

ASSESSING THE PUBLIC DEBT SUSTAINABILITY USING THE PENALIZED SPLINE REGRESSION. EMPIRICAL EVIDENCE FOR ROMANIA

<https://doi.org/10.47743/jopafl-2024-32-16>

GROSU Alexandra Claudia

Alexandru Ioan Cuza University of Iasi, Faculty of Economics and Business Administration

Iasi, Romania

alexandra.grosu@uaic.ro

Abstract: Since the 2008 financial crisis, public debt sustainability has been a major topic in economic discussions. With the added strains of the COVID-19 pandemic and ongoing global conflicts, the conversation around managing and maintaining public debt has only intensified. In the paper, we study governments' reactions to the accumulation of debt from Romania, using annual data from 2000 to 2023. The empirical approach applied in the paper include time series estimations using penalized spline regression. We use a semi-parametric model with time-varying coefficients and we include in the model some control variables which are particularly relevant in the case of Romania.

Keywords: public debt, sustainability of public debt, penalized spline regression, Romania economy.

Introduction

Studying public debt sustainability is increasingly crucial in today's world due to its profound impact on economic stability, fiscal policy, and social well-being. High levels of unsustainable public debt can lead to severe economic crises, including defaults or inflationary pressures, which undermine investor confidence and hinder economic growth. Effective debt management ensures that governments can maintain essential social programs and public services while avoiding excessive financial burdens on future generations. Sustainable debt levels also provide the fiscal flexibility needed to respond to economic shocks, such as the recent pandemic, which has highlighted the need for robust fiscal policies to manage unprecedented spending and economic disruptions.

The COVID-19 pandemic has underscored the importance of studying debt sustainability as governments worldwide have increased borrowing to support public health and economic recovery. Managing this heightened debt responsibly is essential to prevent long-term fiscal instability and ensure that future generations are not unduly burdened. Moreover, sustainable debt levels are critical for maintaining public trust and international credibility, which are vital for accessing capital markets and navigating global financial relations. By focusing on debt sustainability, policymakers can better address current and emerging risks, including those posed by global health crises and economic uncertainties, thereby safeguarding both domestic and international economic stability.

In the context of Romania, studying public debt sustainability is particularly important as the country navigates both the economic impacts of the COVID-19 pandemic and broader fiscal challenges. The pandemic has significantly increased Romania's public debt as the government implemented substantial fiscal measures to support health care, economic recovery, and social protection. Managing this increased debt is crucial to ensuring that

Romania can maintain economic stability, avoid excessive borrowing costs, and continue investing in infrastructure and public services. Sustainable debt levels will help Romania balance its fiscal responsibilities with the need for economic growth and development, while also safeguarding its ability to respond to future crises and maintain investor confidence. Addressing these challenges effectively will be key to Romania's long-term economic resilience and its position within the European Union, where adherence to fiscal norms and sustainability criteria is closely monitored.

In the current geopolitical climate, including the ongoing conflict in Ukraine, studying public debt sustainability in Romania has become even more pressing. The war has introduced additional economic uncertainties and potential disruptions, impacting energy prices, trade routes, and overall economic stability. As Romania faces increased defense spending and humanitarian support costs, the strain on public finances is compounded, making it essential to manage debt sustainably to avoid exacerbating fiscal pressures. Balancing increased expenditures with effective debt management will be critical for maintaining economic stability and resilience. Sustainable debt policies will enable Romania to navigate these turbulent times while preserving its economic growth and stability, ensuring that it remains well-positioned to handle both immediate and long-term challenges.

The primary aim of this paper is to assess the sustainability of Romania's public debt. The empirical study will utilize several statistical variables, including the primary surplus, net public debt ratio, public debt expenditures, a measure of economic cycles (real GDP fluctuations), rule of law, political stability and regulatory quality. Data for these variables, covering the years 2000 to 2023, has been obtained from the International Monetary Fund (IMF) and the World Bank. The analysis of public debt sustainability will employ spline regression as the statistical method. This approach is used to uncover the distinctive features of the country included in the sample.

The paper is structured into four comprehensive sections. The first section offers a succinct review of existing literature on public debt and its sustainability, outlining key theories and findings from prior research. The second section thoroughly describes the data sources and methodological framework used to evaluate public debt sustainability, detailing the approaches and techniques applied in the analysis. The third section provides an in-depth empirical analysis with a specific focus on Romania. Finally, the fourth section summarizes the key conclusions drawn from the study, highlighting the main insights and implications for fiscal policy and debt management.

Literature review

The analysis of whether a government meets its long-term budgetary constraints began with the work of Hamilton and Flavin in 1986. They investigated whether the US federal government was adhering to its present-value borrowing constraints by examining annual data from 1960 to 1984. Their study focused on determining if the data on US federal public debt included any speculative bubbles. The presence of such bubbles would imply that the public debt was exceeding the present value of expected future surpluses, suggesting an unsustainable fiscal policy. Through a range of statistical tests, Hamilton and Flavin provided evidence that supported the sustainability of the US federal debt policy during the period they analyzed. In 1989, Wilcox challenged the approach used by Hamilton and Flavin, arguing that their method failed to consider the impact of fluctuating

interest rates on the analysis. To address this issue, Wilcox introduced a new testing method that evaluates the discounted time series of public debt. According to this approach, if the discounted debt series trends towards zero, it signifies that the debt is sustainable. Applying this revised method to the same dataset used by Hamilton and Flavin, Wilcox discovered evidence indicating that the US federal debt was, in fact, unsustainable.

