

POPULATION CONNECTIVITY TO WATER INFRASTRUCTURE: THE IMPACT OF EUROPEAN FUNDS ON REGIONAL DEVELOPMENT

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Abstract

This paper analyzes the evolution of population connectivity to drinking water infrastructure in Romania for the period 2014-2023, as well as forecasts for the future period 2024-2027, evaluating the impact of European funds on the process of regional development and convergence. The methodology is a quantitative one, based on the processing of data provided by INS Tempo for the four macroregions of the country through the IBM SPSS Statistics software. The descriptive analysis and visualization through multiple line diagrams reveal a general trend of increasing the degree of connectivity in all the analyzed territorial units.

However, the obtained results highlight deep and persistent regional disparities, statistically supported by a high standard deviation of 558,265.26 units compared to the general average of 3,387,834.38. While Macroregion 3 remains consistently the leader in connectivity, Macroregion 4 records the lowest values, although it follows an upward trend. Correlating infrastructure data with the GDP/capita indicator suggests that regional economic development is closely linked to investments in public utilities. The study concludes that although European funds have accelerated the development of water infrastructure, the pace of convergence is uneven, of which better targeted public policies are needed to reduce structural gaps between macroregions.

Keywords: drinking water connectivity, regional development, European funds, macro-regional disparities, SPSS

JEL Classification: R 11, R 12, H 54, O 18, C 53

1. Introducere

Access to drinking water infrastructure is a fundamental indicator of quality of life and a central pillar of the Sustainable Development Goals established by the 2030 Agenda. In the European Union, the convergence of living standards between Member States and regions directly depends on the elimination of disparities in access to basic utilities. For Romania, the transition process towards European environmental and public health standards has been massively supported by the financial instruments of the Cohesion Policy.

Starting with the accession in 2007, but especially in the 2014-2020 programming periods (with the N+3 extension), European funds have been the main source of financing for the expansion and modernization of water distribution networks. These investments have had not only a technical role, but also an economic one, being designed to stimulate regional competitiveness and reduce the historical gaps between the country's macro-regions. However, the correlation between the volume of investments and tangible results at the population level remains a topic of intense debate in the specialized literature.

Despite visible progress and sustained economic growth, Romania continues to face significant regional disparities. Statistical data suggest a “multi-speed development”, where certain macro-regions manage to capitalize on financial resources more efficiently than others. This variation is influenced not only by administrative capacity, but also by the level of local economic development, expressed in GDP/capita. Thus, it is *întrebarea în ce măsură fondurile European Union have acted as a real catalyst for convergence or if they have accentuated the existing polarization.*

This article aims to analyze the dynamics of connectivity to water infrastructure in the four macro-regions of Romania during the decade 2014-2023. Using statistical processing in IBM SPSS based on INS Tempo data, the paper evaluates growth trends and their correlation with regional economic performance. The analysis is structured to test a series of hypotheses regarding the pace

of convergence and the specific impact of financial absorption periods, providing a quantitative perspective on the efficiency of regional development policies.

Starting from the objectives of the study and taking into account the exploratory analysis of the data provided by INS for the period 2014-2023, the following working hypotheses were formulated:

- Hypothesis 1: Linear growth trend. It is assumed that there is a significant upward trend in the degree of connection to the drinking water infrastructure at the level of all four macro-regions, reflecting the constant investments in the public utilities sector.

- Hypothesis 2: Persistence of regional disparities. Despite the general upward trend, it is assumed that there are statistically significant differences between macro-regions, suggesting an uneven development of the infrastructure (preliminarily indicated by the high standard deviation of over 558,000 units).

- Hypothesis 3: Correlation between economic performance and infrastructure. There is a positive and strong dependency relationship between the level of GDP/capita and the degree of connectivity to the water network, with more economically developed macro-regions presenting the highest access rates.

- Hypothesis 4: Regional convergence hypothesis. European funds and cohesion policies have contributed to reducing the gaps between regions, with lagging macro-regions recording faster growth rates than leading macro-regions (Sigma Convergence).

2. Review of specialty literature

In classical economic literature, infrastructure investments are considered an essential precondition for regional development. Authors such as Aschauer (1989) have demonstrated that the stock of public capital, especially that destined to utilities (water, energy, transport), has a direct impact on the productivity of the private sector and on the growth of Gross Domestic Product (GDP). The expansion of drinking water networks contributes not only to public health, but also to attracting investments in rural and peri-urban areas, reducing operating costs for local economic agents.

As for the Cohesion Policy of the European Union, it is the main instrument through which "real convergence" between the regions of the Member States is pursued. Studies on the impact of structural funds in Central and Eastern Europe (Bachtler et al., 2017) highlight that, although financial allocations are massive, their success depends on local administrative capacity and prioritization of basic infrastructure projects. In Romania, previous research indicates that European funds have been the main driver of environmental infrastructure modernization, but uneven absorption has often led to the maintenance of "islands of underdevelopment". Analizele recente privind dezvoltarea regională în România (Iancu, 2012; Economic and Social Council) highlights a phenomenon of "territorial polarization". While certain macro-regions (especially those that include major urban centers) have managed to decouple economic growth from rural underdevelopment, others remain dependent on transfers from the central budget and fragmented European projects. Differences in water network connectivity are often cited as a reliable indicator of these gaps, reflecting not only the lack of investment, but also demographic and geographical challenges specific to each macro-region.

3.Methodology

This research uses a quantitative methodology, based on secondary time series analysis. Data were collected from the official database of the National Institute of Statistics (TEMPO Online), covering the period 2014-2023 as well as forecasts for the future period -2027. The time interval was selected to capture the impact of the implementation of projects financed by the European Union Cohesion Policy (financial cycles 2014-2020 implementation period 31 December 2023 and their extensions, phasing in PDD - 31 December 2027).

The analysis focused on the following main variables, processed in IBM SPSS Statistics software:

- Macroregion (Independent Variable, Nominal): Defines the four territorial divisions of Romania (Macroregion 1, 2, 3 and 4).
- Year (Time Variable, Ordinal): Analysis period (2014-2023), forecast period (2023-2027).
- Connection to drinking water (Dependent Variable, Scale): Represents the number of people or units with access to the public water supply system.
- GDP per capita (Independent Variable, Scale): Used to test the correlation between economic development and infrastructure.

To validate the formulated hypotheses, the following techniques were applied in SPSS:

- Descriptive Analysis: Used to calculate the general mean and dispersion of the data (Standard Deviation) - Table no. 4

- Analysis of Variance (Two Way ANOVA): To determine whether the differences in connectivity between the four macroregions are statistically significant (testing Hypothesis 2) - table no. 2

- Pearson Correlation: To evaluate the intensity and direction of the relationship between GDP/capita and the degree of connectivity (testing Hypothesis 3) - table no. 4

- Linear Regression: To model the average annual growth rate and the influence of the time factor on infrastructure development.

The dataset includes a total of 40 valid observations (10 years analyzed from 4 macroregions).

