CONSIDERATIONS ON ENERGY CONSUMPTION IN THE EUROPEAN UNION

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Abstract

Energy is a current topic, essential for human activity. Political and economic decisions are not spontaneous they are based on complex analyses to assess the level of pollution, the ability to respond to pollution limitation and the greenhouse effect.

This article addresses aspects of the dynamics of solid fossil fuel consumption and final energy consumption in the European Union (EU) and Romania, respectively, and also conducts an econometric study of the dynamics of the average share of electricity from renewable sources. energy in the European Union.

The study is customized at EU level and for Romania, and the periods of 9, 10 and 15 years referred to in the research are considered as a limit that may influence some findings, as insufficiently representative.

The periodic review of the research on an updated and extended statistical data system is a solution to be considered, as a way of operative knowledge of the achievements related to the analysed field. Also, an individual approach of the EU states, as well as of the territorial grouping variants of the states can provide additional information.

The presented research applies a methodology that is rigorously grounded in statistics and econometrics, and can be used as a support for applied information. Eviews software was used to define the econometric model.

The study is completed with conclusions regarding the viability of the econometric model of the dynamics of the average share of electricity from renewable energy sources in the EU, with an indisputable utility for substantiating government decisions aimed at economic policy of monitoring and limiting pollutants.

Keywords: renewable energy, consumption of solid fossil fuels, econometric model.

JEL classification: C13

Introduction

Energy is vital to the provision of essential daily services and products. Lighting, heating of living spaces, spaces of economic and institutional utility, transport, as well as the operation of economic processes is possible only with energy. It is obvious that in order to start computers, to start machines, machines and installations, all these individual actions represent final stages of a complex process of energy production, supply and use.

Statistics provide the necessary information to ensure an understanding of the complex energy processes we use and can help us answer questions such as:

• Where does our energy come from?

• How dependent are we on energy imports?

• What kind of energy do we consume in the European Union and how much does it cost?

Energy is in the spotlight due to its strategic importance for the drive to achieve competitive and sustainable economic growth. In recent years, the EU has faced a number of important energy issues. They pushed the subject of energy into the area of interest of national and European political agendas, with energy statistics providing key information for policy makers.

To meet the growing needs of energy decision - makers, Eurostat has developed a coherent and harmonized system of energy statistics. The annual, half-yearly and monthly data collections provide the necessary information to EU Member States, European Economic Area countries, candidate countries, potential candidates and contracting partners of the energy community.

Eurostat provides operational data on a wide range of topics, such as energy prices, energy dependence, energy savings, infrastructure, renewable energies, etc.

Eurostat collects and publishes monthly energy data on the supply and to a limited extent of the consumption of different fuels; these data currently cover solid fossil coal / fuel, natural gas, oil and petroleum products and electricity.

Literature review

For a clear analysis of the evolution of macroeconomic indicators a number of authors have resorted to models and methods of statistical-econometric analysis, using in this regard a number of specialized programs. Thus, Andrei, T., Bourbonais, R. (2008) present in their paper the possibilities of analysis that the use of simple and multiple linear regression models implies. Also, Stancu, S., Andrei, T., Iacob, A.I., Tusa, E. (2008), Anghelache, C., Anghel, M.G., Manole, A. (2015), Anghel, M.G. (2014) and Iacob, Ș.V.

(2019) addresses and uses the Eviews analysis program in concrete studies on various economic phenomena at micro and macroeconomic level. Macroeconomic indicators are studied in their works by Burghelea, Cristina (2014) and Mihăilescu, N. (2014), and Pagliacci, M., Anghelache G.V., Pocan I.M., Marinescu R.T., Manole A use the multiple regression model in the analysis of financial performance.

Energy policies: challenges and strategies

The realization and efficient functioning of the "Energy Union" is one of the 10 priorities of the European Commission. It aims to bring greater energy security, sustainability and competitiveness. This goal can be achieved by:

- diversification of Europe's energy sources;
- ensuring Europe's energy supply;
- strengthening solidarity and cooperation between countries;
- creating a fully integrated internal energy market;
- improving energy efficiency;
- decarbonising Europe's economy.

