AUTOREGRESSIVE DISTRIBUTED LAG (ARDL) APPROACH TO STUDY THE IMPACT ON ROMANIA'S RGDP OF ELECTRICAL ENERGY IMPORTS AND EXPORTS

NADIA ELENA STOICUȚA *

ABSTRACT: *This article analyses the influence of electricity import and export on economic growth in Romania. The model applied in the analysis is an ADRL (Autoregressive Distributed Lag) type, the analysed period being 31 years (1991-2021). The obtained results show that both electricity import and export have positive and significant influences on economic growth in Romania.*

KEY WORDS: *Autoregressive Distributed Lag, RGDP, imports, exports.*

JEL CLASSIFICATIONS: *C1, J1*.

1. INTRODUCTION

According to the data provided by the National Institute of Statistics, in 2023, the export of electricity in Romania reached 10.43 billion kWh, an increase of 3.88 billion kWh compared to the previous year. If until now, Romania has relied more on imports, through the new investments made in the energy sector, in 2023 our country will become a net exporter of electricity, having the largest exports of electricity in the last 10 years.

On the other hand, according to the National Integrated Plan in the Field of Energy and Climate Change, Romania has given greater importance to the development of internal sources of electricity production. The target proposed by the EU for Romania in 2030, to reach an installed capacity of 30.4 GW, i.e. approximately 76% of it coming from SRE, stimulates our country to build new electricity production capacities from nuclear and natural gas sources, or from renewable sources. At the

* *Lecturer, Ph.D., University of Petroşani, Romania, NadiaStoicuta@upet.ro*

same time, net imports of electricity will have to be kept at an average annual level below 5%.

Also, according to Transelectrica interactive data extracted from Economedia, the year 2023 was a year in which Romania had much more energy exported than imported, the difference between import and export having the highest values since 2014. This could be achieved thanks to a reduced household, but also the industrial one.

As for the GDP in Romania, it experienced continuous growth, reaching a growth of 2% in the third quarter of 2023, compared to the same quarter of 2022.

Even if electricity imports and exports do not have a significant contribution to the growth of Romania's GDP, they have a positive influence on this macroeconomic indicator.

Such conclusions can also be found in Stoicuta, who in the article (Stoicuta, 2022) performs the econometric analysis between electricity imports and exports from Romania and GDP, in the period 1996-2021. The analysis is based on a linear multivariable model. The forecasts obtained for the next four years (2022-2025) suggest that in 2025, the forecasted value of real GDP is 1344830 million lei, i.e. approximately 20% higher than in 2021. The forecasted value of electricity import shows a 13.38% growth in 2025 compared to 2021 and 5.64% electricity export growth compared to 2021.

2. DATA AND METODOLOGY

This article analyses the influence of electricity imports and exports on the real GDP (considered as economic growth) in Romania. The analysis is carried out over a period of 31 years between 1991-2021, by applying an ADRL (Autoregressive Distributed Lag) type model.

2.1. Source of data

The annual information from 1991-2021 (31 years) used in this research are: 1) the gross domestic product (constant 2015 RON lei), denoted RGDP; 2) the import of electricity (billions of kilowatt-hours), denoted IMP; 3) the export of electricity (billions of kilowatt-hours), noted EXP. For the first variable, the data were taken from the World Bank website, and for the second and third variables, the data were collected from International Data Energy.

In the figure below, the evolutions over time of the three analyzed variables are represented. Thus, it can be observed that, while the import of electricity increased in the last two years analyzed, the export of electricity decreased considerably in 2020 compared to the previous year, to then have a slight increase in 2021.