Wilcox's findings were notably influenced by the choice of discount rate used in his test, which is a variable subject to randomness. Because past interest rates do not reliably predict future rates, the results of his test could be heavily affected by the specific discount rate selected. To mitigate this issue, Hakkio and Rush proposed an alternative approach in 1991 that focuses on analyzing the cointegration between government revenues and expenditures. Their method suggests that if revenues and expenditures are cointegrated, it indicates that their first differences are stationary, which supports the notion of a sustainable debt policy, provided that the interest rate remains positive. This approach aims to offer a more stable assessment of fiscal sustainability by examining the long-term relationship between revenues and spending.

Bohn (1995, 1998) criticized the reliance on interest rates in sustainability tests, highlighting the issue that future interest rates are inherently unpredictable. Instead of focusing on interest rates, Bohn suggested an alternative method: examining how the primary surplus as a percentage of GDP responds to changes in the debt-to-GDP ratio. Specifically, he proposed that if the primary surplus increases in response to higher debt levels, ideally in a linear fashion, it would indicate that the debt-to-GDP ratio tends to revert to a more manageable level, thus supporting the sustainability of the debt in a growing economy. This approach is appealing because it aligns with economic intuition—if a government faces high debt, it should increase its primary surplus to ensure long-term sustainability. Bohn's method, known as the fiscal response function, has become a prominent tool in fiscal sustainability research. Beqiraj et al. (2018) provided a comprehensive review of this approach. Recent studies have expanded on Bohn's work by exploring non-linear fiscal behaviors. For instance, the concept of "fiscal fatigue," introduced by Ghosh et al. (2013), suggests that the responsiveness of the primary surplus to debt levels may diminish or even become negative when debt ratios reach very high levels. This phenomenon has been further examined by Checherita-Westphal and Zdarek (2017) and Fournier and Fall (2017), highlighting that the relationship between debt and fiscal responses may not always be straightforward.

The methodological framework of this study is based on the approaches developed by Bohn (1998), Greiner and Fincke (2016), Berti et al. (2016), and Owusu et al. (2023). We used annual data from 2000 to 2023 to estimate models for Romania in our sample. Each model is semi-parametric, addressing the non-linear relationship between the primary balance and the debt ratio, as identified by Greiner and Kauermann (2005). The estimation technique employed is penalized spline regression, which provides more robust estimates compared to ordinary least squares (OLS), as demonstrated by Hastie and Tibshirani (1990) and Ruppert et al. (2003). Early developments in penalized splines were significantly advanced by Hastie and Tibshirani (1990), who pioneered generalized additive models. These models allowed for a more flexible approach to capturing complex relationships between dependent variables and predictors. Building on this foundation, Wood (2000) introduced the concept of mixed models for penalized splines, enhancing their application by incorporating random effects. Additional key contributions to the methodology include

Ruppert et al. (2003), who refined the estimation techniques for penalized splines, and Eilers and Marx (1996), who developed smoothing techniques that improved model fitting. Greiner and Kauermann (2005) further extended the theoretical framework, contributing to a deeper understanding of the properties and advantages of penalized spline methods in various statistical applications.

Recent advancements in penalized spline methodologies have significantly enhanced the analysis of public debt sustainability. Current contributions by Wood (2017) have introduced sophisticated extensions of penalized splines in Bayesian and spatial contexts, which improve the handling of complex, non-linear relationships in economic data. Marra and Wood (2012) have further refined these techniques for use in mixed models, enabling more accurate analysis of hierarchical structures within economic data. Additionally, Sim and Wright (2019) have focused on computational improvements and extensions to high-dimensional settings, enhancing the robustness of spline methods in dealing with large-scale data. These advancements are particularly relevant for studying public debt sustainability, as they allow for more nuanced modeling of the non-linear dynamics between debt levels, primary surpluses, and economic growth, thereby providing deeper insights into the sustainability of fiscal policies and the long-term viability of public debt.

Data and methodology

This paper investigates how the Romanian government has managed its public debt accumulation. We analyzed data from 2000 to 2023, obtained from the International Monetary Fund (IMF) and the World Bank. Our approach is based on the methodologies developed by Fincke and Greiner (2012) and Greiner and Fincke (2016). Specifically, we examine how the primary surplus—expressed as a percentage of GDP—responds to changes in the public debt ratio, also expressed as a percentage of GDP. To ensure that our analysis accounts for specific national factors, we include control variables that reflect the institutional context, including indicators such as the rule of law, political stability, and regulatory quality.

