ANALYSIS OF THE DEPENDENCE BETWEEN THE IMPORT AND EXPORT OF ELECTRICITY FROM ROMANIA AND THE REAL GDP

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ABSTRACT: *In this paper, the relationship between the real GDP in Romania and the import and export of electricity is analysed from an econometric point of view. The analysed period is 1996-2021. The analysed models describe the dependence between GDP and electricity imports, between GDP and electricity exports and between GDP and the two variable mentioned above. Based on the three models, in which a linear trend is also taken into account, forecasts are made at the end of the article for a period of 4 years.*

KEY WORDS: *RGDP, import, export, data series, electricity, econometric model*

JEL CLASSIFICATIONS: *C5, E27, L8.*

1. INTRODUCTION

Starting from the fact that Romania has not been able to produce the electricity it consumes on its own for three years, net imports increased by 44.8% more than in 2019 (this year not being subject to the COVID19 pandemic). According to the reports of the National Institute of Statistics [8], in 2021 the net import of electricity was not made to fuel the growth of the economy, consuming 2.3% less than in 2019. These measures also affected the GDP in Romania, which in the fourth quarter of 2021 decreased by 0.5%. Regarding the export of electricity, in 2021 it increased by 23% compared to the previous year and by 64.7% compared to 2019.

The main purpose of this study is to trace the effect of the influence of the import and export of electricity from Romania on the real level of GDP in the period 2022-2005.

Obviously, based on this study, a series of decisions can be made regarding the much more efficient management of electricity production and a much more optimal energy policy can be adopted. The objective of any state is to have energy

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independence from other states, to reduce the import of electricity as much as possible, and to increase, why not, the export of energy.

As is known, Romania exports electricity to the Republic of Moldova and Ukraine, and imports electricity from neighbouring countries Hungary, Bulgaria and Serbia. Until the start of the war between Ukraine and the Russian Federation, Romania also imported electricity from Ukraine.

2. LITERATURE REVIEW

In the article proposed by Dedeoğlu (Dedeoğlu & Kaya, 2013), the authors investigate the relationship between energy consumption-GDP, energy consumption-exports-trade and energy consumption-imports at the aggregate level in OECD countries. Following the study, the authors find that the pairs energy consumption-GDP, energy consumption-export and energy consumption-import are cointegrated and that there is a bidirectional Granger causality between each pair. Long-run elasticities are also estimated using panel dynamic ordinary least squares.

Another study that examines the dependencies that appear between the growth rate of GDP and the growth rate of imports of goods and services, while reducing energy consumption and material consumption, is the one proposed by Bluszcz (Bluszcz & Manowska, 2019). The study was based on data on the economies of certain European Union states and Poland. The article presents the method of modelling the decoupling phenomenon using the panel data technique.

A more recent study on the econometric modelling of certain energy sectors is the one proposed by Stoicuta in (Stoicuta, 2022). The author of this article analyses the correlation between total energy consumption in Europe and Romania and CO2 emissions.

Likewise, Stoicuta, in the article (Stoicuta &Stoicuta, 2019), econometrically models the shares of renewable energy sources in the total consumption of energy used for heating/cooling, those of energy from renewable sources in the consumption of fuel used in transport, as well as the shares of energy from renewable sources in the final gross energy consumption.

In the article (Stoicuta&Stoicuta, 2018), it analyses the evolution over time of the total production of electricity and the categories of power plants in Romania over a period of 26 years (1992-2017). Within this article, in the following we will analyse from an econometric point of view the link between GDP and the import of electricity from Romania and the link between GDP and the export of electricity, viewed as univariable models and also the link between GDP and import and electricity export, viewed as a multivariable model. Based on these analyses, short-term forecasts will be made in the end.

3. DATA AND SOURCE OF DATA

To carry out these analyses, the data series of the three variables (real GDP, electricity import and electricity export) were collected, series which can be found in the table below. The data were collected after consulting the website of the National

Institute of Statistics. The analysed period is 26 years (1996-2021). The data on the real GDP in Romania were calculated according to the calculation methodology of the European System of Integrated Economic Accounts - SEC 2010. They were deflated using the Consumer Price Index (2010 = 100).