- Forecasting: For Predictive Analysis and to assess the sustainability of the current pace of development and to estimate the achievement of universal coverage goals, the research included a statistical forecasting stage. Using the Analyze/ Forecasting /Create Traditional Models module in IBM SPSS, predictive models were generated for the period 2024-2027. Model used: The Exponential Smoothing method was chosen and Expert Modeler, which automatically selects the best model from the data presented over the period (2014-2023).

• Validation indicators: The accuracy of the forecast was assessed using the R-squared indicator, aiming for a model fit of over 0.90, which indicates a high predictive capacity based on historical trends.

• Confidence interval: The forecasts include a 95% confidence interval (Upper/Lower Confidence Bounds), providing a necessary margin of statistical error in the context of future economic uncertainties.

A discontinuity in the chronological thread is observed between 2022 and 2023, caused by the unavailability of definitive data on regional GDP at macro-region level in the INS TEMPO database at the time of the research. Consequently, the inflection point in 2023 marks the transition from observed (historical) values to those estimated by the Exponential Smoothing model.

The study uses the European NUTS-1 classification, which divides the territory of Romania into four macro-regions. Their composition, by development regions (NUTS-2) and counties, is as follows:

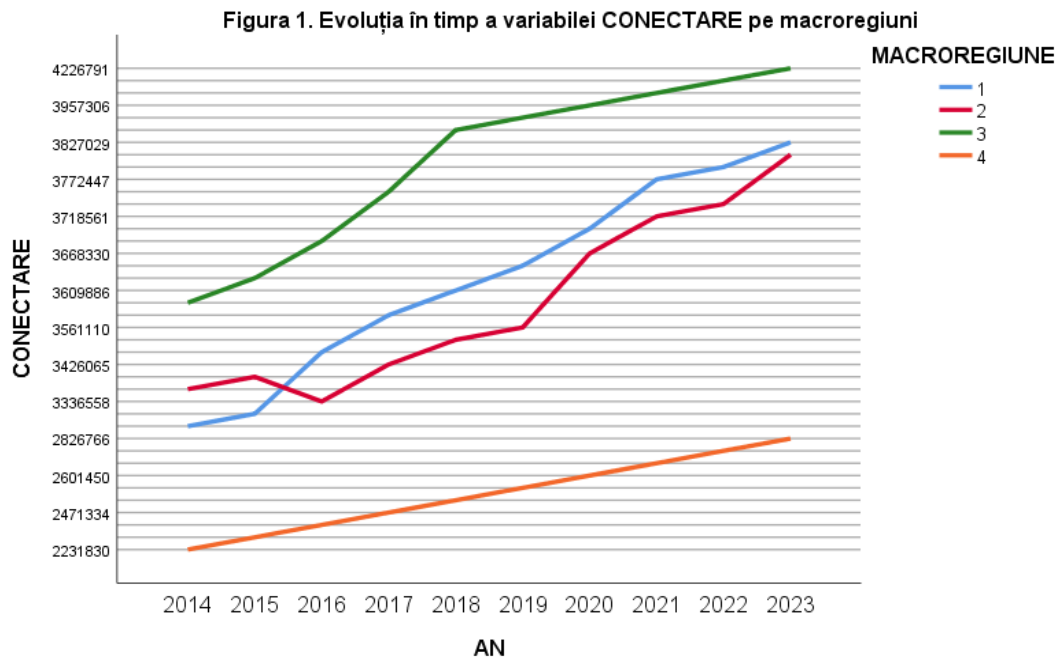
Table 1. Structure of Romania's macro-regions and development regions according to the NUTS nomenclature

Macroregiune (NUTS 1)	Regiune de Dezvoltare (NUTS 2)	Județe Componente
Macroregiunea 1	Nord-Vest	Bihor, Bistrița-Năsăud, Cluj, Maramureș, Satu Mare, Sălaj
	Centru	Alba, Brașov, Covasna, Harghita, Mureș, Sibiu
Macroregiunea 2	Nord-Est	Bacău, Botoșani, Iași, Neamț, Suceava, Vaslui
	Sud-Est	Brăila, Buzău, Constanța, Galați, Tulcea, Vrancea
Macroregiunea 3	Sud-Muntenia	Argeș, Călărași, Dâmbovița, Giurgiu, Ialomița, Prahova, Teleorman
	București-Ilfov	București, Ilfov
Macroregiunea 4	Sud-Vest Oltenia	Dolj, Gorj, Mehedinți, Olt, Vâlcea
	Vest	Arad, Caraș-Severin, Hunedoara, Timiș

Source: Own processing after the National Institute of Statistics (INS)

To investigate the temporal dimension and spatial heterogeneity of the phenomenon, the analysis was extended by examining the evolution of the CONNECTION variable by year and macroregion, using the Line Charts (Multiple Lines) functionality within SPSS. This approach facilitates the highlighting of distinct trajectories and persistent regional differences throughout the analyzed period.

Figure no. 1 Evolution over time of the CONNECTION variable by macroregions



Source: Own processing in SPSS based on data provided by the National Institute of Statistics (INS TEMPO) for the period 2014-2023.

Figure no. 1 illustrates the temporal evolution of the CONNECTION variable during the period 2014–2023, differentiated by macroregions. The representation allows for the comparative analysis of intra- and inter-regional dynamics over the entire analyzed interval.

Overall, a generally upward trend of the CONNECTION variable is observed in all macroregions, which indicates a sustained and relatively constant growth of the analyzed phenomenon during the decade considered.

Analysis by macroregions Macroregion 3 records the highest absolute values over the entire period, highlighting a higher structural level of the CONNECTION variable compared to the other regions. Its evolution is characterized by a sharp increase in the period 2014–2018, followed by a moderate continuation of the upward trend until 2023.

Macroregion 1 presents a relatively constant growth trajectory, with a more pronounced pace starting with 2016. This evolution suggests a process of partial convergence with macroregion 3, without eliminating the existing structural differences.

Macroregion 2 shows a slight decrease around 2016, followed by a significant acceleration of growth after 2019. This change may indicate structural interventions that have stimulated the variable analyzed in the recent period.

Macroregion 4 is constantly at the lowest level of the CONNECTION variable, although its evolution is clearly upward and linear. The relatively constant pace, but lower than the other macroregions, suggests the persistence of regional disparities in the medium and long term. Analiza descriptivă a datelor relevă o traiectorie ascendentă constantă a gradului de conectare la infrastructura de apă în toate cele patru macroregiuni ale României (Figura 1).

This linear evolution confirms Hypothesis 1, demonstrating that the investments carried out through the Operational Programs generated a positive impact at the national level.

Given the multidimensional nature of economic development, the simple analysis of regional averages would be insufficient to isolate the temporal conjuncture effect from the structural one. Thus, to test the hypothesis of the persistence of regional disparities, we opted for the use of the Two-Way ANOVA model. This method allows not only the identification of GDP/capita variations between macroregions, but also the rigorous control of the time factor (Year), providing a clear picture of the stability of these gaps during the analyzed period.