All of these challenges involve several energy-related targets, in terms of the share of energy from renewable sources, primary and final energy consumption, energy dependence or greenhouse gas emissions.

Consumption of solid fossil fuels

The supply, transformation and consumption of solid fossil fuels show a dynamic of gradual and safe reduction, in a constant process of environmental protection, which aims to reduce the greenhouse effect.

In the period 2011 - 2019, the domestic consumption of solid fossil fuels, at the level of EU countries 27_2020, decreased with an average annual rate of -3.49%, respectively with an annual average of -2,185,4487.44 thousand tons. In the case of Romania, for the same period of time there is an average annual decrease rate of -3.72%, with an absolute correspondent of -1,046,777.78 thousand tons. It is obvious that Romania is positioning itself, from this point of view, at a decrease that exceeds the European average by 0.23 percentage points.

Regarding the final energy consumption, the decreasing trend from 2011 to 2018 is maintained at an average annual rate of -2.20%, in the case of EU 27_2020 and at -1.48%, in the case of Romania (Table 1.).

Dynamics of solid fossil fuel consumption and final energy consumption in the European Union and in Romania

Table 1

Year	Domestic consumption of solid fossil fuels			Final energy consumption		
	UE 27_2020 (thousand tons)	România (thousand tons)	Romania's proportion in the EU (%)	UE 27_2020 (thousand tons)	România (thousand tons)	Romania's proportion in the EU (%)
2010	719.696.813	32.611.000	4,531214	47.579.880	1.445.000	3,036998
2011	752.591.427	38.971.000	5,178241	47.725.257	1.797.000	3,765302
2012	751.697.902	35.868.000	4,771598	45.563.916	1.787.000	3,921963
2013	723.156.356	26.631.000	3,682606	43.782.694	1.546.000	3,531076
2014	698.313.203	26.946.000	3,858727	41.054.131	1.549.000	3,773067
2015	695.285.027	27.858.000	4,006702	40.879.858	1.693.000	4,141404
2016	660.184.382	24.842.000	3,762888	40.812.288	1.423.000	3,486695
2017	660.860.836	27.134.538	4,105938	41.337.476	1.240.189	3,000157
2018	635.895.502	25.880.313	4,069900	39.807.901	1.282.301	3,221222
2019	523.006.426p	23.190.000p	4,433980p	-	-	-

Data source: Eurostat; p = forecast

The proportion of domestic consumption of solid fossil fuels recorded by Romania in the total consumption of the European Union had a minimum size of 3.68% in 2013 and a maximum of 5.18% in 2011, with a tendency to maintain in recent years. years of the analyzed period, at a proportion exceeding by at least 4%. If we refer to the final energy consumption, the proportion of Romania has a maximum in 2015, of 4.14% and a minimum of 3.00%, in 2017, with a stabilization trend at a proportion of 3 - 3.5 %.

Econometric study of the dynamics of the average weight of electricity from sources renewable energy sources in the European Union

First of all, we mention Article 3 of Directive 2009/28 / EC which deals with the promotion of the use of energy from renewable sources and provides in section 4 (c) the following: for calculating the contribution of electricity produced from renewable sources and consumed in all types of vehicles and for the production of renewable fuels for the transport of liquid and gaseous substances of non-biological origin, within the meaning of points (a) and (b), Member States may choose to use either the average share of the share of electricity from renewable energy sources in one's own country, measured two years before the year in question.

The reference to the average share of electricity from renewable energy sources should be interpreted in accordance with the definitions and calculation methodologies described in the above-mentioned Directive. Thus, this quota is calculated as a ratio that includes the numerator including the generation of hydro and wind energy, normalized in accordance with the rules set out in Annex II to Directive 2009/28 / EC and excluding the production of electricity in storage units pumped from water which was previously pumped up. The denominator is the total gross electricity consumption (all production minus hydro-pumped production plus imports minus exports).

The values for EU27_2020 are presented in Table 2 and correspond to the values in row 16 on the "EU27_2020" sheets in the MS Excel file, with the results of the SHARES 2018 exercise.

Renewable energy sources propagate a sustainable contribution to environmental health and are primarily used as a sustainable option.