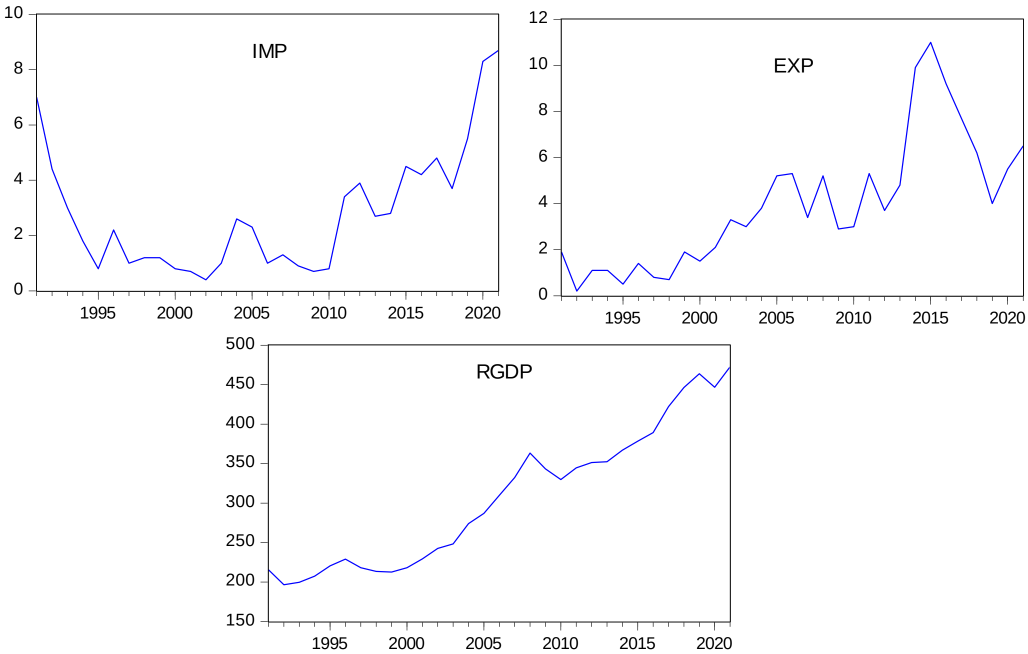

Figure 1. The evolution over time of the three variables

Regarding, RGDP had an upward evolution throughout the analysed period, reaching the maximum value in 2021, of 472 billion RON. According to the data provided by the National Institute of Statistics, the GDP in Romania increased, in real terms, by 2.2% in the first nine months of 2023 compared to 2022.

2.2. Descriptive statistics

Table 1 shows the main properties of the descriptive indicators specific to the three analyzed variables. Thus, both the values of measures of central tendency and those of dispersion and normalization are captured.

Table 1. Values of descriptive indicators

	RGDP	IMP	EXP
Mean	307.2797	2.825806	3.938710
Median	309.8900	2.300000	3.400000
Maximum	472.5300	8.700000	11.00000
Minimum	196.7300	0.400000	0.200000
Std. Dev.	88.44415	2.256394	2.822136
Skewness	0.357265	1.127074	0.819873
Kurtosis	1.843277	3.550579	3.041447
Jarque-Bera	2.387725	6.954749	3.475212
Probability	0.303049	0.030888	0.175941
Sum	9525.670	87.60000	122.1000
Sum Sq. Dev.	234671.0	152.7394	238.9335
Observations	31	31	31

Source. Author's calculation using Eviews 10.1

As can be seen in the table, the real GDP in Romania had an average level of 307.27 billion RON, the minimum being reached in 1992 (196.73 billion RON). Regarding the import of electricity, it reached the maximum (8.7 billion kWh) in 2021, and the export of electricity recorded the highest value in 2015.

Analyzing the values of the indicators that are based on the shape of the distribution of the data series, for the real gross domestic product (RGDP) in Romania, we notice that it presented, throughout the 31 years analyzed, a positive symmetry (the coefficient of asymmetry is 0.32) and slightly platykurtic (coefficient of vaulting of 1.84), the Jarque Berra indicator showing a normal type distribution, for a significance threshold of . The same observations can be made for the other two variables.

2.3. Correlation analysis

In order to establish the sense of association between the variables used, we will perform the correlation analysis. The following table shows the Pearson correlation coefficient values calculated for the three variables.

Table 2. Correlation Matrix of the Variables

	RGDP	IMP	EXP
RGDP	1.00	0.56	0.75
IMP	0.56	1.00	0.39
EXP	0.75	0.39	1.00

Source. Author's calculation using Eviews 10.1

It can be seen from Table 2 that both electricity import and electricity export are positively correlated with RGDP, these correlations showing a strong direct relationship. Thus, it can be seen that the correlation between IMP and RGDP is +0.56 and the correlation between EXP and RGDP is +0.75, which shows (as expected) that electricity exports have a greater contribution to economic growth in Romania than imports.

3. AUTOREGRESSIVE DISTRIBUTED LAG MODEL (ARDL)

As specified above, in this paragraph we will analyse the correlation between the real GDP in Romania (RGDP) - dependent variable, which in the analysed model has the role of economic growth and imports (IMP) and exports (EXP) of energy electrical - independent variables.

The econometric model through which this analysis is carried out is an Autoregressive Distributed Lag (ADRL) model. ARDL models are linear time series models in which both the dependent and independent variables are related not only simultaneously but also between (lagged) historical values.