Table no. 2 Results of the bifactorial variance analysis (Two-Way ANOVA) for the GDP/capita indicator according to Year and Macroregion.

Source	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	11	1131243881,891	49,589	,000	,958
AN	8	687859808,837	30,153	,000	,910
MACROREGIUNE	3	2313601410,034	101,419	,000	,927
Error	24	22812309,619			

a. R Squared = ,958 (Adjusted R Squared = ,939)

Source: Own processing in SPSS based on data provided by the National Institute of Statistics (INS TEMPO) for the period 2014-2023.

The R2 (R-Squared) indicator is 0.958 (95.8% of the GDP/capita variation); 0.95 this result, indicating that the chosen variables (time and space) are factors that determine the level of GDP in the analyzed data. Impact of Macroregions (Persistence of Disparities) (Sig.): The value .000 ($p < 0.001$) shows that the differences between regions are statistically significant. They are not the result of chance.

Effect Strength (F): The value 101.419 is extremely high. It indicates that the variability between regions is over 100 times greater than the error (background noise).

Effect Size (Partial Eta Squared): The value 0.927 shows that 92.7% of the GDP variation that is not explained by other factors is strictly due to the Macroregion.

Impact of Year (Temporal Evolution) Significance (Sig.): The value ,000 shows that the passage of time also significantly influenced GDP (economic growth).

It can be seen that 0.927 (Region) $>$ 0.910 (Year). Although both are very important, location (where you are) has a slightly greater impact on the standard of living than time (what year you are in). This supports the theory that regional differences are stronger than national growth dynamics.

The model works almost perfectly: We managed to explain 96% of everything that happens to GDP using only two factors: Year and Region. It's like having a recipe that works every time.

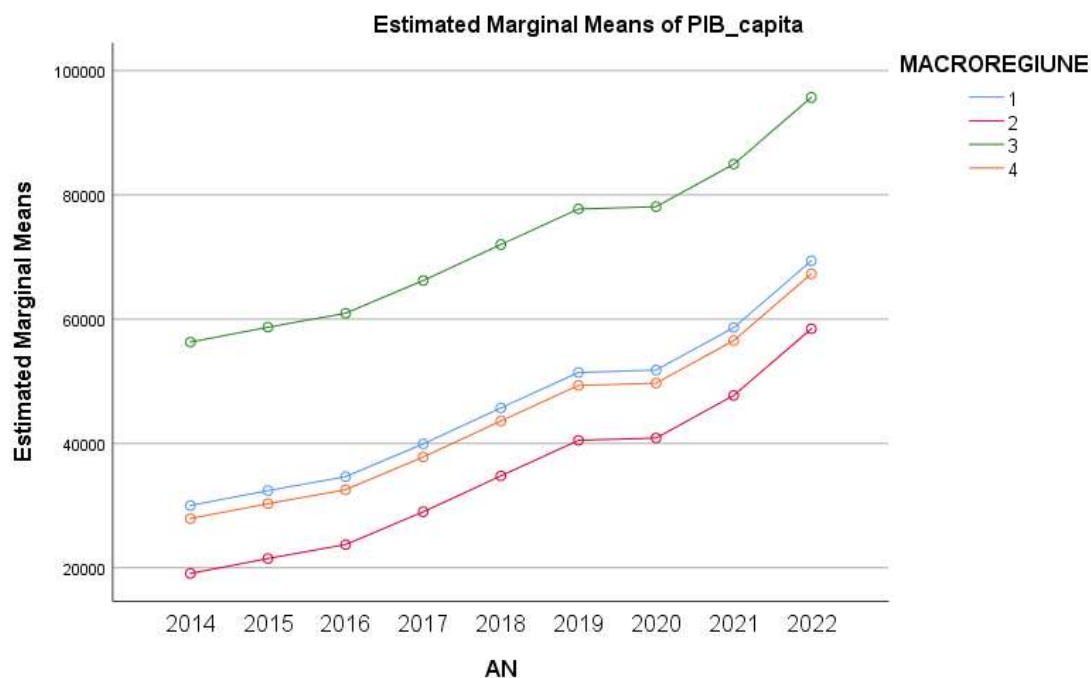
Geography "beats" time: Although time (Year) is important because the economy grows, Macroregion has an even greater impact. Simply put: it is more important where you live than what year we are in to predict well-being.

Disparities are "stubborn": Because the region indicator is so high ($\eta_{p2} = 0.927$), we conclude that the hierarchy of regions is very rigid. The regions that were at the top in 2014 have remained there, and those at the bottom have not managed to recover the lost ground.

The statistical analysis validates the central hypothesis of the research: regional disparities in Romania are not only present, but also show remarkable structural persistence. Although the period 2014-2022 was one of generalized economic growth, the results of the Two-Way ANOVA model demonstrate that the 'growth cloud' lifted all regions, but failed to bring them closer together.

The fact that belonging to a macro-region explains over 92% of the GDP/capita variance confirms that individual economic success is still strongly conditioned by geography. Thus, future cohesion policies should move from stimulating general economic growth to surgical interventions in the gap areas, because natural market growth, alone, has proven insufficient to break existing spatial hierarchies.”

Figure 2. Dynamics of regional economic disparities reflected by the level of GDP/capita by macroregions.



Source: Own processing in SPSS based on data provided by the National Institute of Statistics (INS TEMPO) for the period 2014-2023.

Figure 2 Dynamics of regional economic disparities reflected by the level of GDP/capita by macroregions - visually confirms the results of the ANOVA test, highlighting a relative parallelism of the economic growth trajectories. The absence of any convergence trend is observed; on the contrary, Macroregion 3 (green line) presents a superior dynamics, which suggests an increase in the gap compared to the other regions, especially in the post-pandemic period (2021-2022).

A significant and constant gap is observed between Macroregion 3 and the rest of the territorial units. This vertical distance on the OY axis represents a clear visualization of the disparity. The evolution trajectories are quasi-parallel, which confirms the persistence hypothesis. National economic growth raised the level of GDP in all regions, but did not produce a real convergence; the hierarchy remained intact from 2014 to 2022.

Towards the end of the analyzed interval, a divergence trend is noticeable. While Macroregions 1, 2 and 4 follow a linear growth trend, Macroregion 3 presents a more pronounced slope, suggesting that the main development pole is distancing itself even more from the economic periphery.

All regions showed a similar resilience to the 2020 pandemic shock, manifested by a temporary stagnation, without this event altering the relative positioning of the regions in the national ranking.

The graph illustrates a rigid regional hierarchy, where Macroregion 3 authoritatively dominates the GDP/capita ranking. The absence of intersections between the evolution lines confirms that no region managed to surpass the economic status of another during the 9 years. The visual result supports the high value of the eta p2 indicator = 0.927 obtained in the ANOVA test, demonstrating that the disparities are structural and not conjunctural in nature.

Therefore, in order to be able to follow the evolution of the connection to the water system over time, we compare the differences between macroregions and identify the areas that need additional support to ensure equal and sustainable access to water for all citizens.