Table 1. Data series

Years	RGDP Romania [Mil. lei]	Imports of the electricity [Mil. Kwh]	Exports of the electricity [Mil. Kwh]
1996	7908	2242	1435
1997	10835.5	1038	817
1998	24982.5	1181	715
1999	36868.3	1103	1930
2000	56483.2	774	1470
2001	85093.2	767	2077
2002	124086.2	436	3290
2003	155836.4	962	3046
2004	211931	2584	3766
2005	256110.7	2321	5224
2006	309893.5	989	5262
2007	367557.4	1269	3359
2008	465312.2	921	5169
2009	510049.7	651	2946
2010	510183	767	3041
2011	564743.8	1036	2942
2012	598506.9	1402	1149
2013	622945.9	450	2466
2014	657629.1	1075	8200
2015	690016.3	3776	10504
2016	732904.9	3570	8587
2017	813763.7	3654	6548
2018	902964	2934	5479
2019	996012.7	5110	3592
2020	1024673.5	7601	4809
2021	1121187.5	8114	5916

Source: http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table

As can be seen, from data provided by the National Institute of Statistics, Romania exported in 2021, electricity with 1107 million Kwh more than in 2019, i.e. 23% more. We find the same situation with regard to the import of electricity, which has increased by 513 million Kwh (6.75%) in the last year under analysis, compared to

2019. All this, given that the net production of electricity was 54636 Gwh, with 2712 Gwh higher than in 2019.

The following figures show the dynamics of the real GDP of the Romanian economy for the period 1996-2021, as well as the import and export of electricity.

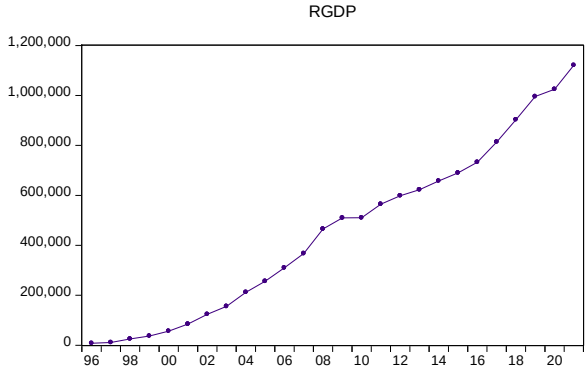

Figure 1. Time representation of real GDP in Romania

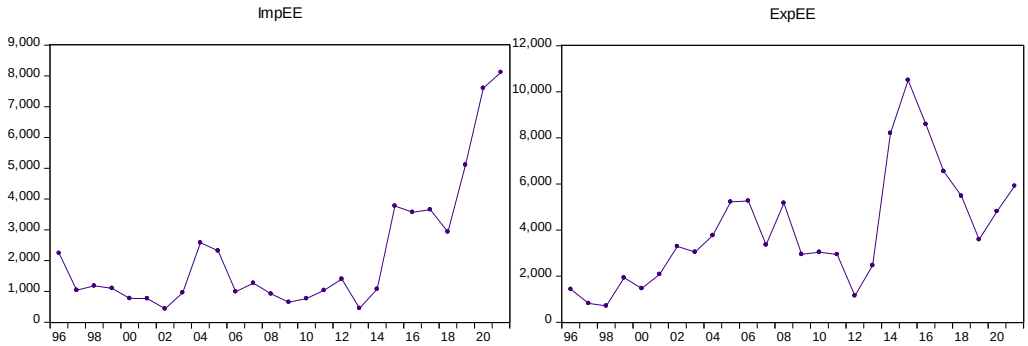

Figure 2. Time representation of the import (left) and export (right) of electricity from Romania

Analizând cele trei grafice, observăm că evoluția în timp a PIB-ului este preponderent ascendentă de la un an la altul, nivelul PIB-ului real atingând un maxim în 2021, de 1.121.187,5 milioane lei. Pe de altă parte, dinamica importului și exportului de energie electrică din România este una oscilantă, importurile ajungând la maximum 8114 milioane Kwh în 2021, iar exporturile de energie electrică având o scădere între 2015 și 2019, după care încep să crească. până în 2021.

