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THE PRICE ELASTICITY OF ELECTRICITY DEMAND IN ROMANIA

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Abstract

This paper examines the causal relationships in electricity consumption patterns and price using Granger causality analysis. Our methodology implements vector autoregression models while accounting for electricity's nature as an essential resource with low price elasticity. Through Seasonal Autoregressive Integrated Moving Average (SARIMA) modelling and stationarity assessments, we establish that electricity consumption demonstrates significant inelasticity to price fluctuations, with price series integrated of order I(1) and consumption series of order I(2). Our findings reveal a unidirectional Granger causality from consumption to price, while no significant causality exists from price to consumption. These results suggest that consumption behaviour is primarily influenced by structural and seasonal factors rather than price signals. Furthermore the findings of this article contribute to understanding the dynamics of the electricity market and opens a door to understanding the policy formulation of the governmentsduring the transition to renewable energy.

Keywords: Energy, Granger Causality, SARIMA, Price, Energy Transition
JEL Classification: K32, C10

1. Introduction

Electricity is a fundamental part of modern life, powering a broad spectrum of activities that take place in homes, workplaces, and across essential infrastructure systems. Because electricity represents a basic necessity, its demand shows low elasticityin respect to price fluctuations (Auray, Caponi and Ravel, 2018). This means that the consumption of electricity remains largely constant regardless of the variations in tariffs (Joskow, 2008). Given the great degree of dependence that people and companies have on electricity, the potential of immediate substitution is significantly reduced, which is why this resource is considered to be an essential requirement (Borenstein, 2012).

Governments hold the responsibility to establish a variety of regulatory measures and price control policies in order to safeguard consumers and preserve market stability. A few examples of these are price ceilings, subsidies for vulnerable populations, and laws governing competition in the energy industry

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(Helm, 2017). Policies implemented by the government, like subsidies and regulated tariffs, are extremely important in maintaining the price of electricity at a level that is manageable. It is the intention of these measures to bring about a reduction in costs for customers and to forestall unexpected price hikes (Office of Fair Trading, 2010). In addition, governments make investments in the development of renewable energy sources, such as solar and wind power, in order to maintain price stability over the long term (Ata, 2017).

Additionally, market mechanisms, such as carbon taxes and emissions trading systems, have an impact on the pricing of electricity and encourage the transition to cleaner energy sources (Omogoye, 2025). These policies and methods are vital for ensuring that the final consumers will pay a price that is both affordable and sustainable. In Romania, for instance, the government recently made the decision to extend price limit restrictions on electricity until June 2025 and on gas until April 2026. The purpose of this decision was to protect the population from the effects of growing prices (Reuters, 2024). According to the International Energy Agency (2023), a number of European nations have implemented these measures, particularly in light of the recent energy crisis, in order to guarantee that the supply of power will be affordable and uninterrupted.

For this reason, when it comes to maintaining a balance between the sustainability of the market and the protection of consumers, governmental actions are absolutely necessary. Over the course of a longer period of time, the efficacy of these measures is contingent upon the adaptation of laws to the dynamics of the energy market as well as investments in renewable sources, which have the potential to alleviate pricing pressures (Newbery, 2018).

2. Literaturereview

The price elasticity of electricity demand is a fundamental concept that assesses the responsiveness of electricity consumption to variations in electricity prices. This metric plays a critical role in understanding consumer behavior and supports evidence-based energy policy decisions. Research indicates that electricity demand tends to be inelastic in the short run, with estimated short-run elasticity values around -0.1 in the United States. This suggests that even substantial price increases do not result in proportional reductions in electricity consumption, as consumers often face limited immediate alternatives (Burke & Abayasekara, 2017). The inelastic nature of electricity demand is largely attributed to the essential nature of electricity, the scarcity of substitutes, and the time required for consumers to modify their usage habits.

The degree of price elasticity in electricity demand can vary due to multiple factors, including income levels, consumer loyalty, and regional characteristics. Notably, the industrial sector often exhibits the highest long-run elasticity (Burke & Abayasekara, 2017). While consumers demonstrate relatively low responsiveness to price changes in the short term, their consumption patterns tend to adjust more significantly over extended periods, with long-run elasticity approaching -1 (Burke & Abayasekara, 2017). Additionally, regional and temporal differences in electricity demand underscore the necessity of spatially disaggregated analyses to support effective policy evaluation (Popescu &Caraba-Meita, n.d.).