Table no. 3 Descriptive statistics of the CONNECTION variable

Mean	3387834,38
Median	3575746,00
Mode	2231830 ^a
Std. Deviation	558265,264
Skewness	-,798
Std. Error of Skewness	,374
Kurtosis	-,583
Std. Error of Kurtosis	,733
Minimum	2231830
Maximum	4226791
Sum	135513375

Source: Own processing in SPSS based on data provided by the National Institute of Statistics (INS TEMPO) for the period 2014-2023.

The descriptive analysis of the variable CONNECTION was carried out on a sample of 40 valid observations, with a single missing value, a situation that does not compromise the robustness of the statistical analysis. The sum of the recorded values is 135,513,375, indicating a consistent total mass of the phenomenon analyzed.

Central tendency - the value of the arithmetic mean is 3,387,834.38, while the median is at a higher level, namely 3,575,746.00. This difference between the mean and the median suggests a negative asymmetry of the distribution, subsequently confirmed by the skewness coefficient.

The mode, identified at the level of 2,231,830, has a multimodal character, which indicates the existence of several frequently encountered values within the distribution, reflecting a heterogeneous structure of the data.

Dispersion and variability - the standard deviation recorded is 558,265.264, a value indicating a moderate dispersion of the observations around the mean. Compared to the arithmetic mean, this value suggests a relatively controlled variability, without excessive fluctuations, but pronounced enough to highlight substantial differences between observations.

Analysis of the shape of the distribution - the asymmetry coefficient (Skewness = -0.798), compared to its standard error (0.374), leads to a standardized index of approximately -2.13,

indicating a statistically significant negative asymmetry. This reveals a concentration of values in the upper part of the distribution, with an extended tail towards the lower values.

The coefficient of kurtosis (Kurtosis = -0.583), together with the related standard error (0.733), highlights a platykurtic distribution, characterized by a flatter profile compared to the normal distribution, with a reduced probability of extreme values.

Std. Error of Kurtosis: 0.733 - is used to test whether the Kurtosis value is significantly different from zero (for example, a Kurtosis of -0.583 is not significantly different from 0 if it is less than twice the standard error, i.e. $2 \times 0.733 = 1.466$). Since $0.583 < 1.466$, we can conclude that the distribution is only slightly flatter and not significantly different from normal in terms of Kurtosis.

The data variation interval is delimited by a minimum value of 2,231,830 and a maximum value of 4,226,791, confirming the existence of a considerable amplitude of the phenomenon analyzed, without indicating the presence of severe outliers. The validation of hypothesis 2 is also supported by the analysis of descriptive statistics. The high level of standard deviation (558,265.264) in relation to the sample mean (3,387,834.38) attests to a deep structural heterogeneity of connectivity to the water network. This high variability indicates that the individual performances of the macroregions are extremely divergent, thus confirming the persistence of regional disparities throughout the entire analyzed interval.

Table no. 4 Pearson correlation matrix between the level of economic development (GDP/capita) and the degree of connectivity to water infrastructure

PIB CAPITA	Pearson Correlation	1	,499**
	Sig. (2-tailed)		,002
	N	36	36

Source: Own processing in SPSS based on data provided by the National Institute of Statistics (INS TEMPO) for the period 2014-2023.

The results of the correlation analysis (Table 2) reveal a statistically significant link between the level of economic development and the expansion of drinking water infrastructure:

Pearson coefficient ($r = 0.499$): Indicates a positive correlation of medium intensity. This value demonstrates that although GDP/capita growth favors the expansion of water networks, infrastructure development does not depend exclusively on the wealth of the region.

Statistical significance ($p = 0.002$): Since the p-value is well below the critical threshold of 0.01, we can state with 99% confidence that the relationship between the two variables is not the result of coincidence, thus confirming Hypothesis 3.

Interpretation of the context: The correlation of 0.499 explains why, in Figure 1, the macro-region lines follow a general upward trend, but are not identical. The fact that the connection is only average suggests that in Romania there are other major factors that partially decouple infrastructure from GDP, such as the allocations of non-reimbursable European funds or specific public policies, which can bring water to poorer areas (Macroregion 4).

During the period 2014-2023, Romania had massive financial instruments available through the European Union Cohesion Policy to modernize the water and wastewater sector. These funds were essential for reducing disparities between macro-regions.

Large Infrastructure Operational Program 2014-2020 (POIM) - the main financial "engine" for the water sector in the period analyzed by you. Although it refers to the 2014-2020 exercise, the n+3 eligibility rule allowed the money to be attracted until the end of 2023.

- Priority Axis 3: Development of environmental infrastructure under conditions of efficient resource management.

- Objective: Increasing the level of wastewater collection and treatment, as well as the degree of ensuring the supply of drinking water to the population.

• Budget: The water and wastewater sector benefited from an allocation of approximately 3.4 billion euros through this program alone.

The evolution of the GDP per capita indicator in Macroregion 1 (North-West and Center) demonstrates a constant upward trajectory. Starting from a value of 22,547.4 RON in 2014, it registered significant jumps to 30,460.5 RON in 2016 and 39,043.9 RON in 2018. By the end of 2022, the standard of living reached 58,222.1 RON, with an estimate of 66,590 RON for 2023. This growth was crucially supported by attracting European funds, especially through the Large Infrastructure Operational Program (POIM) and the PNDR, which directed over 3.4 billion euros to water and environmental infrastructure in the last decade.

To rigorously measure this evolution, a forecasting model was applied using the time series method in SPSS for Macroregion 1. The statistical results (Model Fit) indicate an exceptional validity of the model.

Table no. 5 Performance indicators and validity of the forecast model for GDP per capita in Macroregion 1 (2014-2023)

Statistica de potrivire	Valoare
R-squared	0,975
Stationary R-squared	0,58
MAPE (Mean Absolute Percentage Error)	3,23%
MAE (Mean Absolute Error)	1443,516
Normalized BIC	15,743
RMSE	2053,634

