HOW DOES RENEWABLE ENERGY IMPACT CARBON EMISSIONS? AN EU LEVEL ANALYSIS

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ABSTRACT
Carbon emission recently becomes one of the most important issues for our society. The interest of the researchers in the field is primarily due to factors that have a big impact in reducing the carbon emission levels. In this paper the authors employ a time series cross sectional multiple linear regression analysis with panel data to examine the relationship between economic growth, renewable energy consumption, urbanization and total population, and its impact on total carbon dioxide emission. Our findings indicate that the level of urbanization has the largest negative effect on carbon emissions, while the renewable energy consumption has a positive and direct impact on the reduction of the carbon dioxide emission. Also, levels of urbanization and population growth have also negative and significant impact on the high levels of carbon dioxide emissions. These findings suggest that public policy should be directed towards increasing the use of renewable energy in EU Countries, while level of urbanization and population growth should come with more restriction regarding the carbon dioxide emission.

KEYWORDS: *carbon dioxide emission, renewable energy, multiple linear regression, panel analysis, ANOVA model.*

JEL CLASSIFICATION: *C51, D40, F64*

1. INTRODUCTION

The concentration of carbon dioxide emission in the atmosphere has not been observed until recently. The greenhouse gases concentration will continue to alter climate system if the world leaders would not come up together with policies which would stop the climate change. The ecological contradictions of production processes and use of fossil fuel have been tied to a global system which is based on profit accumulation and exponential growth. However, many institutions and policymakers have been reluctant to address the social relations of the macro-economic system on national levels (World Bank, OECD and UN 2012).
In the past decades, renewable energy sources are becoming more and more popular worldwide. Generation of electricity generated from wind or other renewable sources is not an issue for environmentalists only. It is also a future target of the national power system that has to improve production and restore existing capacities with the goal to meet the increased consumption needs.
Renewable energy is derived from natural resources, which are naturally replenished. Without any limitation, these natural resources are related to: wind, sunlight, tides, rain, and geothermal heat.
In the same time, urbanization and population growth are economic indicators with positive trend in the past decades. While they have many positive impacts on the economy, they also have some negative impact on the environment.

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2. LITERATURE REVIEW

Previous studies have analyzed the relationship between the economic growth, renewable energy and carbon dioxide emission. Ben Aissa et. al. (2014) stated that trade openness and renewable energy consumption had a positive and direct impact on GDP for the 11 African countries used in the sample. Other studies have shown that the main contributor of carbon emission is economic growth (Rosa et. al., 2004 and Dietz et. al., 2007), stating that renewable energy growth has a negative impact on the increasing levels of carbon dioxide emissions. Apergis and Payne (2010) are assessing the correlation between renewable energy consumption and GDP per capita in a panel study of OECD countries. Shafiei et. al. (2014), examining OECD countries, came to the conclusion that an increase in using the renewable energy consumption would lead to a decrease of carbon dioxide levels.

Other studies underlined that there is an asymmetric relation and inequality between the countries and the environmental impact (Rice, 2007; Jorgenson and Clark, 2012; Jorgenson, 2016). The authors have investigated the effect of the consumption of renewable energy on carbon emissions and demonstrated that it varies by country position in the world economic system. Moreover, they have examined the relationship between the economic growth and renewable energy consumption and the impact they have on total carbon dioxide emission efficiency (carbon dioxide per GDP unit).

All these studies suggest that, while renewable energy could decrease carbon dioxide emission, economic growth, urbanization and population growth are factors which could increase the levels of carbon dioxide emissions.

3. RENEWABLE ENERGY SECTOR IN ROMANIA

For over 30 years, Romania's most important source of clean energy is supplied by the large hydropower plants. Up to and including 2012, other renewable sources accounted for only a very small share of electricity production in Romania. In 2014 the situation began to change dramatically in favor of renewable energy sources (other than large hydropower plants) and especially wind.