The rule of law measures how much confidence individuals have in and adhere to societal rules, specifically focusing on the effectiveness of contract enforcement, protection of property rights, the performance of police and judicial systems, and the prevalence of crime and violence. The percentile rank reflects the country's position relative to all other countries included in the aggregate indicator, with 0 representing the lowest rank and 100 the highest. These percentile ranks have been adjusted to account for shifts over time in the countries included in the World Governance Indicators (WGI).

The political stability and absence of violence/terrorism indicator assesses how people perceive the likelihood of political instability or politically motivated violence, including terrorism, within a country. This measure uses a percentile rank to show how a country compares to others globally: a percentile rank of 0 represents the lowest level of stability and security, while a rank of 100 denotes the highest level. The percentile ranks are adjusted to account for changes in the composition of countries evaluated by the World Governance Indicators (WGI) over time. This adjustment ensures that the rankings remain consistent and comparable despite shifts in the global landscape of countries assessed.

Regulatory quality assesses how effectively the government is perceived to design and enforce policies and regulations that facilitate and encourage private sector development. The percentile rank represents the country's position relative to others, with 0 indicating

the lowest performance and 100 the highest. This ranking is adjusted to reflect changes in the countries included in the Worldwide Governance Indicators (WGI) over time, ensuring that shifts in the indicator are not solely due to changes in the sample of countries but reflect actual variations in regulatory quality.

The econometric models estimated in this paper are based on the approach used by Bohn (1998), Greiner and Fincke (2016), and Berti et al. (2016). For the time series estimations, we employed a semi-parametric model, as detailed below:

$$PB_t = \beta_0 + f(Debt_{t-1}) + \beta_1 Expend_t + \beta_2 GDP_t + \beta_3 Z_t + \varepsilon_t .$$

In the model, PB_t denotes the primary surplus as a percentage of GDP, while $Debt_{t-1}$ refers to the debt ratio lagged by one period, accounting for the fact that budget plans are typically set a year in advance. The variables $Expend_t$ and GDP_t represent public spending and real GDP fluctuations, respectively, with the latter acting as a business cycle indicator. These were calculated by removing the long-term trend from the series using the Hodrick-Prescott filter. The Z_t variables are control factors that capture the specific economic characteristics of the countries studied, such as rule of law, military spending and age dependency ratio. $f(Debt_{t-1})$ is a smoothing function, which is unknown but smooth and estimated from the data, applied to the lagged debt ratio. The coefficients β_i , $i = 1, 2, 3$ correspond to the variables $Expend_t$, GDP_t , and Z_t , respectively. The term ε represents the error component.

The relationship between the primary surplus ratio and public debt is generally linear for most variables, except for the lagged debt variable, $Debt_{t-1}$. As highlighted by Greiner and Kauermann (2005), this lagged debt variable has a nonlinear effect on the primary surplus ratio. The strength of the primary surplus's response to changes in the public debt ratio is indicated by a time-varying coefficient. This coefficient reflects how sensitive the primary surplus is to shifts in the debt ratio. According to Greiner and Fincke (2016), nonlinear models can be approximated by linear models with time-varying coefficients if the changes in parameters are gradual, a concept supported by Granger (2008). For public debt to be considered sustainable, it is generally sufficient for the reaction coefficient to be positive and sufficiently large on average.

The analysis utilizes penalized spline regression due to its superior ability to handle nonlinear relationships compared to ordinary least squares (OLS) regression. As detailed by Hastie and Tibshirani (1990), Wood (2000), and Ruppert et al. (2003), penalized spline regression provides more robust and accurate results by applying smooth functions that adjust for complexity within the data. To further ensure the robustness of our findings, we also test various combinations of variables.

The analysis relies on data from the International Monetary Fund (IMF) and the World Bank.

Empirical findings

This paper's empirical study focuses on evaluating the sustainability of public debt in Romania. Prior to discussing the findings, we first offer a concise overview of the variables under analysis and then proceed with the time series estimations.

Data summary

The empirical study utilizes annual data for Romania covering the period from 2000 to 2023. Missing values were addressed through basic imputation techniques. The dynamics of the variables are illustrated in Figures 1 to 7.

The primary surplus

The primary surplus, defined as the difference between general government revenues and general government expenditures (excluding interest payments) and expressed as a percentage of GDP, is illustrated for Romania from 2000 to 2023 in Figure 1:

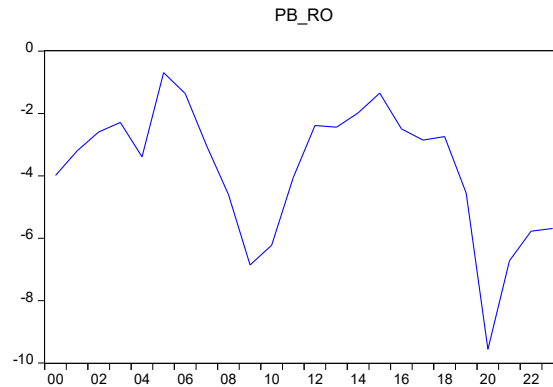


Figure 1. Primary surplus (% of GDP) dynamics for Romania, from 2000 to 2023

Figure 1 illustrates that Romania experienced primary deficits throughout the entire period from 2000 to 2023. Although there were several attempts to better manage government spending and significantly improve revenues, resulting in modest improvements in the primary surplus, these efforts were generally insufficient, even if the country struggled to achieve substantial progress.