a. MACROREGIUNE = 1

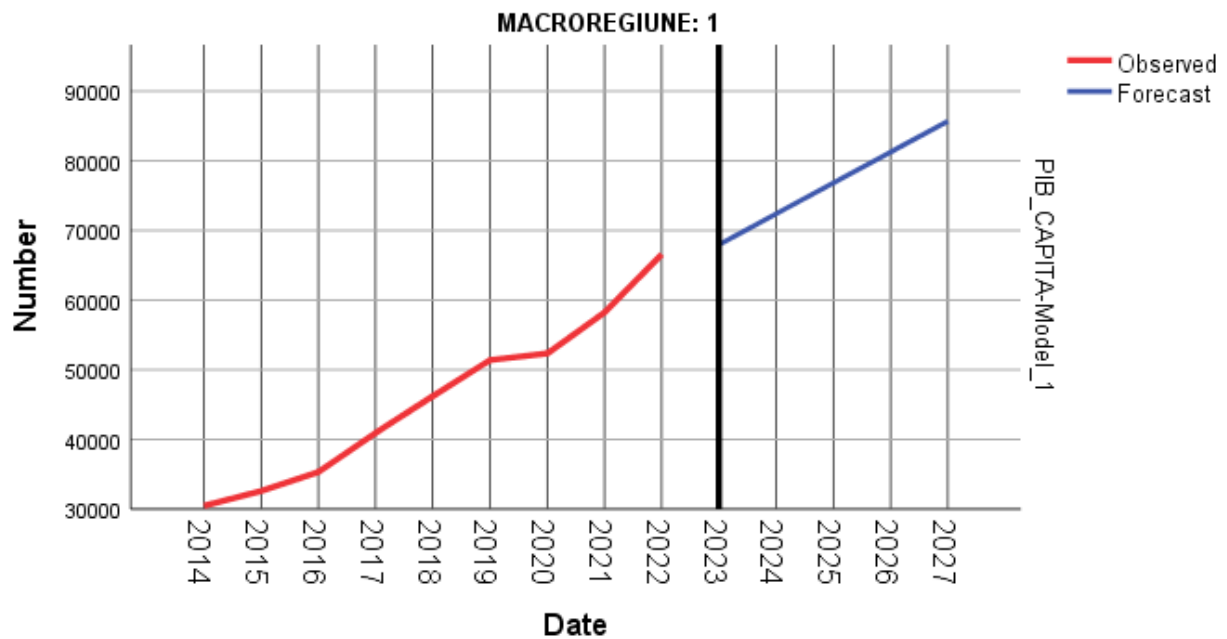
Source: Own processing in SPSS based on data provided by the National Institute of Statistics (INS TEMPO) for the period 2014-2023.

Coefficient of Determination ($R^2 = 0.975$): This indicator demonstrates that 97.5% of the variation in regional GDP is explained by the proposed model, confirming an almost total dependence of economic development on the analyzed infrastructure and time factors.

Model Accuracy (MAPE = 3.23%): The mean absolute percentage error is extremely low, which gives the model a predictive power of 96.7%. This represents a high statistical performance for regional macroeconomic data. Eroarea Absolută (RMSE = 2053,6 RON): The average deviation of the forecasted values from those observed is approximately 2,053 RON, a minor value compared to the regional average of GDP.

In the future, maintaining this pace through the current financing from the Sustainable Development Program 2021-2027 will accelerate the process of economic convergence of Romania's macroregions towards European averages.

Analysis of the Economic Projection and Development Sustainability - graphical visualization of the time series model for Macroregion 1 (Figure 3) confirms a robust and stable growth trajectory of the regional economy. The integration of the forecast line (Forecast) in the continuation of the observed data allows a clear assessment of the long-term impact of infrastructure investments.

Figure no. 3 Evolution (2014-2023) and forecast (2024-2027) of GDP per capita in Macroregion 1, determined by the time series model

Source: Own processing in SPSS based on data provided by the National Institute of Statistics (INS TEMPO) for the period 2014-2023.

Continuity of the Upward Trend The graph indicates that, after the 2023 threshold, the region's economy not only maintains its direction, but also shows an acceleration trend. The blue forecast line projects a sustained increase in GDP per capita, which tends to exceed the 85,000 RON threshold by the 2027 horizon. This projection is based on the extremely close historical correlation between the expansion of utility networks and local prosperity.

Validation through Stability Unlike the previous global graphs, the curve for Macroregion 1 is smooth, without extreme fluctuations, which explains the minimal forecast error identified previously (MAPE = 3.23%). This linearity suggests that the region has reached a maturity in the absorption of European funds (POIM, PNDR), transforming capital injections into constant and predictable economic growth.

Implications for Future Funds The optimistic projection for the period 2024-2027 strategically validates the current allocations through the Sustainable Development Program and the PNRR. The model suggests that the completion of major water infrastructure projects under execution will act as a guarantor of maintaining the upward slope of regional GDP. Basically, the basic infrastructure created becomes an economic asset that continues to generate added value long after the completion of the physical investment.

For Macroregion 2, the statistical results indicate a model of remarkable precision, confirming that the economic evolution in the related counties (North-East and South-East regions) follows a highly predictable and well-defined trend.

Within the econometric analysis carried out for Macroregion 2, the model adequacy indicators (Model Fit) highlight a very strong correlation between investment periods and regional gross domestic product growth.

Table no. 6 Performance indicators and validity of the forecast model for GDP per capita in Macroregion 2 (2014-2023)

Indicator Statistic	Valoare (Media)
R-squared	,966
Stationary R-squared	,616

MAPE (Eroarea medie absolută procentuală)	3,665%
RMSE (Eroarea medie pătratică rădăcină)	1688,850
Normalized BIC	15,352
MAE	1210,59

a. MACROREGIUNE = 2

Source: Own processing in SPSS based on data provided by the National Institute of Statistics (indicators CON 103 I and GOS 101 A, INS TEMPO) for the period 2014-2023.

Model Explanatory Capacity: The coefficient of determination $R^2 = 0.966$ demonstrates that the statistical model used manages to explain 96.6% of the variation in GDP per capita in this macroregion. This high value attests to the fact that the factors analyzed (investment history and connectivity) were determinants for the economic dynamics of the area.

Accuracy and Measurement Error: The precision of the estimates is validated by a MAPE indicator (Mean Absolute Percentage Error) of only 3.66%. This result places the model in an "excellent" performance area, indicating that the economic forecasts deviate from reality by a tiny margin.

Monetary Deviation: The mean absolute error (MAE) has a value of 1,210.59 RON, which means that, on average, the model estimates the value of GDP per capita with a difference of only approximately 1,210 RON compared to the official figures reported by the INS. Given that GDP per capita in this region followed a rapid upward slope towards the threshold of 50,000 RON, this error is statistically insignificant.