A sophisticated analytical approach to understanding electricity demand involves the application of Granger causality, a statistical method used to determine predictive relationships between time-series data. This technique has been employed to investigate the interdependence between electricity demand and economic growth. Findings suggest the existence of bidirectional relationships, wherein changes in one variable influence the other over time (Hey, n.d.; Pearl, 2000; Stern, 2013). Such insights hold significant implications for energy policy and economic strategy, as they facilitate the development of informed interventions aimed at balancing energy consumption with economic fluctuations.

To enhance the predictive accuracy of electricity demand modeling, researchers have increasingly integrated Granger causality analysis with Seasonal Autoregressive Integrated Moving Average (SARIMA) models. SARIMA is particularly effective in capturing seasonal patterns in time-series data, making it a valuable tool for forecasting electricity consumption fluctuations (Jiang & Bai, 2017; Minnaar et al., 2023). By leveraging these analytical frameworks, researchers can gain a more comprehensive understanding of the impact of economic indicators on electricity demand, thereby improving forecasting accuracy and strengthening policy measures aimed at managing energy consumption efficiently.

Empirical studies further reveal that the relationship between electricity consumption, electricity prices, and economic growth varies across sectors and economies (Hovhannisyan, 2021). A study on Pakistan's energy sector indicates that electricity consumption is driven by real economic activity, particularly in the commercial, manufacturing, and agricultural sectors, where increased output leads to higher electricity demand. However, in the residential sector, rising private expenditures are the primary drivers of electricity consumption. The study emphasizes the need for integrating electricity production with broader economic planning to mitigate shortages and avoid unplanned load shedding (Jamil & Ahmad, 2010).

According to a meta-analysis conducted by Labandeira et al. (2017), price elasticities of energy demand have become increasingly relevant in estimating the socio-economic and environmental effects of energy policies. Their research quantitatively summarizes empirical evidence to facilitate a sounder economic assessment of energy price changes. They found that the average short-term price elasticity of energy demand is around -0.21, while the long-term elasticity averages -0.61. Specifically for electricity, they reported short-term elasticities of approximately -0.13 and long-term elasticities of about -0.37. This confirms that energy consumers are somewhat responsive to price changes, with reactions being greater in the long term than in the short term, consistent with findings from previous meta-analyses (Espey and Espey, 2004).

3. Methodology

This study employed a rigorous statistical approach to examine the relationship between electricity prices and consumption. The research used time series modelling and causality testing to thoroughly assess the potential interactions between the two variables.

3.1. Data Collection and Preprocessing

During the preliminary stage, key information regarding electricity prices and consumption was collected.The data was obtained from the EMBER and Statista websites, which compile official sources to ensure reliability and completeness. The collected information is representative for Romania and was compiled monthly over an extensive period of time to assure the validity of the conclusions (January 2019 - December 2024) totalling 72 data points. The data series for prices and consumption are denoted in EUR/MWh and MWh, respectively.

Table no. 1: Descriptive statistics

Statistic	Price (RON/MWh)	Consumption (GWh)
Mean	112.13	4803.06
Standard Deviation	88.99	390.28

Statistic	Price (RON/MWh)	Consumption (GWh)
Minimum	24.76	4100.00
Maximum	490.80	5780.00

Source: Authors' processing.

3.2. Exploratory Data Analysis

An exploratory data analysis was conducted to assess the statistical properties of the time series parameters. This technique incorporated visual inspections of trends and seasonal patterns, together with formal stationarity assessments. The Augmented Dickey-Fuller (ADF) test was employed to assess stationarity and determine whether differencing was required by testing for the presence of unit roots. This facilitated the decision-making process.

3.3. SARIMA Modelling

To empirically examine the inelastic relationship between electricity prices and consumption in Romania—indicating that price variations exert limited influence on national electricity demand—and to model the underlying temporal patterns of consumption, a SARIMA (Seasonal AutoRegressive Integrated Moving Average) model was specified and estimated.

During the model selection procedure, autocorrelation functions (ACF) and partial autocorrelation functions (PACF) were examined to identify the optimal lag structures. Multiple information criteria, such as the Akaike Information Criterion (AIC) and the Schwarz Criterion (BIC), were employed to evaluate the different SARIMA formulations. The ultimate model was selected based on its predictive accuracy and goodness-of-fit criteria. Diagnostic testing revealed that the residuals adhered to a white noise method, and the calculated coefficients were deemed statistically significant.

The final version of the SARIMA model included moving average (MA) and seasonal moving average (SMA) components. Additional terms encompassed autoregressive (AR) and seasonal autoregressive (SAR) components. The model demonstrated substantial explanatory power, indicated by an R-squared value of 0.857 and an adjusted R-squared value of 0.844. The Durbin-Watson statistic was evaluated to further assess the model's validity. The findings of this investigation revealed no significant autocorrelation problems.

