EVOLUTION OF ELECTRICITY PRODUCTION FROM THERMOELECTRIC POWER PLANTS IN ROMANIA: AN ECONOMETRIC APPROACH

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Abstract: This paper analyzes the evolution over time of electricity production from thermal power plants in Romania, by applying an ARMA (Auto Regressive Moving Average) model. The study uses statistical data over a period of 32 years (1992-2023). The results obtained show that time has a significant impact on electricity production from thermal power plants, its negative value indicating that, as time increases, the value of the dependent variable decreases. Also, the first-order moving average component has a significant impact on the dependent variable, the positive value indicating that previous errors have a positive influence on the current values of the time series.

Key words: electricity production, thermoelectric power plants, ARMA model.

1. INTRODUCTION

In the context of the global energy transition and efforts to reduce greenhouse gas emissions, the analysis of electricity production from thermal power plants in Romania becomes particularly relevant.

The European Union has implemented strict policies to reduce greenhouse gas emissions, including by promoting the transition to renewable energy sources and modernizing thermal power plants to make them more efficient and less polluting. In the European Union, it represented approximately 36% of total electricity production in 2022, a decrease of 3.1% compared to the previous year [3]. Germany and Poland are among the EU member states that rely most on thermal power plants, using mainly coal and natural gas for electricity production. In recent years, electricity production from renewable sources has increased significantly in the EU, exceeding production from all fossil sources combined for the first time in 2022 [4].

Romania has a diversified energy profile, with a mix of renewable and non-renewable energy sources. Thermal energy production in Romania is influenced by the available natural resources and national energy policies.

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In Romania, thermal power plants play a crucial role in the national energy mix, providing a significant part of the country's electricity needs. These plants use fossil fuels, such as coal and natural gas, to generate heat, which is then converted into electricity.

The production of electricity from thermal power plants is essential for ensuring the stability and continuity of the electricity supply, especially during peak consumption periods. It contributes significantly to Romania's energy security, providing a reliable source of energy that can be quickly adjusted according to demand.

In recent years, Romania has seen a significant increase in electricity production from renewable sources, such as wind and solar energy, thus reducing dependence on fossil fuels. However, thermal power plants remain an important component of the energy mix, ensuring grid stability and the ability to respond quickly to demand fluctuations.

In the context of the global energy transition and efforts to reduce greenhouse gas emissions, the analysis of electricity production from thermal sources becomes particularly relevant. Even though national and European policies promote the transition to cleaner energy sources, thermal power plants continue to play an essential role in ensuring energy security in the medium term.

In the literature, there are a number of recent studies on the analysis of electricity production from power plants. A recent article that studies the theoretical aspects of the different types of heating installations that can be implemented in buildings, as well as information on the algorithms for calculating the heat demand for heating and hot water preparation, according to current regulations, was reported by Dinu and collaborators in the paper [1]. Also, Stoicuta analyzed the evolution of total electricity production by categories of power plants in Romania over a period of 26 years (1992–2017), in the article [2]. This paper aims to perform an econometric analysis of electricity production from thermal power plants in Romania, identifying the determining factors.

2. ECONOMETRIC ANALYSIS OF ELECTRICITY PRODUCTION FROM THERMAL POWER PLANTS IN ROMANIA

The production of electricity from thermal power plants in Romania plays a significant role in the country's energy mix. Thermal power plants use fossil fuels, such as coal, natural gas and fuel oil, to generate electricity.

These plants contribute to ensuring energy stability and security, having the ability to produce energy constantly, regardless of weather conditions. Currently, in Romania, there are seven thermoelectric power plants in operation, in Rovinari and Turceni - Gorj and in Ișalnița and Craiova - Dolj, in Bucharest (South and West), in Paroșeni - Hunedoara.

2.1. Trend Analyses

The following figure shows the evolution over time of electricity production from thermal power plants in Romania, between 1992 and 2023. The statistical data are analyzed over a period of 32 years and are provided by the National Institute of Statistics [5].