Average share of electricity from renewable energy sources in the EU (%)

Table 2

Year	**Average share of electricity from renewable energy sources in the EU (%)** UE 27_2020 (SER01 = *x*)	Time variable (SER02 = *t*)
2004	15,87	1
2005	16,40	2
2006	16,89	3
2007	17,66	4
2008	18,56	5
2009	20,69	6
2010	21,31	7
2011	23,34	8
2012	25,16	9
2013	26,85	10
2014	28,68	11
2015	29,65	12
2016	30,17	13
2017	31,10	14
2018	32,20	15

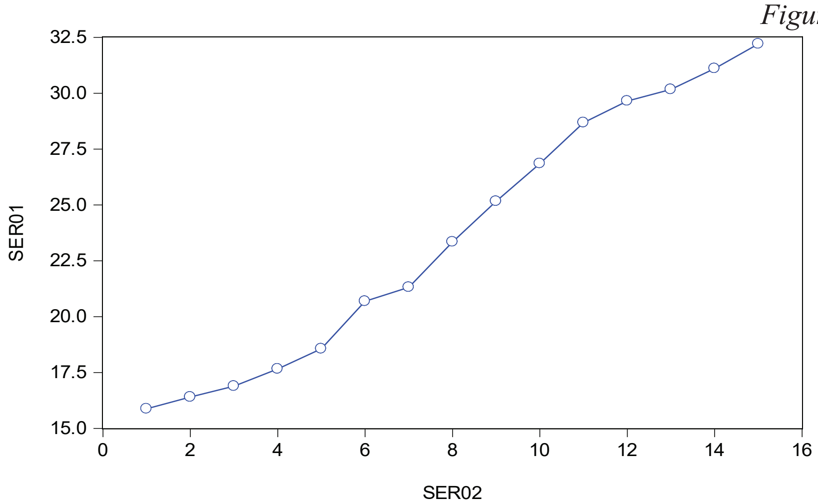
Data source: SHARES 2018. The values in this table will also be the input for the SHARES 2019 instrument, in terms of calculating the final energy consumption of renewable sources in transport and in particular for the option of Member States to use either the values or their own national values.

The graph of the dynamics of the average share of electricity from renewable energy sources in the European Union (Figure 1) foreshadows a clear growth trend from 15.87% in 2004 to 32.20% in 2018.

Graphical representation is a methodological solution that provides sufficient basis for choosing the linear econometric model of the form $x = a + b \cdot t + u$. The parameters of the model are estimated using the least squares method and result: $x = 13,25248 + 1,297857 \cdot t + u$.

Graphical representation of the dynamics of the average weight of electricity from renewable energy sources in the EU (%) - SER01

Figure 1



The indicators that ensure an analytical and at the same time complex characterization of the econometric model (estimated trend equation) are presented in Table 3.

Synoptic table of the system of indicators of econometric representation for the linear model of the dynamics of the average share of electricity from renewable energy sources in the EU (%)

Table 3

Dependent variable: x = Average share of electricity from renewable energy sources in the EU (%) - SER01				
The least squares method				
Period: 2004 – 2018: Number of observations included in the model: 15				
Estimated trend equation: $\hat{x} = a + b \cdot t$; $\hat{x} = 13{,}25248 + 1{,}297857 \cdot t$				
Variables	Coefficient	Estimation of the standard error of the coefficient	t-statistic	Prob. (the threshold of significance)
Time variable (*t*) „*b*”	1,297857	0,047469	27,34140	0,0000
Model constant „*a*”	13,25248	0,431590	30,70617	0,0000
Coefficient of determination: R^2	0,982907	The average value of the dependent variable $\bar{x}$	23,63533	
R^2 adjusted (corrected)	0,981592	Estimation of the standard deviation of the dependent variable	5,854444	

Estimation of the average error of the trend equation (regression): $\hat{\sigma}_{x,\hat{x}}$	0,794301	Jarque - Bera statistical coefficient (*J-B*)	0,723274
The sum of the square of the residue	8,201888	Probabilities (*J-B*)	0,696535
		Hannan-Quinn criterion	2,499852
F-statistic	747,5519	Durbin-Watson statistical coefficient	0,605196
Prob (*F*-statistic)	0,000000	Theil coefficient of irregularity	1,5217%