ARDL models have gained popularity in econometrics in recent years as methods for examining cointegration relationships. Two seminal contributions in this regard are (Pesaran & Shin, 1998) and (Pesaran, Shin, Smith, 2001). The authors of the articles argue that ARDL models are particularly advantageous in their ability to handle cointegration with inherent robustness to misspecification of the integration orders of the relevant variables.

The traditional cointegration methodologies proposed by Engle-Genger (Engle&Granger, 1987), Phillips and Ouliaris (Phillips&Ouliaris, 1990) or Johansen (Johansen, 1995) usually fail because all variables must have identical orders of integration. A prior test is required to show the existence of a unit root in each of the analysed variables, which is clearly subject to misclassification, especially since unit root tests are known to suffer from size problems in many situations (Perron&Ng, 1996).

In general, if denoted by y_t dependent variable, and with $x_1, x_2, \ldots, x_k$ independent variables (where *k* is the number of explanatory variables), the ADRL(p, $q_1, \ldots, q_k$) model has the following representation:

$$y_t = \alpha_1 + \sum_{i=1}^{p} \beta_i y_{t-i} + \sum_{j=1}^{k} \sum_{l_j=1}^{q_j} \delta_{j,l_j} x_{j,t-l_j} + \varepsilon_t \qquad (1)$$

where ε_t are ussual innovations, α_1 este coeficientul constant, iar β_i și δ_j are the coefficients associated with a linear lags of y_t, and lags of k regressors $x_{j,t}, j = \overline{1,k}$.

To apply this model, the following steps will be taken:

• delays are sought in the analysis (criteria of the structure of delays);

• the root of the stationarity unit is tested using the gap created in the first step;

• if the unit root is stationary at level I(0) or I(1), but not I(2), we can apply the ADRL model;

• is apply the test for cointegration and the long-term form (SR and LR estimation);

• the F-statistic test is applied.

If there is cointegration between the variables then the error correction model can be applied, otherwise the VAR model is applied.

Also, in order for the ADRL model to be applied, it is necessary that the error terms do not have an autocorrelation between them, within the data series the phenomenon of heteroscedasticity should not appear (the variance and the mean should remain constant throughout the model), the data must follow a normal distribution and be stationary on either I(0) or I(1) or both. Furthermore, as specified above, if any of the analysed variables is stationary at I(2), the ARDL model cannot run.

The ADRL (1,0,2) model applied in the case of our analysis has the following representation:

$$LNRGDP_t = \alpha_1 + \beta_1 LNRGDP_{t-1} + \delta_1 LNIMP_t + \delta_2 LNEXP_t + \delta_3 LNEXP_{t-1} + \delta_4 LNEXP_{t-2} + \varepsilon_t \qquad (2)$$

The parameters of the model are estimated using the Eviews 10.1 program, their values can be found in the following table.

Table 3. Values of statistical indicators and applied tests

Dependent Variable: LNRGDP
Method: ARDL
Sample (adjusted): 1993 2021
Included observations: 29 after adjustments
Maximum dependent lags: 2 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic): LNIMP LNEXP
Fixed regressors: C
Number of models evalulated: 18
Selected Model: ARDL(1, 0, 2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNRGDP(-1)	0.786847	0.063470	12.39718	0.0000
LNIMP	0.018277	0.011755	1.554813	0.1336
LNEXP	0.018572	0.016950	1.095661	0.2846
LNEXP(-1)	0.024305	0.015511	1.566974	0.1308
LNEXP(-2)	0.022955	0.013832	1.659601	0.1106
C	1.160422	0.341947	3.393570	0.0025

R-squared	0.987126	Mean dependent var	5.712551
Adjusted R-squared	0.984327	S.D. dependent var	0.280492
S.E. of regression	0.035115	Akaike info criterion	-3.678376
Sum squared resid	0.028361	Schwarz criterion	-3.395487
Log likelihood	59.33645	Hannan-Quinn criter.	-3.589779
F-statistic	352.7058	Durbin-Watson stat	1.835310
Prob(F-statistic)	0.000000		

Source. Author's calculation using Eviews 10.1

Analysing the data in the table above, we note that the R-squared value of 0.9871 indicates that the explanatory variables in the model together explain 98.71% of the total variation in economic growth during the study period; and taking degrees of freedom into account, the explanatory variables still explain 98.43% of the total variation in economic growth as revealed by the Adjusted R-Squared. The model has no autocorrelation, given that the Durbin-Watson statistic of 1.84 is in the appropriate range.