Romania experienced primary deficits around 2009 and 2020 due to significant economic disruptions in those years. In 2009, the global financial crisis led to a severe economic downturn, reducing tax revenues and prompting the government to increase public spending to stimulate the economy and address rising unemployment. This combination of decreased revenues and elevated expenditure resulted in a primary deficit. Similarly, in 2020, the COVID-19 pandemic caused a substantial economic slowdown, which, along with lockdowns and decreased economic activity, led to a sharp decline in government revenues. The Romanian government responded with increased spending on healthcare and economic support measures, further exacerbating the primary deficit. Both periods reflect how external economic shocks and increased fiscal measures to counteract these shocks can strain public finances.

Public debt rate

The graph for the public debt ratio for Romania covering the period from 2000 to 2023, is represented in Figure 2.

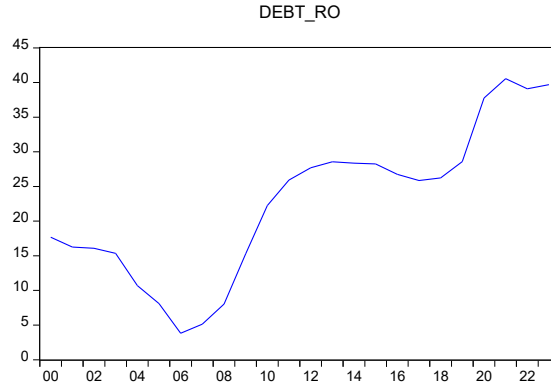


Figure 2. Public debt ratio dynamics for Romania, from 2000 to 2023

From 2000 to 2023, Romania's public debt has experienced notable fluctuations, influenced by various economic and geopolitical events. The debt ratio increased significantly during global economic crises, such as the 2008 financial downturn and the 2020 COVID-19 pandemic, driven by elevated government spending and decreased revenues. Additionally, recent geopolitical tensions and conflicts, such as the ongoing war in Ukraine, have further strained Romania's public finances through increased defense spending and economic disruptions.

Business cycle

The business cycle for Romania, highlighting the variations in real GDP from 2000 to 2023, is illustrated in the graph below, Figure 3.

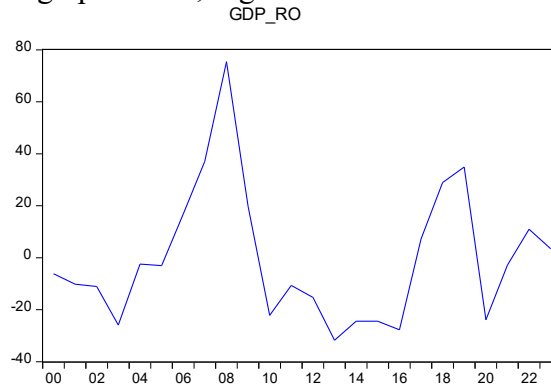


Figure 3. Business cycle dynamics for Romania, from 2000 to 2023

This visualization highlights periods of economic expansion and contraction, reflecting how the country's economic output has varied in response to various domestic and international factors. By examining these changes, one can gain insights into how economic growth and downturns have impacted Romania's overall economic performance and influenced fiscal and monetary policies. This information is crucial for understanding the broader economic context in which public debt and other economic indicators should be evaluated.

Public debt expenditures

Below is a graph depicting the fluctuations in public debt expenditure as a percentage of GDP for Romania from 2000 to 2023, showing how this variable varies around its trend.

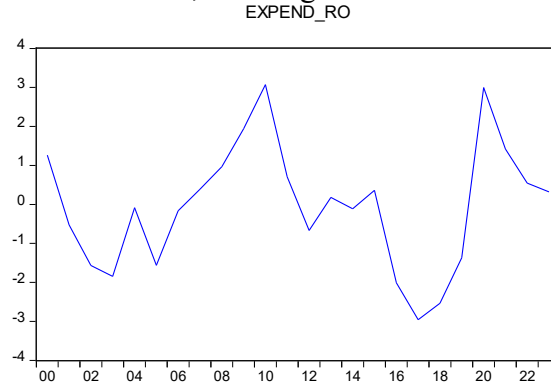


Figure 4. Public debt expenditure dynamics (% of GDP) for Romania, from 2000 to 2023

The graph illustrates how public debt expenditure in Romania, expressed as a percentage of GDP, has fluctuated from 2000 to 2023. By comparing these fluctuations against the long-term trend, the graph provides insights into the variability of debt-related spending over time. This analysis helps in understanding how public debt expenditure has responded to different economic conditions and fiscal policies, revealing periods of higher or lower spending relative to the trend. Such information is valuable for assessing the effectiveness of fiscal management and the impact of economic events on debt expenditure.