Table of confidence intervals for the parameters (coefficients) of the linear model of the average share of electricity from renewable energy sources in the EU (%), under three categories of significance thresholds (q)

Table 4

Confidence intervals for linear model parameters (coefficients)							
The period under analysis: 2004 – 2018; Number of observations included in the model: *n*=15							
		90%; (q = 10%)		95%; (q = 5%)		99%; (q = 1%)	
	Coefficient	lower limit	upper limit	lower limit	upper limit	lower limit	upper limit
„*t*”	*b* = 1,297857	1,213793	1,381921	1,195308	1,400407	1,154869	1,440846
„*C*”	*a* = 13,25248	12,48816	14,01679	12,32008	14,18487	11,95241	14,55254

It is mentioned that the limits, lower (lower limit) and upper (upper limit), calculated for each model estimator (Table 4.) comply with the following methodology:

the lower limit is obtained by subtracting the limit error from the value of the estimator, and

- the upper limit is obtained by adding the limit error to the value of the estimator,

- the permissible limit or maximum error is determined for each significance threshold and for each coefficient estimator, by the product of the critical value with the estimate of the standard error of the coefficient in Table 3,

- the critical value follows a Student distribution law and depends on the size of the significance threshold (q) arranged bilaterally and on the number of degrees of freedom (f). For example, for q = 5% and $f = n - k = 15 - 2 = 13$, $t_{q,f} = \pm 2{,}160$.

As a rule, it is chosen to guarantee the confidence interval for parameter "b" with a probability of 95% (significance threshold 5%) and, in these conditions, at a change of time by one year, the average share of electricity in Renewable energy sources in the EU increase by between 1.195308 and 1.400407 percentage points. The allowed limit or maximum error is $\hat{\Delta} = \pm 2{,}160 \cdot 0{,}047469 = \pm 0{,}102533$ percentage points

Note: *The estimated confidence intervals for the parameter (coefficient) "b" of the model, under the conditions of a certain significance threshold, provide the support to conclude on the interval in which the endogenous variable can change (average share of electricity from renewable energy sources in the EU -%), under the conditions of changing the exogenous variable (time variable) by one unit.*

Table 5 lists comparative data of real and estimated levels, based on the linear trend equation, on the average share of electricity from renewable energy sources in the EU (%), from 2004-2018. The difference between these data categories is the residual levels (error term), and the residue range provides a graphical form of how the residues are arranged in relation to the standard error estimator of the trend equation. The aim is to position the residual values in a form of alternation with the origin, in order to confirm whether they are not affected by the autocorrelation phenomenon but, as it is found, this desideratum is not fulfilled.

The Durbin-Watson statistical coefficient (DW) = 0.605196 (Table 3) does not fall within the range of accepting the hypothesis of rejecting the error autocorrelation state (1.361 - (4 - 1.361 = 2.639), based on the Durbin-Watson distribution, with a probability of 95%); the null hypothesis H_0 is rejected and through this the statistical support for assessing the quality of the linear model warns of a state of vulnerability that refers to:

- the $t_{-statistic}$ values calculated for estimating the significance of the parameters are oversized, which suggests a greater significance of the parameters than in reality.

- the estimation of the average error of the trend equation is undersized compared to the real value and, consequently, the determination coefficient R^2 is oversized, which indicates a better adjustment than it is in reality.

The cause that can produce, in this case, the autocorrelation of the residues is the non-inclusion in the model of a sufficiently large number of observations.

It can also be appreciated that the size of the residue does not exceed the limit error estimate ($\hat{\Delta}$),resulting from the product of the critical value of $t_{-tabular} = \pm 2{,}160$, for a probability of 95% (significance threshold of 5% is arranged bilaterally) and 13 degrees of freedom (based on the Student distribution law), $f = n - k = 15 - 2 = 13$, with the estimation of the mean error of the trend equation, $\hat{\sigma}_{x,\hat{x}} = \pm 0{,}794301$,

($\hat{\Delta} = \pm 2{,}160 \cdot 0{,}794301 = \pm 1{,}71569$ percentage points).