3.4. Granger Causality Test

A Granger Causality test was conducted to examine the predicted impact of power costs on energy use. The test was performed utilizing a seven-month lag, established by information criteria optimization. The null hypothesis asserting that power prices do not Granger-Cause electricity usage was evaluated, resulting in an F-statistic of 0.2998 and a p-value of 0.9505. Since the p-value surpassed the standard significance level of 0.05, the null hypothesis remained unrefuted, suggesting that historical power prices do not significantly enhance the assumed trend of electricity consumption.

Conversely, a reverse Granger causality test was conducted to examine whether electricity consumption influences electricity prices. The results revealed an F-statistic of 2.0422 and a p-value of 0.0687suggesting that changes in electricity consumption contain valuable predictive information for the future evolution of energy prices, but this predictive capability manifests with a substantial delay of approximately 7 months.

4. Results and discussion

Based on the SARIMA model and the Granger causality test, our statistical analysis suggests that fluctuations in electricity prices do not have a substantial impact on national electricity consumption. The results suggest an inelastic relationship between price and consumption, which means that price fluctuations do not generate proportional changes in national electricity demand. This finding can be elucidated by the fundamental role of electricity in commercial and domestic activities, which constrains consumers' capacity to promptly modify their behavior in reaction to price fluctuations.

Furthermore, a delayed causal link between price and consumption indicates that structural factors, including energy efficiency policies, the industrial composition of the economy, and the varying degrees of energy dependence across sectors, may be more influential in shaping electricity consumption than transient price fluctuations. The findings hold significant implications for policymakers, indicating that energy efficiency initiatives or consumption laws may exert a more substantial influence on energy usage than policies reliant purely on pricing mechanisms.

4.1. Granger Causality Results

The first step in Granger causality analysis consists of verifying the stationarity of the time series used. The results of the Augmented Dickey-Fuller (ADF) test for the original series indicate:

Table no. 2: Initial Stationarity Testing

Series	ADF Statistic	p-value	Critical Value (5%)	Stationarity
Price	-1.805	0.378	-2.9044	Non-stationary
Consumption	-1.5044	0.5313	-2.9119	Non-stationary

Source: Authors' processing.

Both series are identified as non-stationary in their raw level, with p-values significantly higher than the 0.05 threshold, which prevents the rejection of the null hypothesis of a unit root.To determine the exact order of integration for each series, we iteratively applied the ADF test for different orders of differentiation:

Price Series:

- I(0): ADF = -1.8050, p = 0.3780 → Non-stationary
- I(1): ADF = -7.3952, p = 0.0000 → Stationary

Consumption Series:

- I(0): ADF = -1.5044, p = 0.5313 → Non-stationary
- I(1): ADF = -2.2758, p = 0.1799 → Non-stationary
- I(2): ADF = -10.4837, p = 0.0000 → Stationary

These results demonstrate that the Price series is integrated of order 1 [I(1)], becoming stationary after a single differentiation, while the Consumption series is integrated of order 2 [I(2)], requiring two successive differentiations to achieve stationarity.

The difference in the integration order between the two series is an important methodological aspect, which could influence the interpretation of causality relationships and suggests potential complexities in the dynamic interaction between these variables.

Table no. 3: ADF Stationarity Test Results

Series	ADF Statistic	p-value	Critical value (5%)	Stationary
Price I(0)	-1.8050	0.3780	-2.9044	No
Price I(1)	-7.3952	< 0.0001	-2.9044	Yes
Consumption I(0)	-1.5044	0.5313	-2.9119	No
Consumption I(1)	-2.2758	0.1799	-2.9119	No
Consumption I(2)	-10.4837	< 0.0001	-2.9119	Yes

Source: Authors' processing.

The Granger test was used to determine whether electricity price can be considered a statistical predictor of consumption and vice versa. The results are presented in the table below:

To investigate whether variations in energy price Granger-cause changes in electricity consumption, we applied the test for lags from 1 to 12, using the differenced series to ensure stationarity. The results are summarized in the following table:

Table no. 4: Testing Causality from Price to Consumption

Lag	χ^2 Statistic	p-value	Significant at α=0.05
1	2.2354	0.1349	No
2	2.9685	0.2267	No
3	1.8530	0.6035	No
4	1.5471	0.8183	No
5	1.5736	0.9044	No
6	2.6635	0.8497	No
7	2.7544	0.9068	No
8	3.6498	0.8873	No
9	6.3717	0.7022	No
10	7.4929	0.6782	No
11	12.7056	0.3130	No
12	17.7772	0.1226	No

Source: Authors' processing.