The result in Table 3 reflects the fact that both changes in electricity imports and exports exert a positive and significant effect on economic growth. Also, the electricity export lag of two units exerts a positive and significant influence on growth. The gap with a unit of RGDP in the amount of 0.78 shows a strong positive and significant effect on economic growth in Romania.

In the following figure, the graphs of the real values and those adjusted by the ADRL model are represented.

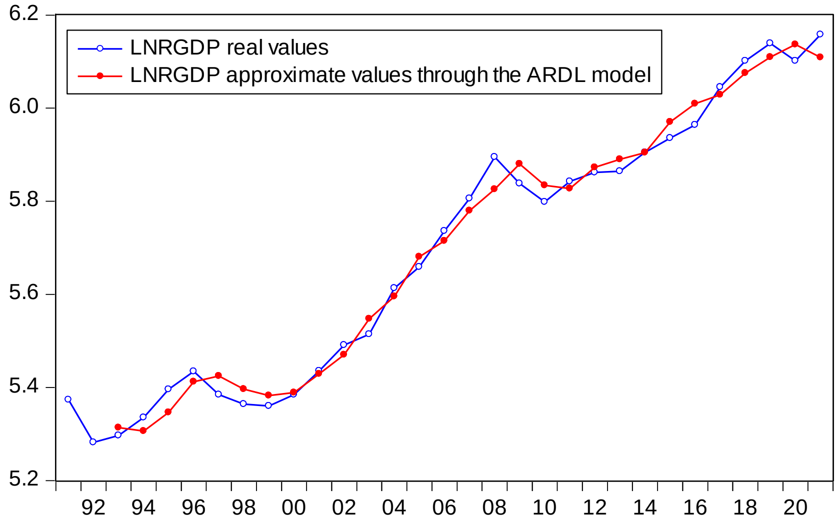

Figure 2. Representation of LNRGDP values in Romania: blue – real values; red – values approximated by the ADRL model

As can be seen, the two graphs are close enough to say that the model analysed here approximates the data series of the dependent variable very well.

To check if the residuals have a normal type distribution, the Jarque-Berra test is applied, the value of which is 1.47. Comparing the values of this statistic to the critical value of the statistic $\chi^2_{2,0.05} = 5.99$, for a significance threshold $\alpha = 5\%$ and two degrees of freedom, it is observed that the inequality $JB < \chi^2$ is verified.

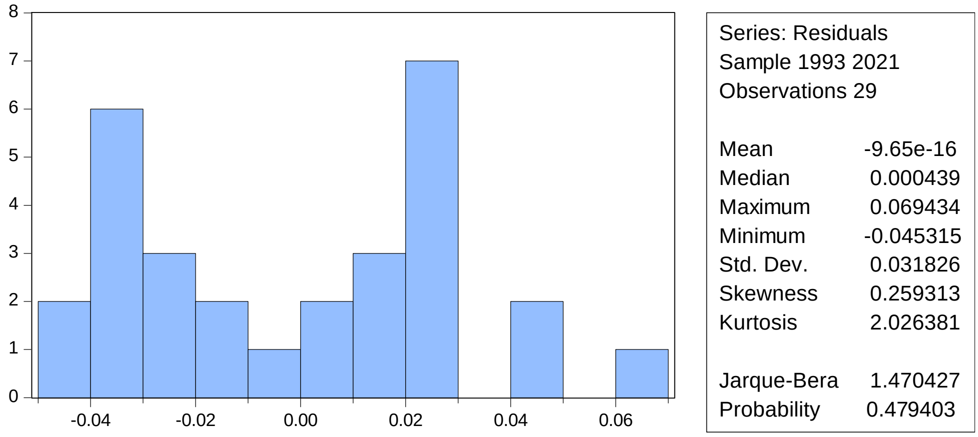

Figure 3. Histogram and residual characteristics

In order to verify whether there is a multicollinearity effect between the analyzed variables, the influence factor analysis is applied. Its values can be found in the following table.

Table 4. Variance Inflation Factors

Variance Inflation Factors
Sample: 1991 2021
Included observations: 29

Variable	Coefficient Variance	Centered VIF
LNRGDP(-1)	0.004028	4.067929
LNIMP	0.000138	2.108614
LNEXP	0.000287	4.391079
LNEXP(-1)	0.000241	4.977512
LNEXP(-2)	0.000191	3.904401

Source. Author's calculation using Eviews 10.1

As all the values are lower than five we can say that the model analyzed here does not present the phenomenon of multicollinearity.