This statistical finding gives the linear model the viability of correct representation of reality, customized for the period 2004 - 2018.

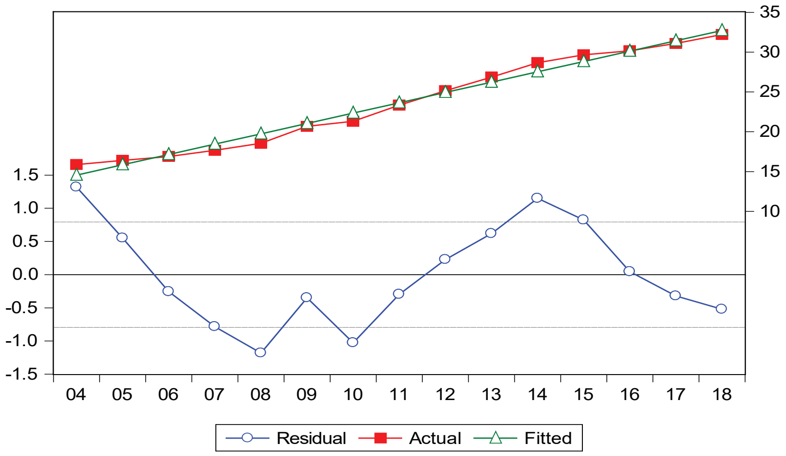
Series of calculation base levels, estimated levels based on the linear residue trend equation and residue range on the dynamics of the average share of electricity from renewable energy sources in the EU (%)

Table 5

<table>
<tr><th>Year</th><th>Average share of electricity from renewable energy sources in the EU (%)
UE 27_2020
x</th><th>Estimated levels of average share of electricity from renewable energy sources in the EU (%)
$\hat{x}$</th><th>Residue
$u = x - \hat{x}$</th><th>Residue range
$\hat{\sigma}_{x,\hat{x}} = 0{,}794301$
$-\hat{\sigma}_{x,\hat{x}} \quad 0 \quad +\hat{\sigma}_{x,\hat{x}}$</th></tr>
<tr><td>2004</td><td>15,8700</td><td>14,5503</td><td>1,31967</td><td>| . | . *|</td></tr>
<tr><td>2005</td><td>16,4000</td><td>15,8482</td><td>0,55181</td><td>| . | * . |</td></tr>
<tr><td>2006</td><td>16,8900</td><td>17,1460</td><td>-0,25605</td><td>| . * | . |</td></tr>
<tr><td>2007</td><td>17,6600</td><td>18,4439</td><td>-0,78390</td><td>| * | . |</td></tr>
<tr><td>2008</td><td>18,5600</td><td>19,7418</td><td>-1,18176</td><td>| * . | . |</td></tr>
<tr><td>2009</td><td>20,6900</td><td>21,0396</td><td>-0,34962</td><td>| . * | . |</td></tr>
<tr><td>2010</td><td>21,3100</td><td>22,3375</td><td>-1,02748</td><td>| * . | . |</td></tr>
<tr><td>2011</td><td>23,3400</td><td>23,6353</td><td>-0,29533</td><td>| . * | . |</td></tr>
<tr><td>2012</td><td>25,1600</td><td>24,9332</td><td>0,22681</td><td>| . |* . |</td></tr>
<tr><td>2013</td><td>26,8500</td><td>26,2310</td><td>0,61895</td><td>| . | *. |</td></tr>
<tr><td>2014</td><td>28,6800</td><td>27,5289</td><td>1,15110</td><td>| . | . * |</td></tr>
<tr><td>2015</td><td>29,6500</td><td>28,8268</td><td>0,82324</td><td>| . | .* |</td></tr>
<tr><td>2016</td><td>30,1700</td><td>30,1246</td><td>0,04538</td><td>| . * . |</td></tr>
<tr><td>2017</td><td>31,1000</td><td>31,4225</td><td>-0,32248</td><td>| . * | . |</td></tr>
<tr><td>2018</td><td>32,2000</td><td>32,7203</td><td>-0,52033</td><td>| .* | . |</td></tr>
<tr><td>Total</td><td>354,5300</td><td>354,5300</td><td>0,00000</td><td></td></tr>
</table>