Figure 3 shows the estimated distribution functions for the two analyzed distribution series. Thus, the Epanechnikov kernel function was used, which is optimal in terms of mean squared errors.

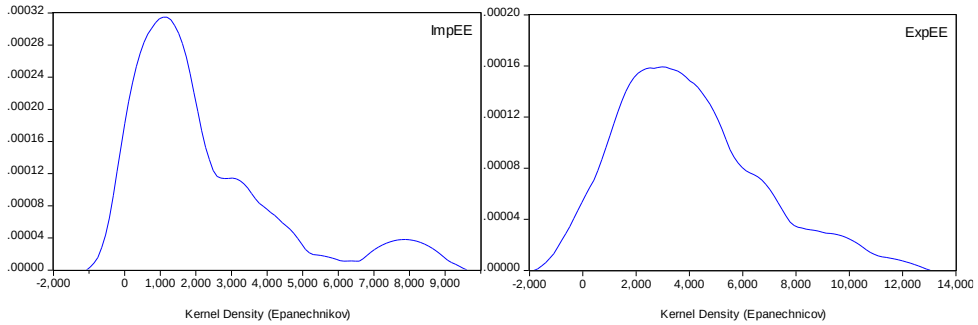

Figure 3. Distribution densities for the series of electricity import and export from Romania

On the other hand, the values of the main statistical indicators for the three variables analyzed in this article are entered in the table below. These values show that all three data series are normally distributed (Jarque-Berra test).

Table 2. Descriptive indicators

	RGDP	**ImpEE**	**ExpEE**
Mean	456095.4	2181.808	3989.962
Maximum	1121188.	8114.000	10504.00
Minimum	7908.000	436.0000	715.0000
Std. Dev.	346977.9	2067.349	2498.047
Skewness	0.278002	0.696673	0.876308
Kurtosis	2.919313	3.102354	3.243115
Jarque-Bera	5.600109	17.26258	3.391668
Probability	0.449305	0.000178	0.183446

3. SPECIFICATION OF THE MODELS

In this paragraph we will analyze the dependence between the real GDP in Romania and the import of electricity on the one hand and the export of electricity on the other. Also, the multiple link between the real GDP in Romania and the two mentioned variables will be analyzed. Based on these analyses, specific econometric models will be created and forecasts will be made over a short period of time (4 years).

Within the models we will use the following notations for the analyzed variables:

- ✓ $\left(RGDP_t\right)_{t=\overline{1,T}}$ represents Romania's real gross domestic product, measured in millions of lei;
- ✓ $\left(ImpEE_t\right)_{t=\overline{1,T}}$ represents the import of electricity from Romania, measured in millions of Kwh;
- ✓ $\left(ExpEE_t\right)_{t=\overline{1,T}}$ represents the export of electricity from Romania, measured in millions of Kwh;
- ✓ $t=\overline{1,T}$ the time period analyzed, between the years 1996-2021;

- ✓ T the number of terms in the series;

3.1. The relationship between real GDP and the import of electricity in Romania

In order to analyze the type of connection between GDP and electricity import from Romania, we will graphically represent the two variables, starting from the fact that GDP is considered as an independent variable, and energy import as an input variable in the model.

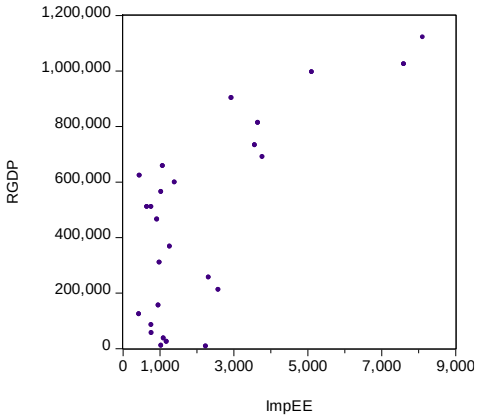

Figure 4. The data cloud specific to the dependence between the real GDP and the electricity import from Romania

In what follows, we will define the econometric model for the analysis of the dependence between the real GDP of the Romanian economy, for the period 1996-2021, and the volume of electricity imports. Thus, we will consider within the model also a linear trend. Therefore, the econometric model has the following representation (Model 1):

$$RGDP_t = C(1)*T + C(2)*\ ImpEE_t + C(3) + \varepsilon_t,\ t = \overline{1,26} \qquad (1)$$

where ε_t represents the residual variable.