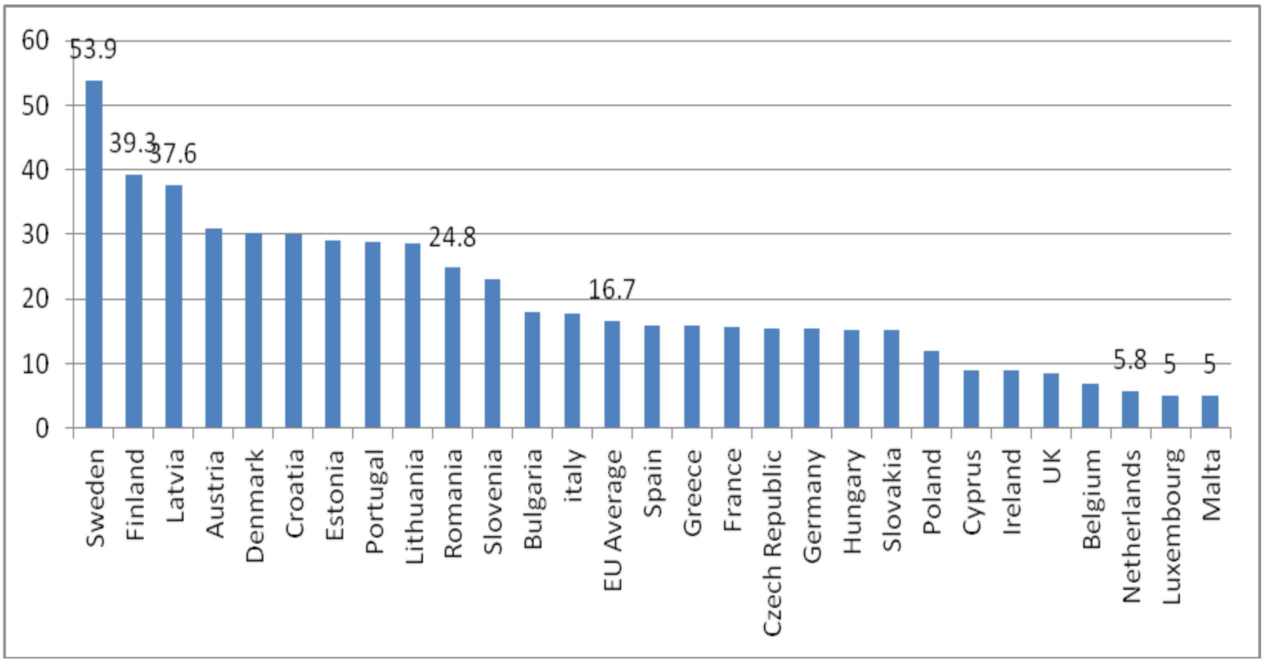

Figure 1. Share of renewable energy in gross final energy consumption in EU member states, in 2015

Source: Romanian Energy Regulatory Authority (ANRE)

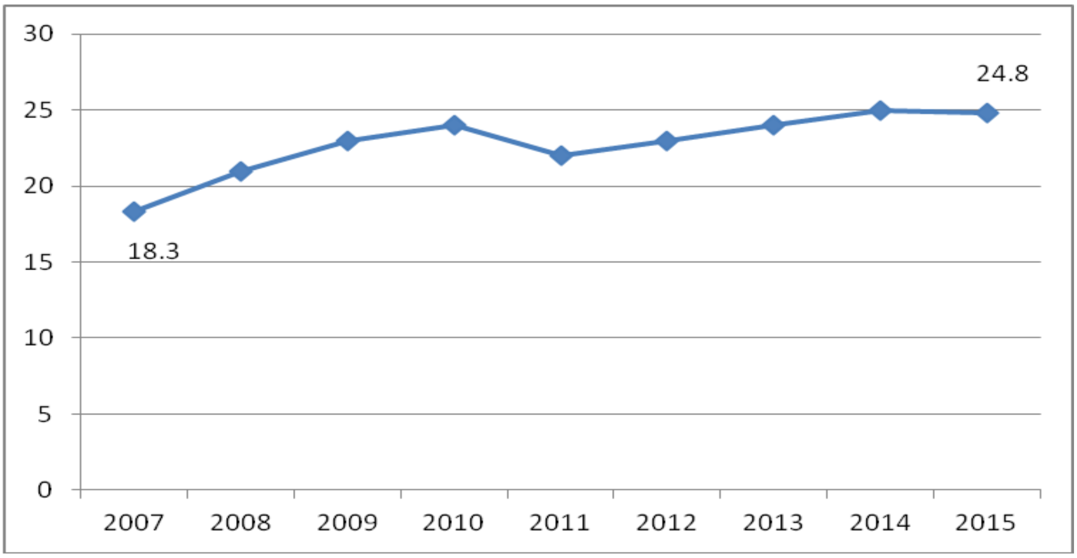

Figure 2. Share of renewable energy in gross final energy consumption in Romania, between 2007-2015

Source: Romanian Energy Regulatory Authority (ANRE)

As we could see in Figure 2, 24.8% of Romania's gross energy consumption in 2015 was covered by alternative energy, which represents a 35.5% increase from 2007. Alternative energy includes: wind energy, which brought the large majority of energy but also hydro energy, photovoltaic and biomass energy.