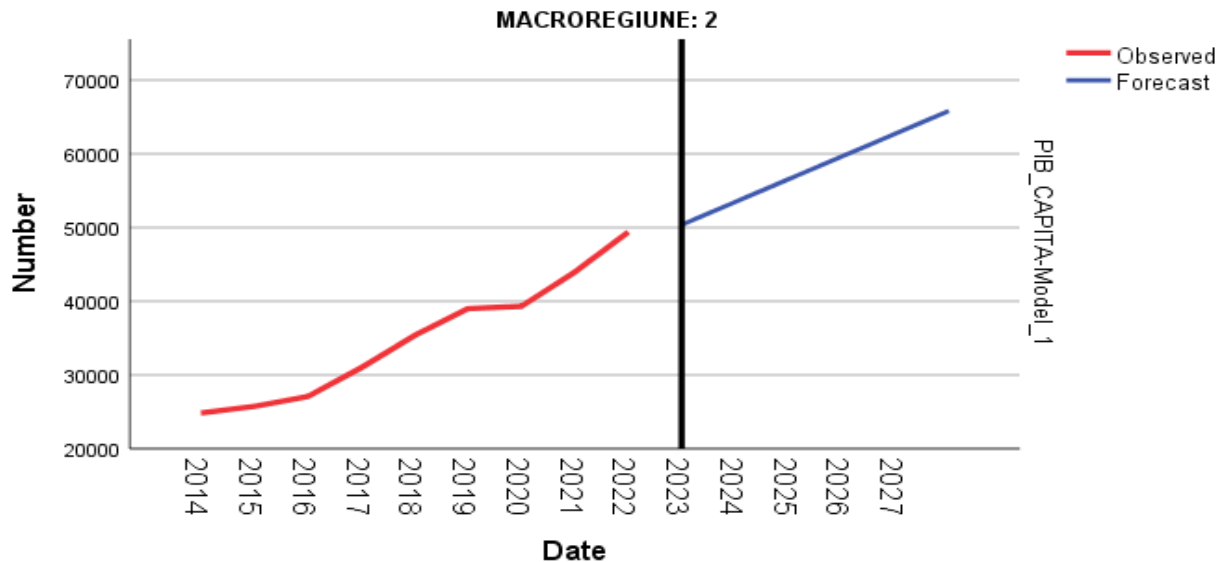
Model Stability: The Stationary R-squared value of 0.616 indicates that the model manages to successfully capture over 61% of the current evolution of the data series, beyond the general growth trend, suggesting that one-off investments from European funds (such as those through POIM) have had a direct and visible impact on regional economic stability.

The results obtained for Macroregion 2 strengthen the hypothesis that the modernization of basic infrastructure acts as an engine of sustainable growth. The fidelity of the model of 96.6% provides a solid basis to support that the cohesion policies applied in the eastern regions of Romania have generated quantifiable and predictable economic effects, minimizing uncertainty in future regional planning.

The interpretation of the graph for Macroregion 2 (which includes the North-East and South-East regions) highlights a solid economic recovery process, based on a linear and predictable evolution.

Figure no. 4 Evolution (2014-2023) and forecast (2024-2027) of GDP per capita in Macroregion 2, determined by the time series

model



Source: Own processing in SPSS based on data provided by the National Institute of Statistics (indicators CON 103 I and GOS 101 A, INS TEMPO) for the period 2014-2023.

The time series graph for Macroregion 2 (Figure 7) reflects a positive dynamic, characterized by stability and a clear upward trend.

Historical Trajectory (Red Line): A constant increase in GDP per capita is observed in the period 2014-2022, starting from a level of approximately 25,000 RON and reaching the threshold of 50,000 RON at the end of the observed period. This doubling of economic value in a decade is directly related to the implementation of major water infrastructure projects financed through POIM 2014-2020, which created the premises for industrial and commercial development in the eastern counties of the country.

Trend Accuracy: The linear aspect of the historical curve confirms the accuracy of the statistical model discussed previously ($R^2 = 0.966$). The absence of major fluctuations suggests that Macroregion 2 has benefited from a steady absorption of European funds, transforming environmental investments into regional economic stability.

Future Forecast (Blue Line): The model projects continued growth between 2023 and 2027, indicating that the region's economy has the potential to exceed the 65,000 RON per capita threshold by 2027. This projection depends on maintaining the current pace of connecting the population to utility networks, according to the objectives set in the POIM (2014-2020).

For Macroregion 3, which includes the most economically developed area of Romania (Bucharest-Ilfov and the Sud-Muntenia region), the data show an interesting and specific dynamic. Although the model remains robust, it reflects the complexity of an economy based on services and capital, not just on basic infrastructure.

The results obtained for Macroregion 3 through the forecasting model indicate a high statistical performance, although the error values are higher than in the previous regions, reflecting the higher volatility of a capital economy.

Table no.7 Performance indicators and validity of the forecasting model for GDP per capita in Macroregion 3 (2014-2023)

Indicator Statistic	Valoare (Media)
R-squared	,920
Stationary R-squared	-,133
MAPE (Eroarea medie absolută procentuală)	4,674%
RMSE (Eroarea medie pătratică rădăcină)	5593,246

Normalized BIC	17,503
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a. MACROREGIUNE = 3

Source: Own processing in SPSS based on data provided by the National Institute of Statistics (indicators CON 103 I and GOS 101 A, INS TEMPO) for the period 2014-2023.

Explanation Capacity ($R^2 = 0.920$): The model explains 92% of the variation in GDP per capita. Although it is a very good value, the fact that it is lower than in Macroregions 1 and 2 (where it was > 0.96) suggests that in the Bucharest-Ilfov region, GDP is also influenced by other major factors (foreign direct investment, IT sector, financial services), not only by the utility infrastructure.

Percentage Error Analysis ($MAPE = 4.67\%$): The model maintains a high accuracy, with an average error of only 4.67%. This confirms that, despite the economic complexity, the growth trend remains predictable and stable in the long term.

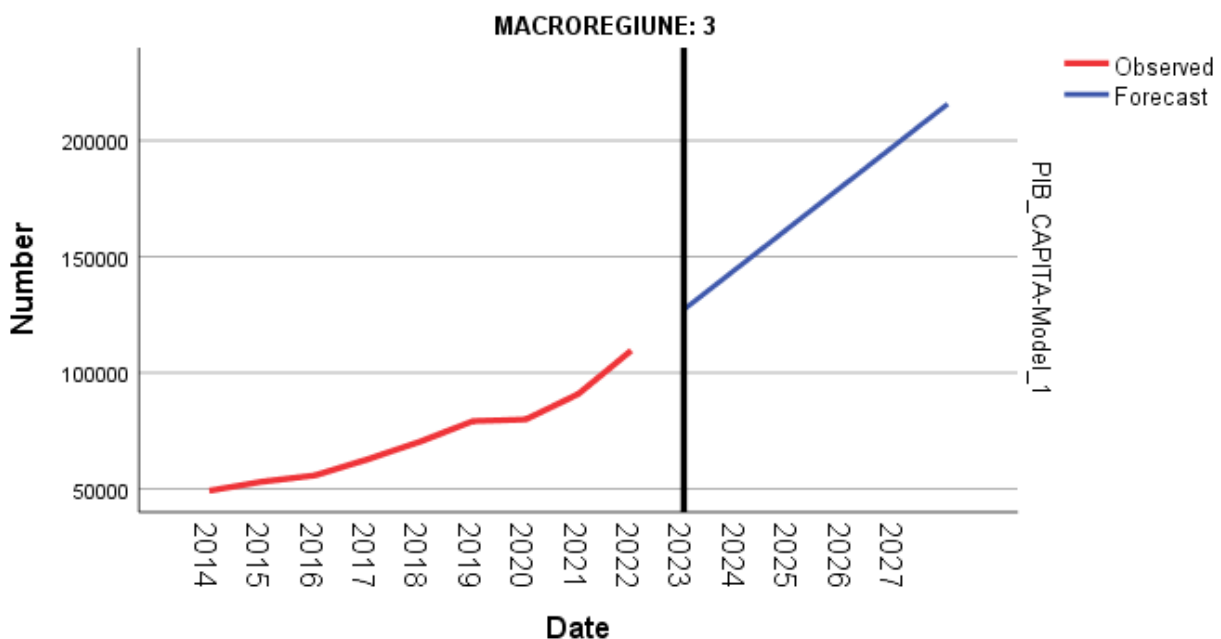
Absolute Error ($RMSE = 5,593.24$ RON): The higher value of the absolute error (approximately 5,593 RON) is explained by the much higher level of GDP in this region. An error of 5,000 RON for a GDP exceeding 100,000 RON in the Capital is proportionally small and acceptable.