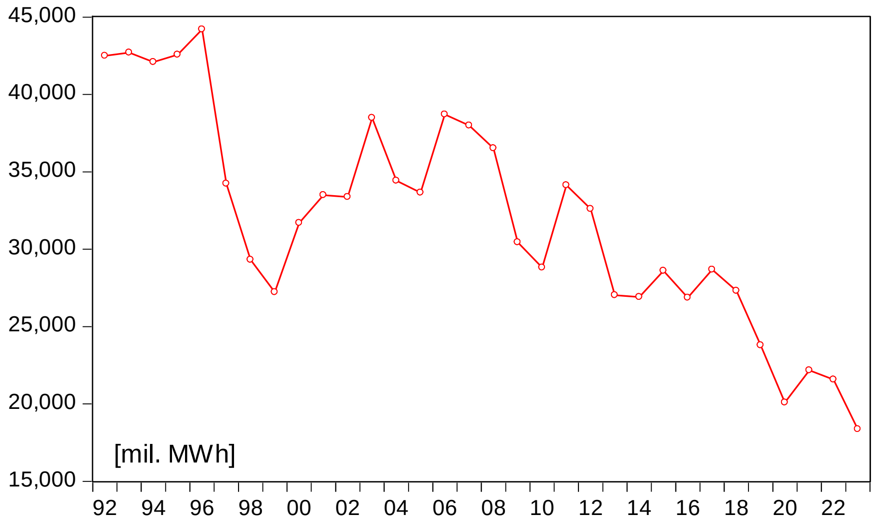

Fig.1. Electricity production from thermoelectric power plants in Romania

Analyzing the above representation, we notice that the graph shows a general downward trend in electricity production from thermal power plants over the analyzed period. This indicates a reduction in dependence on thermal power plants or a transition to other energy sources.

Around 1996, there is a sharp decline in production, followed by stabilization at a lower level. This decline can be associated with changes in energy policy, infrastructure modernization or the closure of old plants.După 1998, graficul arată fluctuații semnificative, cu vârfuri și minime. Aceste fluctuații pot fi cauzate de variații sezoniere, cererea de energie, prețurile combustibililor sau alte factori economici și politici.

By 2022, electricity production from thermal power plants had fallen to around 20,000 million MWh, suggesting a significant reduction compared to the beginning of the period under review.

The long-term downward trend may indicate a transition to cleaner and more sustainable energy sources, such as wind, solar or nuclear power. Changes in energy production may reflect national energy policies, infrastructure investments and environmental regulations.

Fluctuations and declines in production can have an impact on local and national economies, especially in regions dependent on the energy industry.

2.2. Descriptive data and assessments

In 2022, the total installed capacity of thermal power plants in Romania was approximately 32.4% of the total electricity generation capacity. In 2023, electricity production from thermal power plants was 18,367 million MWh, down 14.8% compared to the previous year. The benefits of thermal power plants are that they can operate continuously and ensure constant energy production. They can also be used to cover consumption peaks and stabilize the electricity grid. The major disadvantages of this form of electricity production are high operating and maintenance costs, especially in the context of rising fuel prices, and the burning of fossil fuels that generate greenhouse gas emissions and air pollutants.

The following table presents the values of the main descriptive indicators of electricity production.

Table 1. ***Descriptive indicators***

	Y
Mean	31892.25
Median	32148.50
Maximum	44209.00
Minimum	18367.00
Std. Dev.	6998.514
Skewness	0.022270
Kurtosis	2.217773
Jarque-Bera	0.818485
Probability	0.664153
Observations	32

The electricity production from thermal power plants during the analyzed period is approximately 31892.25 million MWh, which suggests that, on average, the annual production was around this value. As for the median, it represents the middle value of the data, and it is observed that it is very close to the mean, which indicates a relatively symmetrical distribution. The maximum represents the highest value of electricity production during the analyzed period, which is 44209.00 million MWh, and the minimum represents the lowest value of electricity production from thermal power plants during the analyzed period, which is 18367.00 million MWh.