At the end of 2016, the produced electricity in Romania was 61.8 TWh (terawatt hour), which was split in:

- Conventional thermal power;
- Hydropower;
- The nuclear power;
- Wind power and
- Other renewable energy sources.

Figure 3 shows the share of each segment in total electric energy produced in Romania.

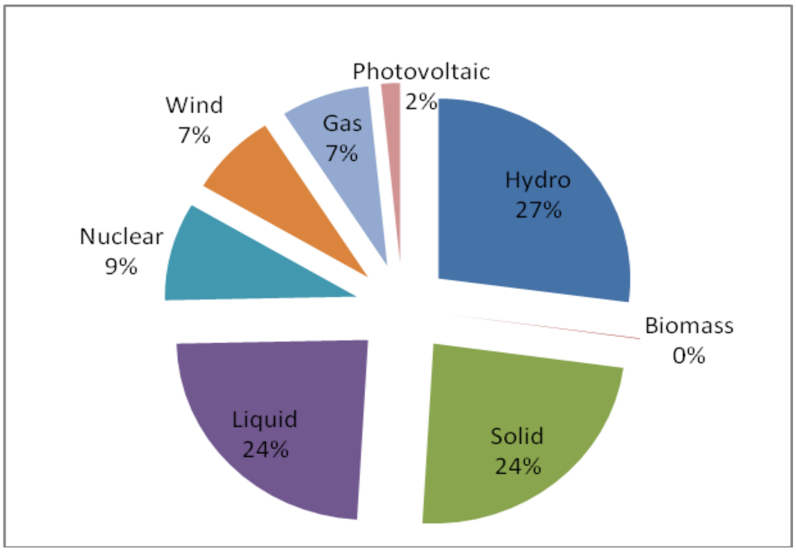

Figure 3. Electricity sources in Romania by primary sources, in 2016
Source: ANRE

4. DATA AND METHODS

4.1. Estimating the econometric model

At the European Union level, 28 Member States joined the Union at different time intervals. In our study, we will take the year 2007 as the basis for our research, because it is the year when Romania joined EU.

The relationship between economic growth, environment and renewable energy has been studied previously in many research papers. It was found that there is a high correlation between environment protection, renewable energy use and economic growth (Poerte and Van der Linden, 1995; Demirbas, 2005). Other authors (Frondel et. al., 2010; Tugcu et. al., 2012) found that, at the European Union level, environment protection and renewable energy have a positive and significant impact on economic growth.

Starting from the empirical studies, mentioned above, we will formulate our research question: "*How renewable energy may impact carbon emissions in Romania?*" Besides what is already known in this field, we will try to make an estimation regarding those factors that have the great impact on the endogenous variable in the regression model.

Hence, we will test the following statistical hypothesis:

Table 1. Statistical Hypotheses of the Regression Model

Hypothesis 1	EU Countries with greater rates of renewable energy have lower carbon emission rates.
Hypothesis 2	EU Countries with higher degree of urbanization have higher rates of carbon emissions.
Hypothesis 3	EU Countries with high economic growth have positive and significant impact on carbon emission rates.
Hypothesis 4	Total population is highly and positively correlated with carbon emission rates in EU countries.

Source: authors

In order to test all four statistical hypotheses, we will make a multifactorial econometric model, as described below.

The econometric model is a multiple linear regression model in which the independent variables will be: renewable energy rate, GDP per capita, total population and urbanization degree. These are representative variables for the endogenous variable in our model, the CO_2 emission rates at the EU level.

The regression analysis uses a cross-sectional panel dataset. The sample selection model and the results from the panel analysis are consistent, according to (Cappa et. al., 2016; Gopal et. al., 2013). Therefore, we could state that the sample size in this study is large enough.