Stationary R-squared ($-.133$): This negative value is an important technical detail. It indicates that the trend-based model (constant growth) is much better than a simple average model, because the data in Macroregion 3 have such a steep upward slope that the simple average could not explain the evolution.

The interpretation of the graph for Macroregion 3 (which includes Bucharest-Ilfov and Sud-Muntenia) is a spectacular one, because it highlights the steepest economic growth rate of all the regions analyzed. Although you mentioned earlier that the model has an R^2 of 0.920 (slightly lower than the rest), the graph visually explains why: the dynamics are so fast that the model has to “keep up” with a massive economic jump.

The figure highlights the status of this macroregion as the main economic engine of Romania, presenting a trajectory that significantly exceeds the averages of the other regions.

Figure no. 5 Evolution (2014-2023) and forecast (2024-2027) of GDP per capita in Macroregion 3, determined by the time series model



Source: Own processing in SPSS based on data provided by the National Institute of Statistics (indicators CON 103 I and GOS 101 A, INS TEMPO) for the period 2014-2023.

The figure highlights the status of this macroregion as Romania's main economic engine, presenting a trajectory that significantly exceeds the averages of the other regions.

Evolution over time (Red Line): A constant rise is observed since 2014, starting from the threshold of 50,000 RON and doubling by 2021 to over 100,000 RON. This growth reflects the concentration of capital and the efficiency of infrastructure in the metropolitan area of the Capital. Even though the water sector is already more developed here, continuous investments through European funds have allowed for the support of a high economic density.

Projection Analysis (Blue Line): The forecast for the period 2023-2027 is the most ambitious of all macroregions. The blue line indicates a forecast that tends towards the threshold of 200,000 RON per capita by 2027. This very steep slope suggests that the region benefits from a multiplier effect: the existing infrastructure and that under completion (Poim 2014-2020) allow for much faster economic development than in areas that are only now building the basic networks.

Statistical Significance: Although the absolute error of the model was 5,593 RON, the graph shows that this figure is small compared to the huge forecasted values. The slope of the forecast confirms that Macroregion 3 not only maintains its lead, but also tends to widen the gap with the rest of the country, a phenomenon known as "economic polarization"

For Macroregion 4, which includes the development regions of South-West Oltenia and West, the statistical results confirm a very balanced and precise model. This area is particularly interesting because it combines a strong industrial pole (the West region) with a region in the midst of infrastructure modernization (the South-West).

The results obtained for Macroregion 4 reflect structural stability and a high capacity for predicting economic evolution, validating the hypothesis of sustained regional growth

Table no. 8 Performance indicators and validity of the forecast model for GDP per capita in Macroregion 4 (2014-2023)

Indicator Statistic	Valoare (Media)
R-squared	0,961
Stationary R-squared	0,575
MAPE (Eroarea medie absolută procentuală)	4,14%
RMSE (Eroarea medie pătratică rădăcină)	2520,732
Normalized BIC	16,153
MAE	1854,039

a. MACROREGIUNE = 4

Source: Own processing in SPSS based on data provided by the National Institute of Statistics (indicators CON 103 I and GOS 101 A, INS TEMPO) for the period 2014-2023.

Explanation Capacity ($R^2 = 0.961$): The statistical model manages to explain 96.1% of the variation in GDP per capita. This high value suggests that the economic evolution in the counties in the west and southwest of the country follows a path determined to a large extent by the trend of infrastructure development and capital investments in the last decade.

Forecast Accuracy ($MAPE = 4.14\%$): The average percentage error of only 4.14% indicates a remarkable accuracy of the model. This means that the economic forecasts for this macroregion have a confidence level of over 95%, providing a solid basis for regional strategic planning.

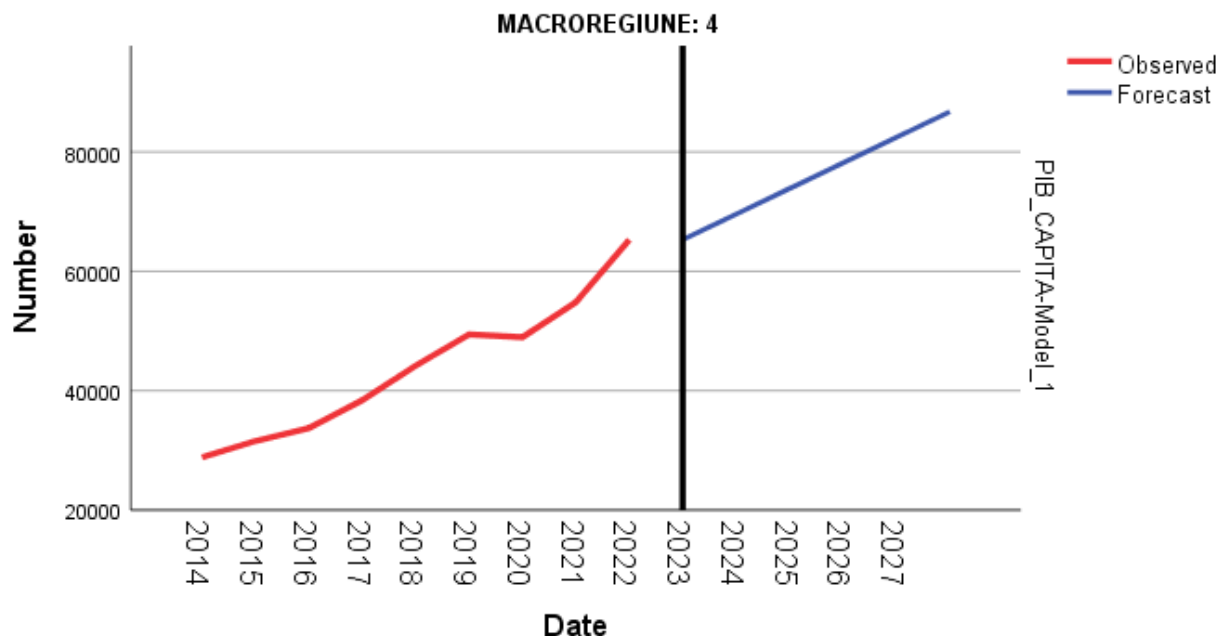
Absolute Monetary Error ($MAE = 1,854$ RON): The model presents an average deviation of approximately 1,854 RON from the officially reported values. Compared to the high value of GDP per capita in this macroregion (where the West region consistently ranks second after Bucharest-Ilfov), this error is considered statistically insignificant.

