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FISCAL SPACE, DEBT SUSTAINABILITY AND THE TRANSITION TO INNOVATIVE GROWTH IN UKRAINE: SYSTEM DYNAMICS APPROACH

Abstract

The purpose of the article is to assess the unique characteristics of government sector debt by employing a system dynamics approach and providing the goodness-of-fit analysis during the war and post-war period in Ukraine. The research formulates a set of proposals for possible post-war period of economic and financial recovery in the context of the debt-to-GDP ratio, fiscal space stability with a transition to an innovation-driven growth model. We use system dynamics tools to analyze and verify data, particularly Stella Architect Software.

The research results are the following: the article indicates the presence of an S-shaped growth pattern in national debt relative to GDP, which indicates the necessity for the government to implement the initiatives to start a debt-free economic growth policy to achieve the goal of long-run independent economic policy making via fiscal reforms, tax revenues optimization, and innovations to foster competitiveness mechanisms. The article proves that strategies implemented for debt restructuring can influence public finances, which subsequently impacts the overall financial standing and stability of the government. It is essential for governments to thoroughly evaluate their options and formulate comprehensive debt restructuring strategies that consider both immediate and long-term financial goals. Neglecting to tackle unsustainable debt levels may result in financial crises, the implementation of austerity measures, and adverse effects on social services and public welfare.

We prove and conclude that public external debt, fiscal space, and total economic capacity, as the elements of government policy, based on a transition to an innovative growth model, are the core elements to promote economic stability and growth while managing the risks associated with public external debt and the limitations of fiscal capacity. The results of the research are useful for the national government of Ukraine to implement fiscal policy with the elements of debt sustainability and innovative development. The execution of these strategies in managing financial debt and fiscal matters is crucial and will be fulfilled in our further research.

Keywords: fiscal space, debt sustainability, national debt/GDP, debt restructuring, economic capacity, system dynamics, S-shaped growth, goodness of fit, debt-dependent model, innovative growth.

JEL classification: H30, O23

Introduction and research problems. There is a growing concern in Ukraine over the further increase in the government's debt ratio, which has become a topic of discussion for scientists and politicians. At the same time, there are views that say economic expansion is necessary in response to a faltering economy due to the current squeezed fiscal space. Fiscal space refers to the gap between the current level of debt and the debt ceiling, which represents the maximum increase in public debt that can be repaid with tax revenues. If the amount of debt exceeds this level, then a state default may be triggered.

Reducing the level of fiscal maneuvering may restrict the government's ability to fully react to negative economic shocks, which is the potential cause of the shortcut budget, an increase in taxes, or shortening the level of social payments.

In the period from 2003 to 2024, the gross foreign debt of Ukraine increased more than 7 times and began to have a pronounced exponential growth pattern, which became especially noticeable after the start of large-scale Russian aggression against Ukraine in 2022 and led to a significant contraction of the fiscal space (Ukraine Total Gross Debt, 2024). At the same time, agreements with the IMF and the EU regarding new tranches and loans in September 2024 made it possible to slightly improve the macro-financial situation in the future, together with the restructuring of Ukraine's external debt in 2024 (Hanina & Rakic, 2024). Such agreements contradict increasing taxes, in particular consumption taxes and corporate income tax, by increasing the taxation of banks and increasing the military levy. Military spending has exponentially increased government purchases and negatively impacted government accounts.

Recent publications analysis. The study of the problems of debt sustainability and fiscal space in Ukraine has a strong connection with the problems of war. Debt restructuring had an ambiguous impact on the economic state of the country in war conditions, with even greater uncertainty in the post-war period. Scientific works devoted to the relationship between external debt and the fiscal space of Ukraine are presented in the works of Bogdan and Jovanović (2023), Petrunenko et al. (2023), Semenenko et al. (2024). The problems of the consequences of the restructuring of the state debt of Ukraine are presented in the works of Chugunov et al. (2024), Thomas (2023), Petrukha et al. (2024), Zhylinskyi (2024), and other scientists.

Unsolved part of the problem. Research conducted in recent years indicates the existence of a significant threat from the growth of external public debt, which undermines the fiscal stability of the national economy. A significant increase in external debt leads to an increase in debt service costs and a greater vulnerability of the national economy to external shocks.

At the same time, budgetary adjustment through external debt regulation and fiscal space stabilization under short-term turbulence (war from an economic shock perspective) are currently not sufficiently covered in the scientific literature, which is largely due to the fact that at the time the article was written, military operations in Ukraine were still taking place. The article claims scientific novelty, since a systemic understanding of the country's macroeconomic stability during the war and after its end has not yet been achieved. The methodology of the article is based on the work of Ghosh et al. (2011).