Standard deviation measures the dispersion of values from their mean. A higher value indicates greater variability in electricity production. Skewness measures the symmetry of the data distribution. A value of 0.022 indicates a nearly symmetrical distribution, meaning that the data is not significantly skewed. Kurtosis measures the "sharpness" of the data distribution. A value of 2.217 indicates a slightly flatter distribution compared to a normal distribution (which has a kurtosis of 3).

The Jarque-Bera test is used to check whether the data follows a normal distribution. A probability of 0.66, which is greater than 0.05, indicates that the data follows a normal distribution.

2.3. The econometric model

To perform the econometric analysis of electricity production from thermal power plants, we will use the following notations:

To analyze the evolution of electricity production from thermal power plants in Romania, we will use an ARMA (1,1) (Auto Regressive Moving Average) model defined by the following expression:

$$Y_t = c + \phi_1 Y_{t-1} + \theta_1 \varepsilon_{t-1} + \varepsilon_t, t = \overline{1,32} \quad (1)$$

where $Y = (y_t), t = \overline{1,32}$ represents the output variable and is given by the time series of electricity production from thermal power plants. The unit of measurement used is millions of MWh;

- c the model constant;
- ϕ_1 is the first-order autoregressive coefficient;
- θ_1 is the coefficient of the first-order moving average;
- ε_t is the error at time t of the model.

Table 2 introduces both the coefficient values from the ARMA model and the values of the statistics applied in the econometric modeling.

Table 2. ***Coefficients and values of statistical tests***

Dependent Variable: Y				
Method: ARMA Maximum Likelihood (OPG - BHHH)				
Sample: 1992 2023				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1325077.	340428.3	3.892383	0.0006
T	-644.2080	169.5736	-3.798988	0.0008
AR(1)	0.216210	0.172102	1.256290	0.2198
MA(1)	0.634965	0.192523	3.298123	0.0027
SIGMASQ	8.010774	2652118.	3.020519	0.0055
R-squared	0.831169	Mean dependent var		31892.25
Adjusted R-squared	0.806157	S.D. dependent var		6998.514
S.E. of regression	3081.274	Akaike info criterion		19.07234
Sum squared resid	2.56E+08	Schwarz criterion		19.30136
Log likelihood	-300.1575	Hannan-Quinn criter.		19.14825
F-statistic	33.23090	Durbin-Watson stat		1.956609
Prob(F-statistic)	0.000000			
Inverted AR Roots	0.22			
Inverted MA Roots	-0.63			

In the context of the ARMA model, SIGMASQ represents the residual variance of the model. This is a measure of the variability of the residual errors of the model. In other words, SIGMASQ indicates how much the observed values of the dependent variable Y vary from the values estimated by the model. A lower value of SIGMASQ indicates that the model fits the data better because the residual errors are smaller. Conversely, a higher value suggests greater variability in the errors and therefore a poorer fit of the model.

The following figure represents the real values and those adjusted by the ARMA(1,1) model of electricity production from thermal power plants.