Rule of law

The visual representation of the rule of law for Romania from 2000 to 2023 is shown in Figure 5.

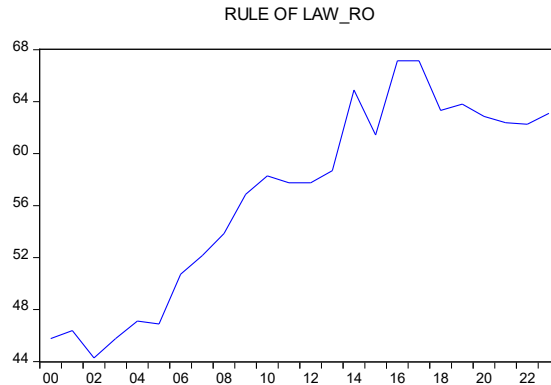


Figure 5. Rule of law for Romania, from 2000 to 2023

The visual representation of the rule of law for Romania, depicted in Figure 5, provides a snapshot of how perceptions of legal and institutional quality have evolved from 2000 to 2023. This figure highlights trends and changes in the effectiveness of contract enforcement, property rights, and the functioning of legal and judicial systems over time. By examining these trends, one can assess how improvements or declines in the rule of law may have influenced Romania's governance, economic stability, and overall investment climate. Understanding these dynamics is essential for evaluating the broader implications of legal and institutional quality on the country's economic and fiscal performance.

The upward trend in the rule of law for Romania from 2000 to 2023 indicates significant improvements in the country's legal and institutional quality. This suggests that over this period, Romania has strengthened its legal framework, enhanced the enforcement of contracts, and improved property rights protection, contributing to a more reliable and secure business environment. Such advancements are likely to foster greater economic stability and attract investment, reflecting positively on the country's overall governance and economic performance.

Political stability

The graph that illustrates the trends in Romania's political stability from 2000 to 2023 can be seen in Figure 6.

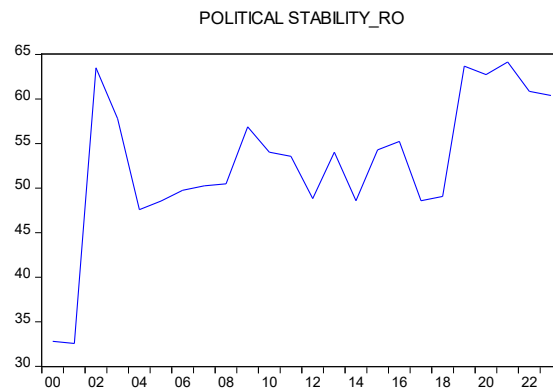


Figure 6. Political stability for Romania, from 2000 to 2023

From 2000 to 2023, Romania's political stability has been marked by both progress and challenges. The early 2000s saw Romania navigating post-communist transitions and aligning with EU standards, culminating in its EU membership in 2007. Throughout this period, the country faced fluctuations in stability due to economic crises, political conflicts, and governance issues.

Regulatory quality

The visual representation of the regulatory quality for Romania from 2000 to 2023 is shown in Figure 7.

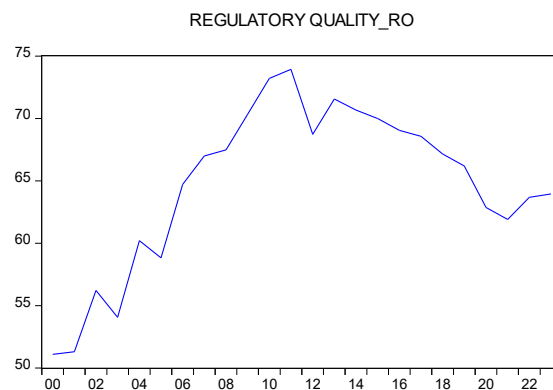


Figure 7. Regulatory quality for Romania, from 2000 to 2023

For Romania, the improving regulatory quality from 2000 to 2011 likely supported economic growth and contributed to better debt management during that period. The subsequent decline after 2011, however, could indicate emerging challenges such as policy reversals or increasing inefficiencies, which may negatively affect economic stability and public debt sustainability. This deterioration suggests potential risks to Romania’s ability to effectively manage and sustain public debt, emphasizing the need for renewed focus on regulatory reforms to stabilize and improve fiscal health.

Estimating spline regression

The results from estimating the econometric models for Romania, which include control variables such as the rule of law, political stability, and regulatory quality, are shown in Table 1. These tables display the models selected based on the lowest generalized cross-validation (GCV) statistic and the highest adjusted R-squared (Adj. R²) value. Only the results where the coefficient of the smooth function is statistically significant are included.

Estimated regression coefficients

The estimated equations are presented in Table 1, with each model incorporating different sets of control variables. Model 1 represents the baseline model without any control variables. Model 2 includes rule of law as a control variable. Model 3 incorporates political stability as the control variable. Finally, model 4 features regulatory quality as the control variable.