Thus, the multilinear regression model is the following one:

$$y = \beta_0 + \beta_1(x_1) + \beta_2(x_2) + \beta_3(x_3) + \beta_4(x_4) + \varepsilon \quad (1)$$

where,

- y- dependent variable
- x_1, x_2, x_3 and x_4 – independent variables
- β_0, β_1, β_2, β_3 and β_4 – parametric coefficients

- ε – the white noise

In the regression model, we will use the dependent and the independent variables previously described and we will get the following multiple linear regression equation:

$$CO2\ emmisions = \beta 0 + \beta 1(Renewable) + \beta 2 \left(\frac{GDP}{capita}\right) + \beta 3\ (Population) + \beta 4\ (Urbanization) \quad (2)$$

Where:

- CO_2 emissions – represent the total CO_2 emission in each EU country
- Renewable – the rate of renewable energy in total energy produced
- GDP/capita – is a proxy for economic growth
- Population – represents the total population (in millions) in each EU country
- Urbanization – the degree of urbanization in total population

The data collected for the above mentioned variables have been collected from Eurostat.

4.2. Estimation of the results

The regression equation we have used in the model was estimated through the ordinal Least Square Method (OLS). We have used this method to test our four Statistical hypothesis described above. The regression equation describes a function of the endogenous equation to describe the exogenous variables.

Taken together, the regression equation is significant (Sig. = 0.44), with a coefficient of determination of 0.766 and a R_squared adjusted value of 0.650, while the Durbin Watson test validates the non-collinearity problems of the regression equation (DW=1.948). The Multiple R value (R=0.857) certifies the fact that the endogenous variable is directly and highly correlated with the exogenous variables, and the variation of the dependent variable is explained by about 76.6% of the variation of independent variables.

The multiple linear regression equation which has resulted from the econometric analysis carried out in SPSS 22 led to the following equation:

$$CO2\ emmisions = 21.975 - 3.6(Renewable) + 1.688 \left(\frac{GDP}{capita}\right) + 3.124\ (Population) + 1.907\ (Urbanization) \quad (3)$$

Since all beta coefficients of the independent variables in the model are significant (Sig. values less than 0.05) (Table 4), we conclude that all four independent variables in the model are significant. Moreover, the negative value of β_1 coefficient does confirm our expectations that EU countries with greater rates of renewable energy have lower carbon emission rates, which validates our Hypothesis 1. Also, the positive values of β_1, β_2 and β_3 also confirm our presumptions that the EU countries with high economic growth, higher degree of urbanization and population growth have positive impact on the carbon emission rates.

Hence, after the statistical analysis was performed, the four hypotheses led to the conclusion that all Hypothesis 1, 2, 3 and 4 all valid. (Table 2)

Table 2. Validation of the statistical hypotheses

Hypothesis No.	Validated
Hypothesis 1	Yes
Hypothesis 2	Yes
Hypothesis 3	Yes
Hypothesis 4	Yes

Source: authors

A general description of the variables used in the model could be seen in table 3.

Table 3. Descriptive statistics

Variable	N	Mean	Std. Deviation
CO2_emmisions (tones)	28	103915.3924	14775.95551
Renewable	28	19.8107	11.91206
GDP_capita (thousand)	28	27.4750	18.57646
Population (mil.)	28	20.6706	6.47882
Urbanization (%)	28	38.3321	14.01439

Source: Authors' determined values by using SPSS 22 software package

4.3. Discussion of the results

In this section we will discuss the multifactorial analysis performed by OLS method. The authors used this method to calculate the impact of renewable energy, GDP per capita, population volume and degree of urbanization on the carbon emissions.

As it was described in the previous chapter, the relationship between carbon emissions and renewable energy has received, in the past years, considerable attention in the literature. The multiple linear regression model used in this study was estimated through OLS method, and the statistical software used in the regression analyses was SPSS 22 software.

The evolution of carbon emissions at the EU 28 level, analyzed from 2010 to 2015, according to the exogenous variables (renewable energy, GDP per capita, population volume and degree of urbanization), and the following results were obtained for the regression function using multiple linear regression model (table 4): $Y=21.97-3.6X1+1.68X2+3.12X3+1.9X4$, with the standard error coefficients: (0.2236, 0.1462, 0.6123 and 0.8941).

Table 4: Estimation of regression equation coefficients

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	21.975	11.480		.185	.855		
	Renawable	-3.600	0.2236	-.290	-1.610	.001	.923	1.083
	GDP_capita	1.688	0.1462	.214	1.155	.026	.876	1.141
	Population	3.124	0.6123	.510	2.803	.018	.907	1.103
	Urbanization	1.907	0.8941	.117	.641	.028	.897	1.115