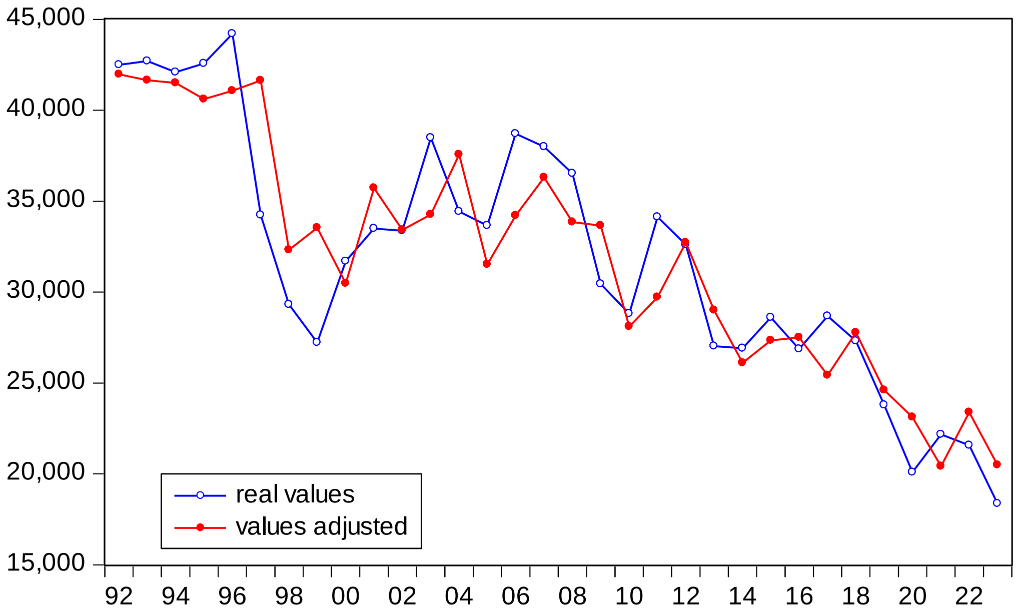

Fig.2. Actual values (blue) and adjusted values (red) through the ARMA model

As can be seen, the two plots are close enough to say that the ARMA(1,1) model performs well.

The stability of the ARMA model is essential to ensure that the long-term predictions of the model are reliable and that the model does not produce explosive or oscillating values. This is determined by the roots of the characteristic polynomials of the autoregressive (AR) and moving average (MA) components (Figure 3).

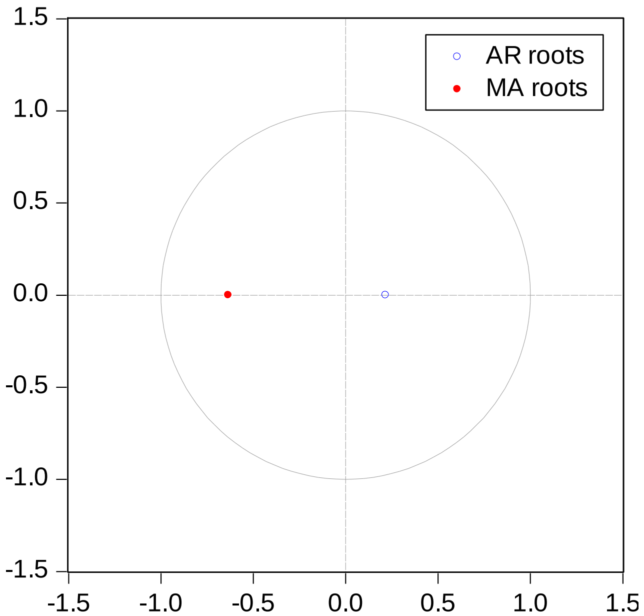

Fig.3. Inverse Roots of ARMA Polynomials

The impulse response shows how long the effect of a shock on the time series lasts. In a stable model, the impact of a shock should diminish over time.