In the table below are entered the values obtained for the parameters $C(1), C(2)$ and $C(3)$ of Model 1, obtained by applying the least squares method, after running the Eviews program package. Also, the values of the main statistical indicators specific to the analysis of econometric models are represented.

Analyzing the values of the three coefficients within the model represented in relation (1), we observe that both the linear trend of GDP and the import of electricity have positive influences on the level of real GDP in Romania for the analyzed period. In the first five months of 2022, imports totaled over 712 million euros, being 298% higher than in the first five months of 2021.

Table 3. Values of parameters and statistical indicators - Model 1

Dependent Variable: RGDP
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 01/02/23 Time: 16:43
Sample: 1996 2021
Included observations: 26
RGDP=C(1)*T+C(2)* ImpEE+C(3)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	41649.95	1505.970	27.65655	0.0000
C(2)	18.11175	5.571610	3.250721	0.0035
C(3)	-83237349	3016718.	-27.59203	0.0000

R-squared	0.985768	Mean dependent var	456095.4
Adjusted R-squared	0.984531	S.D. dependent var	346977.9
S.E. of regression	43155.87	Akaike info criterion	24.29119
Sum squared resid	4.28E+10	Schwarz criterion	24.43636
Log likelihood	-312.7855	Hannan-Quinn criter.	24.33299
F-statistic	796.5421	Durbin-Watson stat	1.585694
Prob(F-statistic)	0.000000		

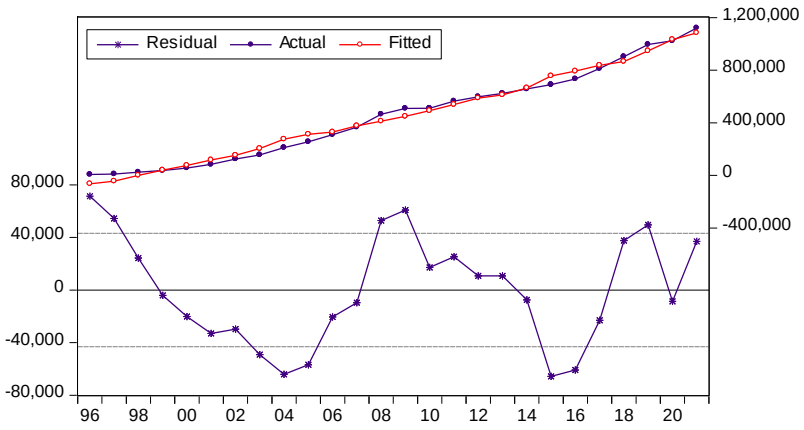

Figure 5. The graphs of real values, values approximated by Model 1 and residuals

As can be seen, the two graphs are very close, which shows that the model defined by relation (1) approximates the data series quite well.

3.2. The relationship between real GDP and the export of electricity in Romania

Regarding the dependence between the real GDP level in Romania and electricity exports, in the period 1996-2021, we will represent the graph of the data cloud specific to the two variable analyzed.

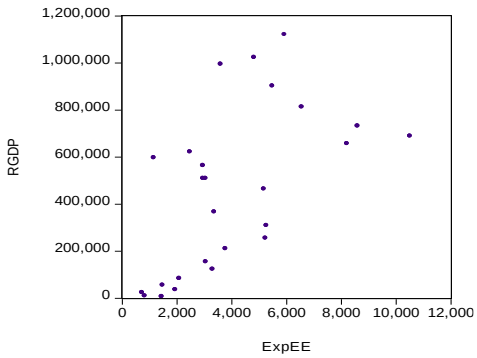

Figure 6. The data cloud specific to the dependence between the real GDP and the electricity export from Romania

In this case the model with linear trend (called Model 2) is represented in the following relationship:

$$RGDP_t = C(1)\cdot T + C(2)\cdot ExpEE_t + C(3) + u_t,\ t = \overline{1,26} \qquad (2)$$

where u_t represents the residual variable.