a. Dependent Variable: CO2_emmisions

Source: Authors' determined values by using SPSS 22 software package

The results of the estimation model are significant for a level of significance of 5% for all four exogenous variables included in the model. The OLS assumptions are verified for the same significance level, except the autocorrelation test, which was tested with Durbin-Watson test (table 5). The value of the statistic test was DW=1.948, close to 2, which suggests that the errors are not auto correlated. The software package SPSS 22 was also used to calculate the variance Inflection Factor for each exogenous variable (table 4). All these four variables (1.083, 1.141, 1.103, and 1.115) are less than 3, and hence we could state that the exogenous variables are not correlated to each other. This is also confirmed by the results from table 6, where all (Pearson) correlation coefficients between the exogenous variables are small. The linear relationship intensity between the variables of the regression model is measured by the value of the multiple linear correlation ratio $R_{y/x1, x2, x3, x4}$ equal to 0.857 (table5). That means, the relationship between the variables included in the model are direct and of high intensity. Also, the independent variables of this model are explaining 76.6% of the variation of independent variables (table 5, R square = 0.766), with the remaining 24.4% representing the influence of other factors. Our results are consistent with the work of Thombs (2017) who developed a regression model of carbon emission which partially endogenized the renewable energy rates at the EU level.

Table 5. The econometric model[b]

Model Summary[b]					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.857[a]	.766	.690	133005961.00758	1.948

a. Predictors: (Constant), Urbanization, Population, Renawable, GDP_capita
b. Dependent Variable: CO2_emmisions

Source: Authors' determined values by using SPSS 22 software package

Table 6. The correlation matrix.

Correlations						
		CO2_emmisions	Renewable	GDP_capita	Population	Urbani-zation
Pearson Correlation	CO2_emmisions	1	-.258	.104	.399	.079
	Renewable	-.258	1	-.126	.162	-.198
	GDP_capita	.104	-.126	1	-.243	-.192
	Population	.399	.162	-.243	1	-.107
	Urbanization	.079	-.198	-.192	-.107	1

Source: Authors' determined values by using SPSS 22 software package

Checking the accuracy of the multilinear regression model and the multiple correlation ratios, based on the Fisher F-test, we will make the following conclusion: since the p_value probability (*Sig.* F = 0.044) is less than 0.05, the multiple linear regression model is valid at the confidence level of 0.05 (table 7). Also, we conclude that the exogenous variables included in the model have an influence on the variation of the endogenous variable (EU 28 carbon emission rate) contributing to its average annual carbon emission rate). The main conclusion of the multilinear regression model was that renewable energy, GDP per capita, population number and degree of urbanization influence in a significant share of 76.6% the carbon emission rates for the group of 28 EU countries.

Table 7. ANOVA[a] Model.

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	182550963806359000	4	45637740951589700	2.580	.044[b]
	Residual	406883470261650000	23	17690585663550000		
	Total	589434434068008000	27			

a. Dependent Variable: CO2_emmisions

b. Predictors: (Constant), Urbanization, Population, Renawable, GDP_capita

Source: Authors' determined values by using SPSS 22 software package

In conclusion, it could be observed that the model is correctly specified and validates that renewable energy, GDP per capita, population volume and degree of urbanization are relevant factors for carbon emissions in EU 28 countries since the estimators of the model are significantly different from zero and they correctly identified as the model explains a big share of the carbon emissions at the EU 28 level. Our study underscores previous statements, as mentioned before, according to which economic growth and renewable energy are correlated with CO_2 emissions.

5. CONCLUSIONS AND RECOMMENDATIONS

In this paper, the authors have proven that some of the most important factors in carbon dioxide emission are renewable energy, economic growth, level of urbanization and population growth. While renewable energy factor is inversely correlated with carbon emission, the other three independent factors in de model, urbanization level, economic and population growth have a significant impact and are positively correlated with carbon dioxide emission, at EU 28 level. While the exogenous factors of the regression model are explaining most of the carbon dioxide emissions at the European Union level, there are still other factors which are explaining the carbon emissions in the EU countries.

Moreover, both the lack of autocorrelation and the collinearity between the independent variables demonstrate that there is not a significant juxtaposition among the variable used in the model.

Given that in calculating the macroeconomic indicators used in our regression analysis it was covered a ten year period of time, the main limitation of this research is the data base used in the factorial analysis. Therefore, future research in this area should include longer period of time as well as more macroeconomic variables.

The present work could be extended to other countries, which are similar to Romania in terms of economic development, such as Croatia and Bulgaria. Croatia, the newest EU country, has many similarities with Romania, such as economy and demography, while Bulgaria, our neighbor country, who joined EU in 2007, at the same time with Romania, also has a similar trend in its economic development. This could also be part of a future research study.

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