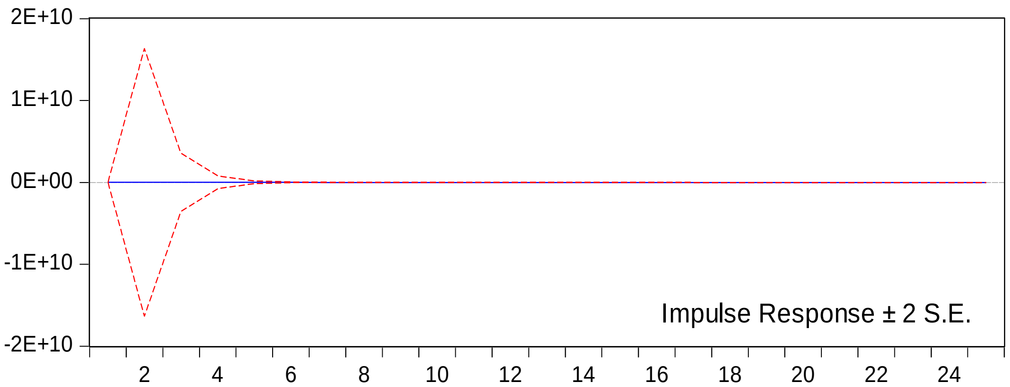

Fig.4. Impulse response

The impulse response is useful for understanding the dynamics of a time series and assessing the stability of the model. It can also be used to analyze the effects of policies, external shocks, or other factors on the variable under analysis.

The following table presents the results of the autocorrelation and partial autocorrelation analysis for a time series, along with the corresponding Q-statistics and p-values.

Table 3. ***Correlogram of residuals***

<table>
<tr><td colspan="2">Sample: 1992 2023</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Included observations: 31</td><td></td><td></td><td></td></tr>
<tr><td>Autocorrelation</td><td>Partial Correlation</td><td></td><td>AC</td><td>PAC</td><td>Q-Stat</td><td>Prob</td></tr>
<tr><td>. | . |</td><td>. | . |</td><td>1</td><td>0.038</td><td>0.038</td><td>0.0480</td><td>0.827</td></tr>
<tr><td>***| . |</td><td>***| . |</td><td>2</td><td>-0.353</td><td>-0.355</td><td>4.4401</td><td>0.109</td></tr>
<tr><td>. *| . |</td><td>. | . |</td><td>3</td><td>-0.085</td><td>-0.062</td><td>4.7067</td><td>0.195</td></tr>
<tr><td>. | . |</td><td>. *| . |</td><td>4</td><td>-0.027</td><td>-0.169</td><td>4.7351</td><td>0.316</td></tr>
<tr><td>. |* . |</td><td>. | . |</td><td>5</td><td>0.081</td><td>0.039</td><td>4.9932</td><td>0.417</td></tr>
<tr><td>. | . |</td><td>. *| . |</td><td>6</td><td>-0.065</td><td>-0.170</td><td>5.1665</td><td>0.523</td></tr>
<tr><td>. | . |</td><td>. | . |</td><td>7</td><td>0.010</td><td>0.057</td><td>5.1704</td><td>0.639</td></tr>
<tr><td>. *| . |</td><td>.**| . |</td><td>8</td><td>-0.123</td><td>-0.260</td><td>5.8406</td><td>0.665</td></tr>
<tr><td>.**| . |</td><td>.**| . |</td><td>9</td><td>-0.207</td><td>-0.213</td><td>7.8360</td><td>0.551</td></tr>
<tr><td>. |* . |</td><td>. | . |</td><td>10</td><td>0.138</td><td>-0.037</td><td>8.7684</td><td>0.554</td></tr>
<tr><td>. |**. |</td><td>. |* . |</td><td>11</td><td>0.248</td><td>0.095</td><td>11.905</td><td>0.371</td></tr>
<tr><td>. | . |</td><td>. | . |</td><td>12</td><td>0.038</td><td>-0.001</td><td>11.984</td><td>0.447</td></tr>
<tr><td>.**| . |</td><td>. *| . |</td><td>13</td><td>-0.214</td><td>-0.141</td><td>14.594</td><td>0.333</td></tr>
<tr><td>. *| . |</td><td>. *| . |</td><td>14</td><td>-0.093</td><td>-0.072</td><td>15.109</td><td>0.371</td></tr>
<tr><td>. |* . |</td><td>. |* . |</td><td>15</td><td>0.206</td><td>0.094</td><td>17.821</td><td>0.272</td></tr>
<tr><td>. |* . |</td><td>. | . |</td><td>16</td><td>0.095</td><td>0.028</td><td>18.434</td><td>0.299</td></tr>
</table>

The analysis of autocorrelation and partial autocorrelation suggests that there is no significant autocorrelation in the residuals of the time series at the analyzed lags, as the p-values are greater than 0.05 for all lags. This indicates that the model used to generate the time series is appropriate and there is no significant residual autocorrelation.