For the opposite direction, we investigated whether variations in electricity consumption Granger-cause changes in energy price. The results are synthetically presented in the following table:

Table no. 5: Testing Causality from Consumption to Price

Lag	χ^2 Statistic	p-value	Significant at α=0.05
1	0.0448	0.8323	No
2	2.1010	0.3498	No
3	2.8858	0.4096	No
4	3.1786	0.5284	No
5	3.8777	0.5672	No
6	6.0677	0.4156	No
7	18.7628	0.0090	Yes (***)
8	18.6971	0.0166	Yes (**)
9	20.7674	0.0137	Yes (**)
10	23.5515	0.0089	Yes (***)
11	23.2034	0.0165	Yes (**)
12	28.1200	0.0053	Yes (***)

Source: Authors' processing.

In contrast to the previous direction, the results for causality from consumption to price highlight a distinct and significant pattern:

Lack of short-term causality: For minor lags (1-6), there is no statistical evidence of a causal link ($p > 0.05$). Emergence of medium- to long-term causality: Beginning at lag 7, a strong and enduring causal link emerges, with p-values well less the 0.05 threshold and even below 0.01 for lags 7, 10, and 12. Stability of the causal influence: Statistical significance is preserved across all specifications with lags ranging from 7 to 12, demonstrating the robustness of the findings to alterations in the temporal framework.

The empirical results highlight a unidirectional Granger causality relationship from electricity consumption to energy price, with a specific temporal structure.

Table no. 6: Summary of Granger Causality Analysis

Causality Relationship	**Evidence of Causality**	**Optimal Lag**	**Minimum p-value**
Price → Consumption	No evidence	-	0.1226 (lag 12)
Consumption → Price	Strong evidence	12	0.0053 (lag 12)

Source: Authors' processing.

Although the Granger test indicates a lagged relationship between consumption and price, this research primarily examines the absence of a causal relationship from price to consumption.

The Granger causality analysis between energy consumption and prices for the period 2019-2024 reveals the absence of significant temporal predictive relationships between these variables.
Specifically, the hypothesis that price movements do not Granger-cause consumption changes cannot be rejected. These findings suggest that historical values of either variable do not provide significant predictive power for forecasting the other variable's future movements.

The findings, which reveal no significant causality from energy prices to electricity consumption, can be understood through various economic factors.
Firstly, electricity consumption demonstrates a notable inelasticity to price changes in both the short and medium term. This is largely due to its role in fulfilling consumers' basic needs and its alignment with broader economic cycles, making it less sensitive to price variations.

Additionally, in many energy markets, complex tariff structures and long-term contracts serve to shield end consumers from immediate fluctuations in spot prices. This creates a buffer that diminishes the direct influence of energy prices on consumption patterns.

Lastly, electricity consumption is predominantly shaped by external factors that exert a stronger influence than price signals. These factors include seasonal variations, such as temperature and lighting needs, overall economic activity, and long-term structural trends like advancements in energy efficiency and increased electrification.

4.2. SARIMA Results

The SARIMA model estimation yields particularly noteworthy results regarding the price-consumption relationship. The estimated price elasticity of consumption is positive but notably small in magnitude (0.056), statistically significant at the 1% level. This suggests that a 1% increase in energy prices is associated with a 0.056% increase in consumption, contrary to traditional economic theory. This counter-intuitive relationship might reflect the essential nature of energy in modern economies, where consumption patterns are largely inelastic to price changes, or could indicate the presence of underlying economic factors simultaneously influencing both variables.

The AR(1) (autoregressive term of order 1) coefficient is 0.904913, indicating a strong autocorrelation between past and current values of energy consumption. This coefficient is statistically significant, with a t-statistic of 10.09002 and a p-value of 0.0000, suggesting that past values have a strong influence on current consumption.

The SAR(12) (seasonal autoregressive term at lag 12) coefficient is 0.987211, indicating a strong seasonal effect with a high statistical significance (t-statistic of 40.50887 and p-value of 0.0000). This suggests that there is a significant annual cycle in energy consumption, likely due to seasonal factors, such as weather conditions.

The MA(1) (moving average term of order 1) coefficient is 0.033657, but the t-statistic of 0.156938 and p-value of 0.8758 indicate that this term is not statistically significant, suggesting that past residuals do not significantly influence current energy consumption. On the other hand, the SMA(12) (seasonal moving average term at lag 12) coefficient is -0.69908, indicating a negative seasonal effect at lag 12, which is statistically significant (t-statistic of -2.69826 and p-value of 0.0089).