3.1. Unit Root Test

Given that our study uses time series data in its analysis, it is necessary to explore the unit root properties of the variables. This is done by implementing the Augmented Dickey-Fuller (ADF) unit root test developed by Dickey & Fuller, 1979. Table 5 presents the results obtained by applying this test, where I(0) shows that the variable is stationary at level, and I(1) shows that the variable is stationary at first difference.

Table 5. Augmented Dickey-Fuller (ADF) Unit Root Test Result

Variable	ADF Statistic at Level	ADF Statistic at First Difference	Probability	Order of Integration
LNRGDP	0.46	-4.83	0.0006	I(1)
LNIMP	-1.81	-5.51	0.0001	I(1)
LNEXP	-1.5	-5.85	0.0001	I(1)

Source: Author's calculation using Eviews 10.1

Analyzing the obtained results, it is observed that the three variables are stationary at the first difference. Therefore the ADRL model can be applied.

3.2. Test for cointegration

The cointegration test is performed to detect whether there is any long-run relationship between the variables within the model. To achieve this, the ARDL Bounds test for the level relationship is performed and Table 6 shows the result. The test is performed using the 5% significance level in comparing the upper and lower bounds. The null hypothesis is that there is no level relationship in the model.

Table 6. ARDL Bounds Test Result

Test Statistic	Value	Significance	I(0)	I(1)
F-statistic	7.89	10%	3.17	4.14
k	2	5%	3.79	4.85
		2.5%	4.41	5.52
		1%	5.14	6.36

Source. Author's calculation using Eviews 10.1

The F-statistic value in Table 6 is 7.89, the lower bound for a 5% significance threshold is 3.79 and the upper bound is 4.14. Since the F-statistic lies outside the lower and upper bounds, the null hypothesis of no level relationship is rejected. Consequently, there is cointegration in the model.

3.3. Stability test

The cumulative sum test (CUSUM) and the cumulative sum of squares test (CUSUMSQ) are used to check the stability of the ADRL model parameters. By applying the CUSUM test, both the presence of outliers within the data series and the structural breaks within the series are highlighted. Figure 4 shows the two tests.

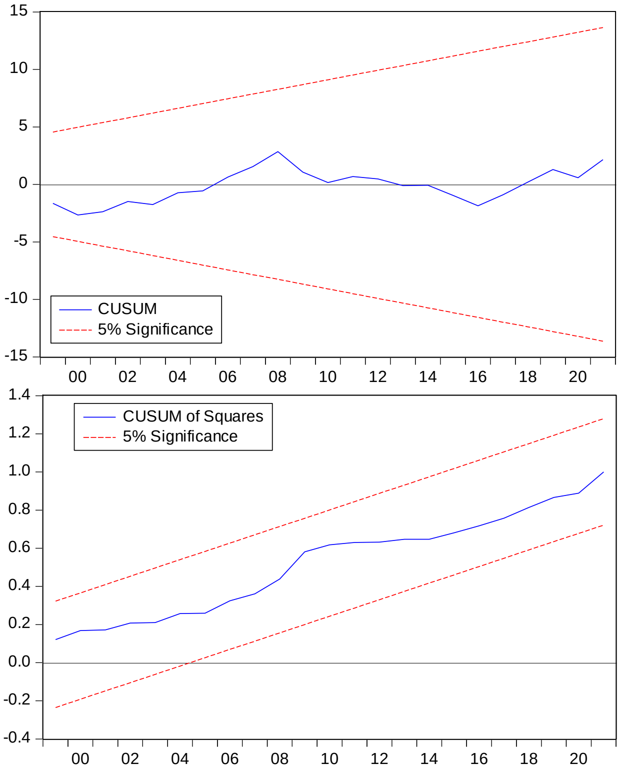

Figure 4. Cumulative Sum Test for Stability

For the reason that the 5% line lies within the upper and lower bounds, we have clear evidence that the parameter estimates of the model are stable for inference.

4. CONCLUSIONS

Even if in this article, the dependence between RGDP (economic growth) in Romania and the import and export of electricity, in the long and short term, was not analyzed, the results obtained by applying the ADRL model show that both imports and exports of electricity have a positive influence on economic growth in Romania during the analyzed period.

Also, the results show that, while the lag of electricity export by two units exerts a positive and significant influence on economic growth in Romania, the lag by one unit of RGDP, amounting to 0.78, shows a strong positive and significant effect on economic growth.

On the other hand, both electricity import and electricity export are positively correlated with RGDP, these correlations showing a strong direct relationship.

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