Table 1: Coefficients for the four analyzed models (Dependent Variable: primary surplus as a Percentage of GDP)

Variables	Model1	Model2	Model3	Model4
Constant	-3.493 **	12.738 **	1.143	1.238
	(1.500)	(5.573)	(2.753)	(9.510)
PB_{t-1}	0.101	0.084	0.124	0.107
	(0.213)	(0.180)	(0.209)	(0.216)
$Debt_{t-1}$	-0.126	-0.150	-0.035	-0.103
	(0.129)	(0.114)	(0.141)	(0.130)
$Expend_t$	-1.030 ***	-0.973 ***	-0.984 ***	-0.946 ***
	(0.220)	(0.178)	(0.224)	(0.259)
GDP_t	0.002	0.003	-0.001	0.005
	(0.014)	(0.010)	(0.015)	(0.016)
Rule_of_law _t		-0.336 **		
		(0.105)		
Political_stability _t			-0.037	
			(0.040)	
Regulatory_Quality _t				-0.072
				(0.147)
sm_t	F.stat.	F.stat.	F.stat.	F.stat.
	3.063 **	7.125 ***	2.432 *	2.614 *

Standard error in brackets
 ***p<0.01; **p<0.05; *p<0.1.

The data in Table 1 shows that, for Romania from 2000 to 2023, the coefficients for government spending are significant negative across all models. This significant negative relationship indicates that, during periods of higher public expenditures, the primary surplus ratio tends to decrease. In other words, as government spending increases, the primary surplus, which is the fiscal balance excluding interest payments, becomes smaller. This suggests that higher levels of public spending are associated with a reduced capacity to generate a surplus, highlighting the impact of expenditure on Romania's fiscal balance over the observed period.

In model 2, we observe that for Romania, the coefficient for the rule of law is significantly negative. This result implies that an improvement in the rule of law is associated with a decrease in the primary surplus. Specifically, this negative relationship suggests that while stronger rule of law institutions are generally beneficial for economic stability, they might be correlated with lower primary surpluses in the short term. This finding can be interpreted as follows: enhancements in the rule of law may lead to increased public spending or investments in legal and regulatory reforms, which could temporarily reduce the primary surplus. These expenditures, while potentially lowering the primary surplus in the short run, are likely to foster a more stable and transparent economic environment in the long term. Such improvements can contribute to better fiscal management and economic growth, potentially leading to higher primary surpluses in the future as the benefits of stronger legal institutions take effect. Therefore, the negative coefficient should be understood in the context of a broader fiscal strategy where short-term reductions in the primary surplus are offset by long-term gains in economic stability and fiscal health. This underscores the importance of balancing immediate fiscal objectives with investments in institutional quality, which can enhance overall fiscal sustainability and economic performance over time.

The statistically insignificant results for net debt across all four models imply that there is insufficient evidence to dismiss the hypothesis that Romania's public debt policy may be unsustainable. Specifically, the lack of significant findings suggests that the relationship between net debt and the primary surplus does not support a conclusion of fiscal sustainability. This means that, based on the data analyzed, there is no strong indication that Romania's current approach to managing public debt is adequate to ensure long-term fiscal stability. Consequently, the hypothesis that Romania might be following an unsustainable public debt policy remains plausible.

Validation of the estimated models

The validation of the models relies on two key criteria: the adjusted R-squared and the cross-validation approach. The adjusted R-squared measures the proportion of variance explained by the model, adjusted for the number of predictors, providing insight into the model's explanatory power. Cross-validation, on the other hand, involves systematically excluding one data point at a time to assess how well the model predicts that excluded point. This process helps ensure that the model's performance is robust and not overly fitted to the included data, often described as the "leave-one-out" or "drop-out" method. By minimizing the residual sum of squares (RSS) while excluding individual points, this technique helps evaluate the model's generalizability and accuracy.

Formally, this method is defined as $CV(\lambda) = \sum_{i=1}^n \{y_i - \hat{f}_{-1}(x_i; \lambda)\}^2$, where $\hat{f}_{-1}(x_i; \lambda)$ represents the spline function fit excluding the point (x_i, y_i) . This approach enables us to find λ for a given spline basis that minimizes this value, considering the prediction of new points while avoiding overfitting. However, a significant issue with this method is its computational intensity. Each iteration requires finding a new spline fit, which demands substantial computation time for large datasets.

This computation time can be substantially reduced using an approximation from Ruppert et al. (2003), which is generally valid. The approximation is given by $\hat{f}_{-1}(x_i; \lambda) = \frac{\sum_{j=1, j \neq i}^n S_{\lambda, ij} y_j}{\sum_{j=1, j \neq i}^n S_{\lambda, ij}}$, where S_{λ} is the smoothing matrix of the penalized linear spline function.

Consequently, the cross-validation criterion can be rewritten as $CV(\lambda) = \sum_{i=1}^n \left(\frac{y_i - \hat{y}_i}{1 - S_{\lambda, ii}} \right)^2$.

This revised form significantly reduces computation time, as it relies on the normal residual of the originally adjusted model and requires only the diagonal entries of the smoothing matrix, thereby eliminating about half of the steps involved in the previous approach.