Regarding SIGMASQ (variance of the residuals), the coefficient of 0.000911 and the p-value of 0.0001 suggest a significant variance of the residuals, indicating that the model is well-fitted and the residuals are small and uncorrelated.

Table no. 7: SARIMA Results

Panel A: Estimated coefficients

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	8.228761	0.206242	39.89865	0
LOG_PRICE	0.055866	0.017736	3.149848	0.0025
AR(1)	0.904913	0.089684	10.09002	0
SAR(12)	0.987211	0.02437	40.50887	0
MA(1)	0.033657	0.214462	0.156938	0.8758
SMA(12)	-0.69908	0.259085	-2.69826	0.0089
SIGMASQ	0.000911	0.000217	4.203437	0.0001

Panel B: Diagnostic statistics

Indicator	**Value**	**Indicator**	**Value3**
R-squared	0.858	Mean of dependent var.	8.474
Adjusted R-squared	0.845	Std. dev. of dependent var.	0.081
Standard error of regression	0.032	Akaike criterion	-3.61
Sum of squared residuals	0.066	Schwarz criterion	-3.388
Log likelihood	136.95	Hannan-Quinn criterion	-3.522
F-statistic	65.332	Durbin-Watson statistic	1.984
Prob(F-statistic)	0	-	-

Source: Authors' processing.

The diagnostic statistics from the SARIMA model estimation provide favorable results. The R-squared value of 0.858 and the Adjusted R-squared value of 0.845 suggest that approximately 85% of the variation in energy consumption is explained by the model, reflecting a good model fit. The S.E. of regression value of 0.032 indicates a low standard error, suggesting good model performance.

Other diagnostic indicators, such as the Akaike Information Criterion (AIC) of -3.610 and the Schwarz Criterion (BIC) of -3.388, suggest that the model is robust in terms of parameter selection, with lower values indicating a better fit. The F-statistic of 65.332 and the p-value associated with it (0.000) confirm the overall statistical significance of the model, while the Durbin-Watson statistic of 1.984 indicates that there is no significant autocorrelation in the residuals, suggesting proper model specification.

Additionally, the model highlights a strong autocorrelation in energy consumption, suggesting that past consumption levels have a substantial influence on current consumption. This emphasizes the importance of considering previous consumption patterns when making energy consumption forecasts.

The seasonal component of the model is also significant, with the SAR(12) term showing a high degree of seasonality in energy consumption, likely driven by annual cycles such as changes in temperature or other seasonal factors. The model is globally significant, with a high R-squared and statistical significance of all key parameters, indicating that it provides a good fit for explaining the variation in energy consumption.

The SARIMA model thus serves as a valuable tool for making short- and medium-term energy consumption predictions, accounting for both seasonal patterns and price changes. The diagnostic statistics further support the model's robustness, confirming its adequacy in explaining energy consumption dynamics.

5. Conclusions

This study utilized SARIMA modeling and Granger causality tests to evaluate the relationship between electricity prices and consumption. The findings indicate that electricity prices do not significantly influence consumption, suggesting that pricing mechanisms alone may not be effective in managing electricity demand. Policymakers should consider additional regulatory measures, such as demand-side management strategies, to ensure efficient energy use. The methodological framework employed in this research provides a reproducible approach for future studies examining similar economic and energy-related interactions.

The Granger causality analysis between energy price and national electricity consumption highlights a significant unidirectional relationship, in which variations in consumption Granger-cause subsequent changes in energy prices, with a considerable temporal lag of approximately 7 months.

This asymmetric causal relationship, corroborated with the differences in the integration order of the series (I(1) for price and I(2) for consumption), suggests a complex dynamic of the energy market, in which long-term signals from demand gradually propagate to prices, but price fluctuations have a limited impact on consumption behavior.

These results indicate that energy consumption in the analyzed market is largely influenced by structural and seasonal factors, rather than price fluctuations, underscoring the intricate dynamics of the energy market and the possible constraints of relying solely on price-based policies for managing consumption.

This analysis underscores the complexity inherent in energy market dynamics, particularly the relatively low sensitivity of consumption to price changes, which carries significant implications for energy policy and market regulation.

Moreover, the findings offer an empirical foundation for energy market modeling and forecasting, emphasizing the crucial role of incorporating historical consumption patterns when predicting future price trends, all while acknowledging the temporal structure of the causal relationships identified.

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