3. RESULTS AND DISCUSSION

Analyzing the results obtained using the Eviews 10.1 program, we can draw the following conclusions:

- The value of the constant is statistically significant ($p < 0.05$), which suggests that it has a significant impact on the dependent variable. This represents the base value of the time series when all other variables are zero.
- The coefficient for time is statistically significant ($p < 0.05$), which suggests that time has a significant impact on the dependent variable. The negative value indicates that as time increases, the value of the dependent variable decreases.
- The value of the AR(1) coefficient is not statistically significant ($p > 0.05$), suggesting that there is no significant first-order autocorrelation in the data. However, the positive value indicates a slight positive dependence between the current and previous values of the time series.

- The MA (1) coefficient is statistically significant ($p < 0.05$), which suggests that the 1st order moving average component has a significant impact on the dependent variable. The positive value indicates that past errors have a positive influence on the current values of the time series.
- The value of the R-squared coefficient of determination suggests that approximately 83.12% of the variation in the dependent variable is explained by the model.
- The F statistic, which has a value of 33.23090, shows that the model is statistically significant ($p < 0.05$), which suggests that at least one of the coefficients is different from zero.
- The Durbin-Watson statistic, with a value of 1.956609, suggests that there is no significant autocorrelation of the residuals.
- The values of the roots of the characteristic polynomials indicate the stability of the ARMA model, since the roots lie inside the unit circle (i.e., the absolute values of the roots are less than 1).
- In the graph in Figure 4, the impact of the shock diminishes over time, indicating the stability of the model. On the other hand, the amplitude of the impulse response indicates the magnitude of the shock's effect on future values of the time series. A large impulse response suggests that the shock has a significant impact on the time series. The initial response is significant, but it stabilizes quickly.
- The sign of the impulse response (positive or negative) indicates the direction in which the shock affects the time series. In the impulse response graph, initial fluctuations around zero suggest that the shock has a variable impact on the time series.

To reduce dependence on fossil fuels, some thermal power plants have started to use biomass and other alternative fuel sources. This can help reduce carbon emissions and promote energy sustainability.

Thermal power plants can be integrated with renewable energy sources, such as solar and wind power, to create a more balanced and sustainable energy mix. This can help stabilize the electricity grid and reduce dependence on fossil fuels.

Investment in research and development is essential to improve the efficiency and sustainability of thermal power plants. The development of new technologies and processes can help reduce costs and minimize environmental impact.

4. CONCLUSIONS

Romania aims to reduce its dependence on fossil fuels and increase the share of renewable sources in the energy mix. However, thermal power plants will continue to play an important role in ensuring energy security in the short and medium term.

To reduce the impact on the environment, it is necessary to modernize existing thermal power plants and implement more efficient and less polluting technologies. For example, the use of combined steam-gas cycles can increase efficiency and reduce emissions.

In the long term, the transition to renewable energy sources is essential to reduce dependence on fossil fuels and combat climate change. However, thermal power plants will continue to play an important role in the energy mix in the medium term.

Governments play a crucial role in promoting energy sustainability by implementing strict policies and regulations on emissions and energy efficiency. Financial incentives and subsidies can encourage the modernization of thermal power plants and the transition to cleaner energy sources.

In conclusion, thermal power plants remain an essential component of the energy mix both in Romania and globally, but the transition to cleaner and sustainable energy sources is imperative to ensure a sustainable and environmentally friendly energy future.

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