.S.: Evidence from panel mean group estimators. *Renewable and Sustainable Energy Reviews*, 77, 731-747.

BP. (2016). BP Statistical Review of World Energy Workbook 2016. http://www.bp.com/statisticalreview(16.08.2017)

Cook, R.D. (1977). Detection of influential observations in linear regression. *Technometrics,* 22, 494–508.

Cook, R.D., and Tang, T. (2010). Macroeconomic conditions and capital structure adjustment speed. *Journal of Corporate Finance,* 16(1), 73-87.

Dechezlepretre, A., Glachant, M., Hascic, I., Jonhstone, N., and Meniere, Y. (2011). Invention and transfer of climate change-mitigation technologies: a global analysis. *Review of Environmental Economic Policy*, 5(1), 109-130.

Deniz, Ö. (2005). Poisson regresyon analizi. *İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi*, 4(7), 59-72.

Dinda, (2004). Environmental Kuznets Curve Hypothesis: A Survey. *Ecological Economics,* 49, 431-455.

Dunn, R.M., Mutti, J.H. (2004). International Economics. London. Routledge. http://tabesh.edu.af/Books/economic/International%20Economics.pdf

Felbermayr, G., and Gröschl, J.(2011). Natural Disasters and the Effect of Trade on Income: A New Panel IV Approach. *Cesifo Working Paper, No:3541*. https://www.econstor.eu/bitstream/10419/49463/1/665794355.pdf(07.05.2017)

Fischer, C., and Newell, R. (2008).Environmental And Technology Policies For ClimateMitigation. *Journal of Environmental Economics and Management,*55(2), 142-162.

Fournier, J-M., Domps, A., Gorin, Y., Gouillet X., and Morchoisne, D. (2015).Implicit Regulatory Barriers in the EU Single Market. *OECD Economics Department Working Papers No. 1181*, 1-29.

Fox, J. (2009). Regression diagnostics. http://socserv.socsci.mcmaster.ca/fox/ Courses/Brazil-2009/slides-handout.pdf. (19.05.2017)

Furchtgott-Roth, D. (2012). The elusive and expensive green jobs. *Energy Economics*, 34, 43-52.

Gabriel, C-L., Kirkwood, J., Walton, S., and Rose, E.L. (2016). How do developing country constraints affect renewable energy entrepreneurs?. *Energy For Sustainable Development*, 35, 52-66.

Groba, F., and Cao, J. (2014). Chinese Renewable Energy Technology Exports: The Role of Policy, Innovation and Markets. *Environmental and Resource Economics*, 60(2), 243-283.

Gruebler, A., Nakicenovic, N., and Victor, D.G. (1999). Dynamics of energy technologies and global change. *Energy Policy*, 27, 247-280.

Hassett, T., and Borgerson, K. (2009). Harnessing nature's power: deploying and financing on-site renewable energy. World Resources Institute, Washington. https://www.wri.org/sites/default/files/pdf/harnessing_natures_power.pdf (04.11.2017)

Hsu, S-L. (2016). Capital Transitioning: A Human Capital Strategy for Climate Innovation.*FSU College of Law, Public Law Research Paper*, 809, 1-24. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2804841## (07.12.2016)

IRENA. (2016). Renewable Energy and Jobs. Annual Review 2016. https://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Jobs_Annual_Review_2016.pdf (15.05.2017)

Iwata, K., Katayama, H., and Arimura, T.H. (2015).Do households misperceive the benefits of energy-saving actions? Evidence from a Japanese household survey. *Energy For Sustainable Development*, 25, 27-33.

Johnstone, N., Hai, I., and Popp, D. (2010). Renewable Energy Policies And Technological Innovation: Evidence Based On Patent Counts.*Environmental and Resource Economics,* 45, 133-155.

Kelly, S. (2011). Do homes that are more energy efficient consume less energy?: A structural equation model of the English residential sector. *Energy,* 36, 5610- 5620.

Kinab, E., and Elkhoury, M. (2012). Renewable energy use in Lebanon: Barriers and solutions. *Renewable and Sustainable Energy Reviews*, 16, 4422-4431.

Koźluk, T., and Timiliotis, C. (2016). Do environmental policiesaffect global value chains?: a new perspective on the pollutionhaven hypothesis. *OECD Economics Department WorkingPapers*, No. 1282, OECD Publishing, Paris.

Lawrence J.L., Jamison, D.T.; Louat,F.F. (1991). Education and productivity in developing countries : an aggregate production function approach. Policy Research and External Affairs working papers, WPS 612. World Development Report. Washington. DC: World Bank. http://documents.worldbank.org/ curated/en/720681468739788036/Education-and-productivity-in-developing-countries-an-aggregate-production-function-approach

Liu X., Cheng, G., and Wu J.W.(2002). Analyzing outliers cautiously. I*EEE Transactions on Knowledge and Data Engineering*, 14(2), 432-437.

Lutz, W., Muttarak, R., and Striessnig, E. (2014). Universal education is key to enhanced climate adaptation. *Science,* 346 (6213), 1601-1602.

Luzzati, T., and Orsini, M. (2009). Investigating the energy-environmental Kuznets curve. *Energy*, 34, 291-300.