The values of the three parameters $C(1), C(2)$ and $C(3)$ of the Model 2, as well as the values of the main statistical indicators are entered in the following table. The model parameters were obtained by applying the least squares method, following the running of the Eviews software package.

Table 4. Values of parameters and statistical indicators Model 2

Dependent Variable: RGDP
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 12/30/22 Time: 18:04
Sample: 1996 2021
Included observations: 26
RGDP=C(1)*T+C(2)* EXPEE+C(3)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	47354.79	1581.612	29.94084	0.0000
C(2)	-11.78868	4.842586	-2.434376	0.0231
C(3)	-94608965	3164355.	-29.89834	0.0000

R-squared	0.983485	Mean dependent var	456095.4
Adjusted R-squared	0.982049	S.D. dependent var	346977.9
S.E. of regression	46489.16	Akaike info criterion	24.43999
Sum squared resid	4.97E+10	Schwarz criterion	24.58516
Log likelihood	-314.7199	Hannan-Quinn criter.	24.48180
F-statistic	684.8222	Durbin-Watson stat	1.508660
Prob(F-statistic)	0.000000		

Analyzing the values of the three coefficients within Model 2, we observe that the linear trend of the GDP has a positive influence on its level, in Romania for the analyzed period. Our country exported in the first half of 2022 electricity worth 450 million euros, 182.4% more than in 2021. Electricity exports from Romania go to Ukraine and the Republic of Moldova.

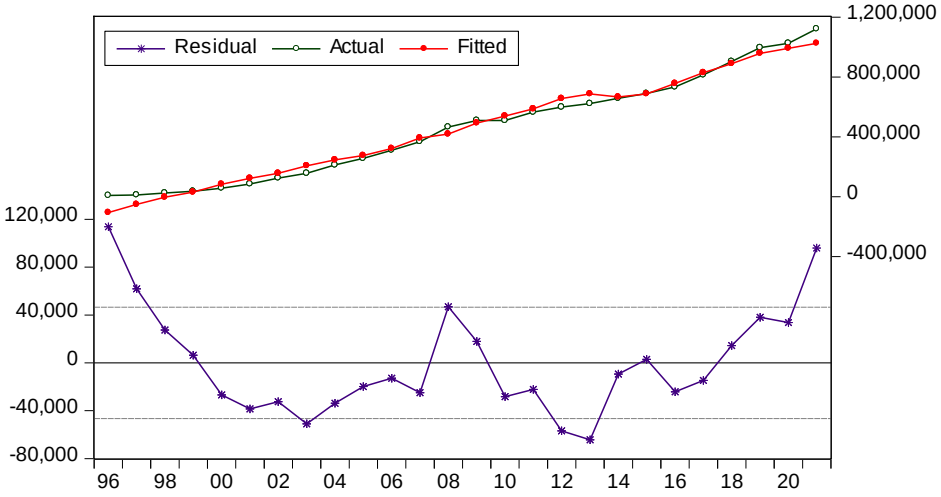

Figure 7. The graphs of real values, values approximated by Model 2 and residuals

As the two graphs show, the values approximated by model 2 are very close to the real values of the two quantities analyzed.

3.3. The relationship between real GDP and the import and export of electricity in Romania

To see the degree of influence of electricity import and electricity export on real GDP, we will next analyze a multivariable model where GDP is the output variable of the model and the two variable mentioned above are the input variables in the model. Thus, the multivariable model (Model 3) with linear trend is defined by the following expression:

$$RGDP_t = C(1)\cdot T + C(2)\cdot\ ImpEE + C(3)\cdot ExpEE_t + C(4) + v_t,\ t = \overline{1,26} \qquad (3)$$

where v_t represents the residual variable.