Graphical presentation of residues, (real) calculation base levels and estimated levels based on the linear trend equation of the average share of electricity from renewable energy sources in the EU

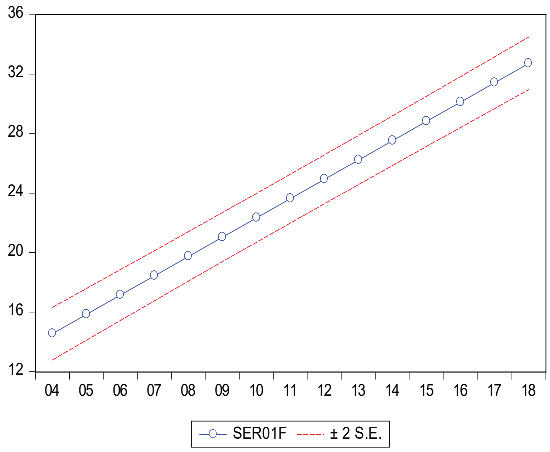
Figure 2



Note: *The chart legend (Figure 2.) is explained as follows:*
Residual = series of values of the residual variable
Current = series of real values of the average share of electricity from renewable energy sources in the EU (%)
Fitted = series of estimated values of the average share of electricity from renewable energy sources in the EU (%) based on the linear trend equation

Graphical presentation of the estimated levels of the average share of electricity from renewable energy sources in the EU (%), based on the linear trend equation, framed by two estimates of the mean error of the trend equation

Figure 3



Forecast: SER01F	
Actual: SER01	
Forecast sample: 2004 2018	
Included observations: 15	
Root Mean Squared Error	0.739454
Mean Absolute Error	0.631594
Mean Abs. Percent Error	2.971936
Theil Inequality Coefficient	0.015217
Bias Proportion	0.000000
Variance Proportion	0.004310
Covariance Proportion	0.995690

Note: *The chart legend (Figure 3.) is explained as follows:*
SER01F = series of estimated values of the average share of electricity from renewable energy sources in the EU (%) based on the linear trend equation
$\pm 2\ \mathrm{SE} = \pm 2 \cdot \hat{\sigma}_{x,\hat{x}} = \pm 2 \cdot 0{,}794301$

The graphical representations in Figure 2 and Figure 3 illustrate the overlap of the real levels with the estimated ones, as a confirmation of the viability of the model and also the linear form of the econometric model illustrates the statistical legitimacy of the average weight of electricity from renewable sources energy consumption in the EU (%), from 2004-2018 and, at the same time, a predictable upward trend of this indicator can be outlined in the next time segments.

Synoptic table of indicators for testing the heteroskedasticity of the residual variable

Table 6

Heteroskedasticity Test: White			
„*criterion F*”**:** *F*-statistic	0,843717	Prob. *F* (2,12)	0,4541
„*criterion* χ^2”: χ^2-statistic = $n \cdot R^2$	1,8492 53	Prob. Chi-Square (2)	0,3967
Auxiliary trend equation (regression) test:			
Dependent variable: $u^2 = z = (x - \hat{x})^2$			
The least squares method			
Period: 2004 - 2018; Number of observations included in the model: *n* =15			
Auxiliary trend equation (regression): $\hat{z} = a + b \cdot t + c \cdot t^2$			

Variables	Coefficient	Estimation of the standard error of the coefficient	*t*-statistic	Prob. (the threshold of significance)
C „*a*”	1,009101	0,514056	1,963018	0,0732
t „*b*”	-0,083322	0,147844	-0,563578	0,5834
t^2 „*c*”	0,002471	0,008985	0,274999	0,7880

Coefficient of determination: R^2	0,123284	The average value of the dependent variable: $\overline{z}$	0,546793
R^2 adjusted (corrected)	-0,022836	Estimation of the standard deviation of the dependent variable	0,570637
Estimation of the mean error of the auxiliary tendency (regression) equation: $\hat{\sigma}_{z,\hat{z}}$	0,577115	Durbin-Watson statistical coefficient	2,055681
The sum of the square of the residue	3,996744		
F-statistic	0,843717	Prob. (*F*-statistic)	0,454104

Interpretation of econometric representation indicators and assessment of the viability of the linear model on the dynamics of the average share of electricity from renewable energy sources in the EU (%), from 2004 to 2018

The interpretation of the obtained results refers to the significance of the indicators of econometric representation based on which the quality and respectively the attestation of viability of the model are appreciated.