Manning, W.G., and Mullahy, J. (2001). Estimating log models: to transform or not to transform?. *Journal of Health Economics*, 20(4), 461-94.

Markandya, A., Arto, I., González-Eguino, M., and Román, M.V. (2016). Towards a green energy economy? Tracking the employment effects of low-carbon technologies in the European Union. *Applied Energy*, 179, 1342-1350.

Marques, A.C., Fuinhas, J.A., and Pires Manso, J.R. (2010). Motivations driving renewable energy in European countries: a panel data approach. *Energy Policy*, 38, 6877-6885.

Marques, A.C., and Fuinhas, J.A. (2011). Drivers promoting renewable energy: A dynamic panel approach. *Renewable and Sustainable Energy Reviews*, 15, 1601-1608.

Mehrara, M., Rezaei, S., and Davoud, H.R. (2015). Determinants of renewable energy consumption among ECO countries; based on bayesian model averaging and weighted-average least square. *International Letters of Social and Humanistic Sciences*, 54, 96-109.

Mondal, A.H., Hawila, D., Kennedy, S., and Mezher, T. (2016). The GCC countries RE-readiness: Strengths and gaps for development of renewable energy technologies*Renewable and Sustainable Energy Reviews,* 54,: 1114–1128 .

Newell, R. (2011). *The Energy Innovation System: A Historical Perspective, Accelerating Energy Innovation: Insights from Multiple Sectors.* University of Chicago Press for the National Bureau of Economic Research, Chicago, Chapter 2, 25-47.

Obydenkova, A.V., and Salahodjaev, R. (2017). Climate change policies: The role of democracy and social cognitive capital. *Environmental Research*, 157:182-189.

Omri, A., and Nguyen, D.K. (2014). On the determinants of renewable energy consumption: International evidence. *Energy*, 72, 554-560.

Omri, A., Daly, S., and Nguyen, D.K. (2015). A robust analysis of the relationship between renewable energy consumption and its main drivers. *Applied Economics*, 47(28), 2913-2923.

Orr, J. M., Sackett, P. R., and DuBois, C. L. Z. (1991). Outlier detection and treatment in I/O Psychology: A survey of researcher beliefs and an empirical illustration. *Personnel Psychology*, 44, 473-486.

Pal, D., and Mitra, S.K. (2017). The Environmental Kuznets Curve for carbon dioxide in India and China: growth and pollution at crossroad. *Journal of Policy Modeling,* 39(2), 371-385.

Parente, S.L. (1994). Technology adoption, learning by doing, and economic growth. *Journal of Economic Theory*, 63, 246-369.

Pfeiffer, B., and Mulder, P. (2013). Explaining the diffusion of renewable energy technology in developing countries. *Energy Economics,* 40, 285-296.

Pollet, T.V., and van der Meij, L. (2016). To Remove or not to Remove: the Impact of Outlier Handling on Significance Testing in Testosterone Data. *Adaptive Human Behavior and Physiology* .http://link.springer.com/article/10.1007/s40750- 016-0050-z. (15.08.2017)

Popp, D., Hascic, I., and Medhi, N. (2011). Technology and diffusion of renewable energy. *Energy Economics*, 33, 648-662.

Raitano, M., Romano, E., and Zoppoli, P. (2017). Renewable energy sources in Italy: Sectorial intensity and effects on earnings. *Renewable and Sustainable Energy Reviews*, 72, 117-127.

REN21. (2016). Renewables 2016global status report. Paris, REN21 Secretariat. http://www.ren21.net/wp-content/uploads/2016/06/GSR_2016_Full_Report.pdf(20.08.2017)

REN21. (2017). Renewables 2017global status report. Paris, REN21 Secretariat.http://www. ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf(03.11.2017)

Rennings K, Ziegler A, Zwick T. The effect of environmental innovation on employment changes: an econometric analysis. *Business Strategy and The Environment,* 13(6),374–87.

Rolls, B.J, Elizabeth, A.J., Castellanos, V.H., Chow, M., Pelkman, C.L, and Thorwart, M.L. (1999). Energy density but not fat content of foods affected energy intake in lean and obese women. *The American Journal of Clinical Nutrition,* 1-9.

Salim, R., and Rafiq, S. (2012). Why do some emerging economies proactively accelerate the adoption of renewable energy?. *Energy Economics,* 34(4),1051-1057.

Santos Silva, J.M.C., and Tenreyro S. (2006). The log of gravity. *The Review of Economics and Statistics,* 88, 641-658.

Santos Silva, J.M.C, and Tenreyro S. (2011). further simulation evidence on the performance of the Poisson pseudo-maximum likelihood estimator. *Economic Letters,* 112, 220-222.

Seetharamana, A., Sandanaraj, L.L., Moorthy, M.K., and Saravanan, A.S. (2016). Enter prise framework for renewable energy. *Renewable and Sustainable Energy Reviews,* 54, 1368–1381.

Stern, N. (2006). what is the economics of the climate change?. *World Economics,* 7(2), 1-10.

Viardot, E. (2013). The role of cooperatives in overcoming the barriers to adoption of renewable energy. *Energy Policy,* 63, 756-764.

Whitmarsh, L. (2009). Behavioural responses to climate change: Asymmetry of intentions and impacts. *Journal of Environmental Psychology*, 29, 13-23.