Analyzing the values of the three coefficients within model 3, we observe that the linear trend of the GDP as well as the import of electricity has a positive influence on its level, in Romania for the analyzed period.

Table 5. Values of parameters and statistical indicators Model 3

Dependent Variable: RGDP
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 01/02/23 Time: 16:55
Sample: 1996 2021
Included observations: 26
RGDP=C(1)* T+C(2)* IMPEE+C(3)*EXPEE+C(4)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	44120.19	1498.167	29.44944	0.0000
C(2)	18.36283	4.727002	3.884667	0.0008
C(3)	-12.03800	3.813911	-3.156341	0.0046
C(4)	-88151336	2995420.	-29.42870	0.0000

R-squared	0.990204	Mean dependent var	456095.4
Adjusted R-squared	0.988868	S.D. dependent var	346977.9
S.E. of regression	36608.63	Akaike info criterion	23.99459
Sum squared resid	2.95E+10	Schwarz criterion	24.18815
Log likelihood	-307.9297	Hannan-Quinn criter.	24.05033
F-statistic	741.2764	Durbin-Watson stat	1.951076
Prob(F-statistic)	0.000000		

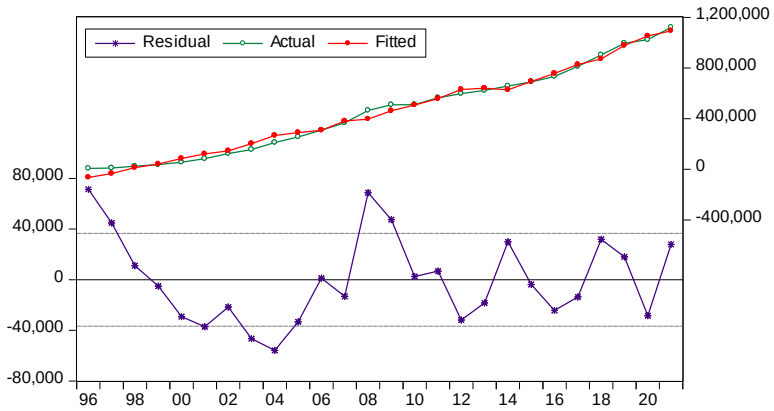

Figure 8. The graphs of real values, values approximated by Model 3 and residuals

As can be seen, Model 3 approximates the data series of the analyzed quantities very well.

4. INTERPRETATION OF THE RESULTS

Analyzing the three models described above, we can make the following observations:

- The value of the coefficient of determination R^2 and that of the adjusted coefficient of determination $Adjusted - R^2$ is the highest given by Model 3;
- The lowest value of the criteria based on information theory is the Akaike criterion given by Model 3, which shows us that this model best estimates the analyzed data series;
- For all three analyzed models, the specific assumptions of the econometric models are verified. Thus, in the following table, the hypothesis of homoscedasticity is verified for all three models. As can be seen, the Breusch-Pagan-Gogfrey test is applied, via the LM statistic. If the calculated value of this statistic $LM = n \cdot R^2$ is less than the tabulated value of the statistic $\chi^2_{2;0,05} = 5,991$ then the hypothesis is verified. It can be seen that for each model this inequality is satisfied.

Table 6. Heteroskedasticity Test: Breusch-Pagan-Godfrey

Model 1

F-statistic	1.358074	Prob. F(2,23)	0.2770
Obs*R-squared	2.746128	Prob. Chi-Square(2)	0.2533
Scaled explained SS	0.977153	Prob. Chi-Square(2)	0.6135

Model 2

F-statistic	0.842684	Prob. F(2,23)	0.4434
Obs*R-squared	1.775123	Prob. Chi-Square(2)	0.4117
Scaled explained SS	1.613425	Prob. Chi-Square(2)	0.4463

Model 3

F-statistic	1.334290	Prob. F(3,22)	0.2888
Obs*R-squared	4.002429	Prob. Chi-Square(3)	0.2612
Scaled explained SS	2.018241	Prob. Chi-Square(3)	0.5686