The econometric model expressed by a linear trend equation is used to synthesize the dynamics of the average share of electricity from renewable energy sources in the EU (%), from 2004-2018, which has the following analytical form:

$$\hat{x} = 13,25248 + 1,297857 \cdot t$$

and based on the calculations and tests performed, the qualification of viable model can be granted, because it has the necessary statistical support. In support of this assessment, the following results are available:

1.- Based on the "Criterion t", the parameters (coefficients) of the trend equation have significantly different sizes from zero, because the verification of the null hypothesis of each parameter is assessed by significance thresholds lower than 5%.

This finding concludes that the model has been correctly specified, identified and estimated, the parameters of the trend equation have a good efficiency, if it is used to extrapolate the evolution or to calculate forecasts.

2.- The test of normality of the distribution of the residual variable ("Jarque-Bera test") confirms the hypothesis of a significant similarity between the empirical distribution and the normal theoretical distribution (Gauss-Laplace), with a probability of 69.6535% - is accepted thus, the null hypothesis. This statistical confirmation fulfils a viability condition and a working hypothesis necessary when developing an econometric model.

It is mentioned that the Jarque-Bera statistical indicator follows a distribution law χ^2, with 2 degrees of freedom.

3.- "Durbin-Watson statistical coefficient", by its size (DW = 0.605196), attests the existence of the phenomenon of autocorrelation of the variants of the error term (the null hypothesis H_0 is rejected) and, through this, the statistical support for quality assessment the model confirms a state of vulnerability.

4.- based on "Criterion F", the correlation ratio of the endogenous variable, depending on the time variable, is significantly different from zero (the null hypothesis H_0 is rejected), with a probability close to unity, legitimizing the model as viable.

5.- The relative expression of the standard error estimate of the linear trend equation in relation to the average value of the average share of electricity from renewable energy sources in the EU, from 2004 to 2018, is 3.36%, a convenient size, positioned below a restrictive limit of 10%, in order to consider the model fully viable.

$$V = \frac{\hat{\sigma}_{x,\hat{x}}}{\bar{x}} \cdot 100 = \frac{0,794301}{23,63533} \cdot 100 = 3,36\%$$

6.- "Theil coefficient of irregularity (inequality)" confirms, by its size, positioned below the threshold of 5%, Th = 1.5217%, that the linear trend equation is statistically supported for the calculation of the forecast, by extrapolating the evolution identified in the period 2004 - 2018.

7.- “Heteroskedasticity Test: White” confirms the homoscedasticity state of the developed model, the square of the residual variable does not correlate with the exogenous variable (time variable) and, under these conditions, we obtain statistical proof that the residue dispersion is constant. The resulting conclusion is formulated on the basis of two statistical criteria: “Criterion F” and “Criterion χ^2” . This supports the viability of the model, represented by the linear trend equation.

Based on these statistical findings, the calculation of efficient estimates of the average share of electricity from renewable energy sources in the EU for future time segments is ensured by taking into account a limit error ($\hat{\Delta}$) calculated as the product of the probability factor ($t_{q, f = n - k}$), following a Student distribution law and estimation of the mean (standard) error of the trend equation, $\hat{\sigma}_{x, \hat{x}}$.

Conclusions

Increasing the average share of electricity from renewable energy sources in the EU is a legitimacy that, as has been statistically confirmed, is supported by political and economic decisions by all EU states, as a necessary response to environmental degradation, global warming through pollution. The results obtained in this field have a transitory value that must be continued and for which a decisive role is played by scientific research, with a decisive contribution to the development and improvement of technological solutions.

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