The optimal outcomes from this estimation process are achieved when the cross-validation criterion is minimized and the adjusted coefficient of determination is maximized. Specifically, a lower value of the cross-validation criterion indicates a better fit of the model to the data, as it reflects reduced prediction error when excluding individual data points. Meanwhile, a higher value of the adjusted coefficient of determination signifies that the model explains a greater proportion of the variability in the dependent variable, while accounting for the number of predictors. Thus, the ideal model balances a minimal cross-validation criterion with a high adjusted R-squared, demonstrating both robust predictive performance and strong explanatory power.

The results of the model validation criteria for Romania, based on the four models analyzed over the period from 2000 to 2023, are summarized in Table 2.

Table 2: The results for Adj. R2 and GCV tests for the four analyzed models (Dependent Variable: primary surplus as a Percentage of GDP)

	Model1	Model2	Model3	Model4
Adj. R ²	0.830	0.913	0.809	0.811
GCV	1.516	0.982	1.727	1.7476

By comparing the empirical results from the econometric models estimated for Romania, which incorporate various statistical variables reflecting the country’s specific characteristics—such as rule of law, political stability, and regulatory quality—it becomes evident that Model 2, which includes the rule of law, performs the best. This model stands out due to its achievement of the lowest generalized cross-validation (GCV) values and the highest adjusted R-squared, indicating superior accuracy in replicating the data generation process. The model’s robust performance suggests that it is better at capturing the underlying dynamics affecting Romania and, by extension, could serve as a more valuable tool for economic policy development. Its effectiveness in reflecting the complexities of the Romanian context makes it highly useful for crafting informed and targeted economic strategies.

Conclusions

In this paper, we analyze the sustainability of public debt in Romania from 2000 to 2023, a period marked by significant economic and political shifts. Romania's journey through these years includes its accession to the European Union, which brought both opportunities and challenges. The sustainability of public debt has become a pressing issue, especially given the country's historical context of rapid economic reforms and ongoing macroeconomic vulnerabilities. The situation was further complicated by the global financial crisis of 2008, the economic impacts of the COVID-19 pandemic, and recent geopolitical tensions, including the ongoing war in Ukraine. These events have exerted additional pressure on Romania's fiscal policies and debt management strategies. This analysis seeks to provide insights into how Romania's public debt dynamics have evolved in response to these multifaceted challenges and to evaluate the implications for future economic stability and policy formulation.

In assessing the sustainability of public debt, we adopted the approach outlined by Fincke and Greiner (2012) and Greiner and Fincke (2016), which is particularly relevant given Romania's unique economic and institutional context. This methodology allows us to rigorously evaluate the long-term viability of Romania's public debt within the framework of its historical and structural characteristics. Moreover, our econometric model is enhanced by the inclusion of control variables that reflect crucial institutional dimensions. These variables encompass rule of law, political stability, and regulatory quality. By incorporating these factors, we aim to account for the broader institutional environment that influences fiscal policy and debt sustainability. The rule of law captures the effectiveness of legal frameworks and enforcement, political stability addresses the consistency and predictability of the political environment, and regulatory quality measures the efficiency and transparency of regulatory practices. This comprehensive specification helps to ensure that our analysis of public debt sustainability is robust and takes into consideration the complex interplay between economic policies and institutional factors.

Our analysis of the four models reveals that model 2, which includes the rule of law as a control variable, provides the most accurate representation of the data generation process. This conclusion is supported by its superior performance, as indicated by the lowest generalized cross-validation (GCV) values and the highest adjusted R-squared.

The significantly negative coefficient for the rule of law in Model 2 suggests that improvements in legal institutions are associated with a reduction in Romania's primary surplus. This outcome may initially appear counterintuitive, as stronger rule of law typically fosters economic stability and efficiency. However, it likely reflects the short-term fiscal costs of investing in legal and regulatory enhancements. While these investments may temporarily decrease the primary surplus, they are crucial for long-term fiscal health and economic resilience. Strengthening legal institutions can improve governance and reduce economic risks, ultimately supporting more sustainable fiscal policies and higher primary surpluses in the future. Thus, the negative association highlights the importance of considering both immediate fiscal impacts and long-term benefits when evaluating the effects of institutional reforms.

The statistically insignificant results for net debt across all four models suggest that there is insufficient evidence to reject the hypothesis that Romania's public debt policy may lack sustainability. The lack of a significant relationship between net debt and the primary

surplus implies that current data does not adequately demonstrate fiscal stability. Consequently, this data does not provide a solid basis to confirm that Romania's approach to managing public debt is sufficient for long-term fiscal health. Therefore, the possibility that Romania's public debt policy could be unsustainable remains a valid concern.

Despite the limitations of our research, notably the small data series, the results are consistent with existing literature for similar countries and suggest important considerations for Romania's fiscal policy. The statistically insignificant findings related to net debt imply that the hypothesis of an unsustainable public debt policy cannot be rejected. Therefore, even within the constraints of the available data, these results advocate for Romania to consider a more cautious and prudent fiscal approach to enhance long-term economic stability.