- The autocorrelation hypothesis of the errors is also checked. Thus, the calculated value of this statistic is between the limits $d_2 < DW_{calculat} < 4 - d_2$, then there is no significant linear correlation of the first order at the level of the residuals, that is, they are independent. The tabular values of this statistic, for a number of 26 observations and a significance threshold $\alpha = 0,05$, are $d_1 = 1,3$ and $d_2 = 1,46$. Looking at the data in Tables 3,4 and 5, we notice that the above double inequality is verified for all three models.
- The hypothesis of normalization of the residuals is verified by the Jarque-Bera test, whose calculated values for the three models are in the following table. The calculated value of this test is compared with the tabulated value of the statistic $\chi^2_{2,\alpha}$, for a significance threshold of $\alpha = 5\%$, ie $\chi^2_{2;0,05} = 5,991$. As the inequality

$JB < \chi^2_{2,0,05}$ is verified for each model, we can say that the assumption of normalization of the residuals is accepted.

Table 7. Jarque-Bera test

	Jarque-Bera	Kurtosis	Skweness
Model 1	1,288	1,909	-0,001
Model 2	3,803	3,322	0,922
Model 3	4,079	3,49	0,938

5. FORECASTS

Within this paragraph, forecasts will be made for a period of 4 years, 2022-2025. For each model analyzed, it was taken into account that the parameters of the three models remain unchanged for the period for which forecasts are made, that is, at the level of the evolution of the analyzed phenomenon, no special phenomena intervened to disturb the forecasted values.

The following figures show the predicted values for the three analyzed models, taking into account the fact that the values of electricity import and export have a slight upward trend. The values of the two variable are entered in the following table.

Table 8. The proposed values for the two variable analyzed in order to make predictions

Years	Electricity import [Mil. Kwh]	Electricity export [Mil. Kwh]
2022	8149	6000
2023	9017	6120
2024	9133	6200
2025	9200	6250

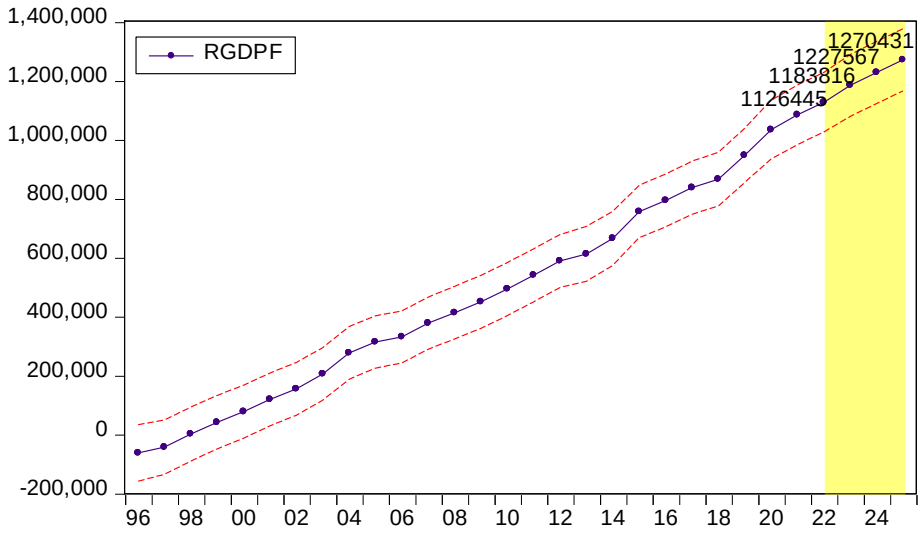

Figure 9. The evolution over time of the forecasted values of the real GDP in Romania in the period 2022-2025 for Model 1 [Mil. lei]