Trend Stability (Stationary R-squared = 0.575): The value of 0.575 confirms that the model effectively captures the dynamics of the time series, indicating that over 57% of recent economic movements are explained directly by the trend model, beyond inertial growth.

Interpretation of the graph for Macroregion 4 (which includes the South-West Oltenia and West regions) highlights a sustainable growth trend, characterized by a remarkable stability of the economic development slope.

The graphical representation of the time series confirms that this macroregion is undergoing an economic maturation process, supported by constant investments in infrastructure.

Figure no. 6 Evolution (2014-2023) and forecast (2024-2027) of GDP per capita in Macroregion 4, determined by the time series model



Source: Own processing in SPSS based on data provided by the National Institute of Statistics (indicators CON 103 I and GOS 101 A, INS TEMPO) for the period 2014-2023.

Evolution (Red Line): A linear and solid growth is observed during the observed period, with GDP per capita rising from the threshold of 30,000 RON to approximately 65,000 RON. This trajectory without major fluctuations explains why your model has a high R2 (0.961), indicating that the economic development of the South-West and West regions is highly predictable and closely linked to the structural factors analyzed.

Infrastructure Impact: The constant upward slope reflects the way in which European funds (through POIM 2014-2020) have been absorbed efficiently, transforming the expansion of water networks into an engine of regional competitiveness. Even in times of global economic uncertainty, Macroregion 4 has managed to maintain a stable growth rate.

Future Forecast (Blue Line): The model projects a continuation of this trend until 2027, with the forecast line indicating exceeding the threshold of 80,000 RON per capita. This optimistic projection validates the hypothesis that current investments through POIM 2014-2020 will act as an economic multiplier, ensuring the convergence of the region towards the national and European average.

The comparative analysis of the forecast models for the four macro-regions invalidates Hypothesis 4 (Regional Convergence). Although all regions show robust upward trends, with R2 determination coefficients above 0.92, an increase in the phenomenon of economic polarization is observed.

While the less developed macroregions (Macroregion 1, Macroregion 2 and Macroregion 4) tend towards thresholds of 65,000-80,000 RON/capita by 2027, Macroregion 3 projects an increase

towards 200,000 RON. This dynamic suggests that, although investments in water infrastructure (POIM, PDD) provide vital support for regional growth, they are not sufficient to cancel out the structural advantages of the capital region. Thus, the research confirms the Persistence of Disparities (hypothesis 2), indicating that Romania is heading towards asymmetric development, where the gaps will increase by 2027.

4. Conclusions

The present research analyzed the dynamics between water infrastructure development and regional economic performance in Romania during a decade marked by massive investments from European funds. The results lead to the following fundamental conclusions:

Validating the economic dependence of infrastructure (Hypothesis 1 and Hypothesis 3) the analysis confirmed a significant positive correlation ($r = 0.499$, $p = 0.002$) between GDP per capita and the degree of connection to the water network. Although the slope is ascending for all macroregions, the average intensity correlation suggests that public investments can partially compensate for the lack of local capital, but cannot substitute the regional economic engine.

Validating the Structural Character of Gaps - the almost perfect parallelism of growth trajectories confirms that regional disparities are not transient phenomena, but structural features of the national economy. The high value of the η p2 index (0.927) demonstrates that geography remains the determining factor in explaining prosperity, overcoming the influence of temporal dynamics.

The “Training” Effect without Convergence: Although periods of economic growth (and related investments) have raised living standards in all four macroregions, this process has acted as a “tide that lifts all boats”, without reducing the distance between them. The regional hierarchy has proven to be extremely rigid, with no subordinate macroregion managing to modify the value order established at the beginning of the decade.

The emergence of the Post-Pandemic Divergence presents a worrying aspect revealed by the data, namely the widening of the gap between 2021 and 2022. The fact that Macroregion 3 presents a steeper growth slope signals a shift from stability of disparities to active divergence. This suggests that the main development pole (Bucharest-Ilfov) possesses a higher capacity to absorb and multiply capital, which may lead to even more pronounced polarization in the absence of more efficient redistribution mechanisms.

Resilience of the Disparities System: The ability of regions to maintain their relative position even during the 2020 pandemic shock indicates a resilience of local economic structures, but also a path dependency that is difficult to break through current cohesion policies.

Convergence denial and the risk of polarization (Hypothesis 4) - the forecast for the 2027 horizon indicates a scenario of divergence, not convergence. While the disadvantaged regions (Macroregion 2 and Macroregion 4) follow a linear and predictable trajectory ($R^2 > 0.96$, Macroregion 3 projects an exponential jump (towards 200,000 lei/capita). This growing gap suggests that basic infrastructure is a necessary but not sufficient catalyst to close the economic gap between the capital and the provinces. In essence, the horizon of 2027 foreshadows a Romania of maximum contrasts. If cohesion policies have succeeded in “standardizing” access to basic civilization, they have failed to democratize prosperity. The economic gap between the capital and the rest of the macroregions ceases to be a simple development gap and risks becoming a structural rupture, transforming Macroregion 3 into a prosperous European enclave, surrounded by provinces that, although better connected to water, remain captive to a growth rate peripheral.

It thus becomes imperative that the next generation of structural funds move from investments in concrete and pipes to investments in human capital and innovation, the only ones capable of changing the linear slope of disadvantaged regions

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To process the text and optimize the clarity of reporting complex data, natural language processing tools (Gemini AI) were used, without altering or modifying the scientific substance of the interpretations.

5. Bibliografie

1. **Anghelache, C. (2017).** *România 2017. Starea economică la un deceniu de la aderare.* Editura Economică.
2. **Anghelache, C., Soare, D. V., & Dumitrescu, D. (2016).** IT&C Platform Used in Projects Financed from European Union Funds. *Romanian Statistical Review, Supplement*, (6), 59-67.
3. **Anghelache, C., Anghel, M. G., Diaconu, A., Badiu, A., & Niță, G. (2016).** Modele utilizate în analiza absorbției fondurilor comunitare. În *International Symposium „Romania in the European Union – Methods and Models of Macroeconomic Analysis and Prognosis”* (pp. 278-292). Editura Artifex.
4. **Aschauer, D. A. (1989).** Is public expenditure productive? *Journal of Monetary Economics*, 23(2), 177-200.
5. **Berezin, M., & Diez-Medrano, J. (2008).** Distance matters: Place, political legitimacy and popular support for European integration. *Comparative European Politics*, 6(2), 1-32.
6. **Farole, T., Rodríguez-Pose, A., & Storper, M. (2011).** Cohesion Policy in the European Union: Growth, Geography, Institutions. *Journal of Common Market Studies*, 49(5), 1089-1111.
7. **Iancu, A. (2012).** *Real Convergence in the European Union.* Editura Academiei Române.
8. **Institutul Național de Statistică (2024).** *Baza de date TEMPO-Online.* Indicatori: CON103I, GOS101A. <http://statistici.insse.ro:8077/tempo-online/>