References

1. Beqiraj, E., Fedeli, S., Forte, F. (2018). Public debt sustainability: An empirical study on OECD Countries. *Journal of Macroeconomics*, 58, pp. 238-248. <https://doi.org/10.1016/j.jmacro.2018.10.002>
2. Berti, K., Colesnic, E., Desponts, E. (2016). Fiscal reaction functions for European Union countries. *European Economy Discussion Paper*, No: 028, pp. 1-44.
3. Bohn, H. (1995). The sustainability of budget deficits in a stochastic economy. *Journal of Money, Credit and Banking*, 27, pp. 257-271. <https://doi.org/10.2307/2077862>
4. Bohn, H. (1998). The behaviour of U.S. public debt and deficits. *Quarterly Journal of Economics*, 113, pp. 949-963. <https://doi.org/10.1162/003355398555793>
5. Checherita-Westphal, C., Žďárek, V. (2017). Fiscal reaction function and fiscal fatigue: evidence for the euro area. *European Central Bank, Working Paper Series No. 2036*, pp. 1-36.
6. Eilers, P.H.C., Marx, B.D. (1996). Flexible smoothing with B-splines and penalties. Vol.11, pp. 89-121. <https://doi.org/10.1214/ss/1038425655>
7. Fincke, B., Greiner, A. (2012). How to assess debt sustainability? Some theory and empirical evidence for selected euro area countries. *Applied Economics*, No. 44, Issue 28, pp. 3717-3724. <https://doi.org/10.1080/00036846.2011.581213>
8. Fournier, J.M., Fall, F. (2017). Limits to Government Debt Sustainability. *OECD Economics Department Working Papers*, No. 1229, OECD Publishing, Paris.
9. Ghosh, A.R., Ostry, J.D., Qureshi, M.S. (2013a). Fiscal space and sovereign risk pricing in a currency union. *Journal of International Money and Finance*, 34, pp. 131-163. <https://doi.org/10.1016/j.jimonfin.2012.11.008>
10. Ghosh, A. R., Kim, J.I., Mendoza, E.G., Ostry, J.D., Qureshi, M.S. (2013b). Fiscal fatigue, fiscal space and debt sustainability in advanced economies. *The Economic Journal*, 123, F3-F30. <https://doi.org/10.1111/eoj.12010>
11. Granger, C.W.J. (2008). Non-linear models: Where do we go next – Time varying parameter models?. *Studies in Nonlinear Dynamics & Econometrics*, 12(3), article 1: 1-9. <https://doi.org/10.2202/1558-3708.1639>
12. Greiner, A., Kauermann, G. (2005). Sustainability of US public debt: Estimating smoothing spline regressions. *Center for Empirical Macroeconomics, Working Paper*, No. 83, Bielefeld University.
13. Greiner, A., and Fincke, B. (2016). *Public Debt, Sustainability and Economic Growth*. Springer International.
14. Hakkio, C.S., Rush, M. (1991). Is the Budget Deficit Too Large?. *Economic Inquiry*, 29, pp. 429-445. <https://doi.org/10.1111/j.1465-7295.1991.tb00837.x>
15. Hamilton, J.D., Flavin, M. (1986). On the limitations of government borrowing: A framework for empirical testing. *The American Economic Review*, 76, pp. 808-819. <https://doi.org/10.3386/w1632>
16. Hastie, T.J., Tibshirani, R.J. (1990). *Generalized additive models*. London, Chapman and Hall.

17. Marra, G. and Wood, S.N. (2012). Practical variable selection for generalized additive models. *Computational Statistics & Data Analysis*, Vol 55, pp. 2372-2387. <https://doi.org/10.1016/j.csda.2011.02.004>
18. Owusu, B., Bökemeier, B., Greiner, A. (2023). Assessing Non-Linearities and Heterogeneity in Debt Sustainability Analysis: A Panel Spline Approach, *Empirical Economics*, Springer, Vol. 64(3), pp. 1315-1346, March. <https://doi.org/10.1007/s00181-022-02284-8>
19. Ruppert, R., Wand, M.P., Carroll, R.J. (2003). *Semiparametric regression*. Cambridge University Press, Cambridge.
20. Sim, J., & Wright, M. (2019). Computational enhancements and extensions of spline methods for high-dimensional data. *Journal of Computational Statistics*, 35(4), 1234-1256.
21. Wilcox, D.W. (1989). The sustainability of government deficits: Implications of the present-value borrowing constraint. *Journal of Money, Credit and Banking*, 21, pp. 291-306. <https://doi.org/10.2307/1992415>
22. Wood, S.N. (2000). Modelling and smoothing parameter estimation with multiple quadratic penalties. *Journal of the Royal Statistical Society, Series B*, 62: pp. 413-428. <https://doi.org/10.1111/1467-9868.00240>
23. Wood, S.N. (2017). *Generalized Additive Models. An Introduction with R*. Chapman and Hall/CRC, New York.



This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution - Non Commercial - No Derivatives 4.0 International License.