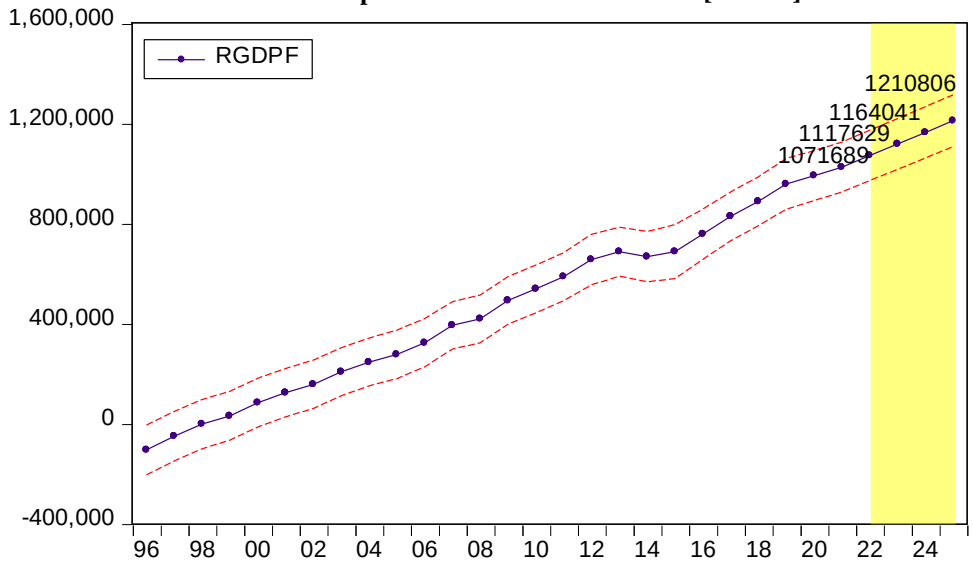

Figure 10. The evolution over time of the forecasted values of the real GDP in Romania in the period 2022-2025 for Model 2 [Mil. lei]

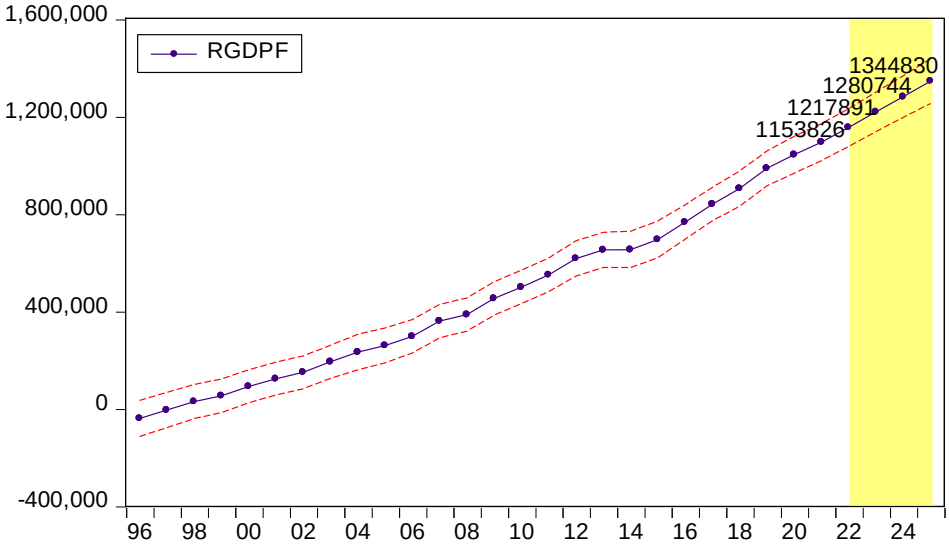

Figure 11. The evolution over time of the forecasted values of the real GDP in Romania in the period 2022-2025 for Model 3 [Mil. lei]

Analyzing the forecast values of the real GDP, in the period 2022-2025, it is observed that the biggest influence in the increase of the level of this macroeconomic variable is the import and export of electricity, taken in tandem (Model 3). Thus, in

2025, the predicted value of the real GDP (Model 3) is 1344830 million lei, i.e. by approximately 20% compared to 2021, for a 13.38% increase in electricity import compared to 2021 and an increase in electricity export of 5.64% compared to 2021.

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