Purpose and objectives of the article. This article is based on three basic principles – debt sustainability, fiscal space, and system dynamics as a research tool. The scientific problem of the research is based on the section of external debt theory, which concerns the issue of external indebtedness. The main purpose of this article is to study the critical solvency of Ukraine's external debt, which helps ensure the stability of fiscal space using the method of system dynamics and, accordingly, simulation modeling with the development of a scenario-based approach to the optimal level of external borrowing.

The objectives of the article are the following:
– to explore Ukraine's debt sustainability level;
– to evaluate the capacity of fiscal space;
– to develop simulation models with appropriate fit statistics;
– to apply innovative growth elements into the national debt model.

Main findings. The Ministry of Finance of Ukraine predicts a reduction in public debt by 2025 from 100.5% to 97% of GDP (Shevko, 2024), which will lead to a slowdown in its growth dynamics. Despite the projected improvement in the debt situation, the sustainability of the fiscal space remains under threat. In October 2024, the European Parliament approved an emergency loan for Ukraine of up to 35 billion euros, which must be repaid from future proceeds from frozen Russian assets. At the same time, the growth rate of the national debt indicates that such measures are not sufficient without identifying internal endogenous factors to overcome the debt crisis (Fig. 1). We associate national debt with public debt.

The data in Figure 1 confirm the data of the Ministry of Finance of Ukraine (Shevko, 2024), regarding a possible gradual reduction in debt. Thus, in 2025, the debt/GDP ratio should be 106.6%, and in 2029, it will be 92%. The change in this ratio is likely to be the result of a favorable combination of economic growth, effective fiscal policy, implementation of political reforms, and possible deeper integration of Ukraine into the EU. These factors interact with each other, forming positive feedback loops that contribute to reducing the debt burden on the national economy. For in-depth analysis, this scientific work uses system dynamics models that demonstrate the endogenous nature of the economy's exit from a situation of excessive debt overhang.
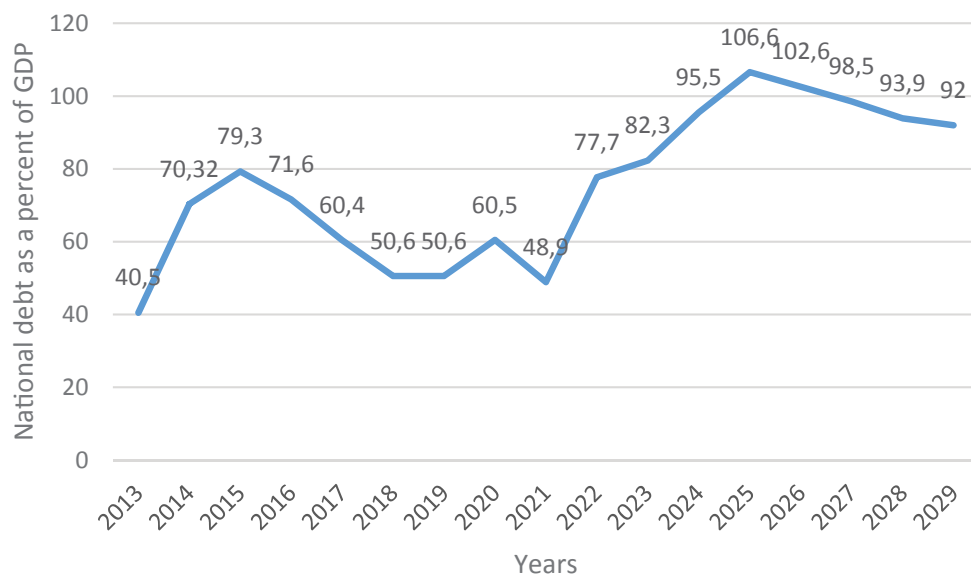
Fig. 1. National debt of Ukraine in relation to gross domestic product (GDP) from 2013 to 2029
(Ukraine: National debt. Statista.com, 2024)
Source: calculated by the author

The end of hostilities and Ukraine's likely victory over the aggressor (Russia) contribute to the further restoration of the country's economic system in the post-war period.

The dynamics of external debt relative to GDP (Fig. 1) indicate the presence of an S-shaped growth, which illustrates a process that is initially characterized by slow growth, then moves to rapid acceleration, and ultimately ends with slow growth or stabilization.

We need to formulate feedback loops for the suggested S-shaped growth (Table 1).

Causal loops: the results of the analysis are reflected in the causal loop diagram, where $r - g$ is the risk – free rate – growth rate. We also add to it the intrinsic economic growth rate (carrying capacity) parameter, which reflects the capacity of the economy to develop autonomously without external debt injections (Fig. 2).

Table 1. **Feedback loops modelling for the suggested S-shaped growth archetype**

| The name of the loop	The nature of the loop	Explanation
R1 Fiscal solvency	Reinforcing loop	The increase in fiscal solvency will lead to an increase in debt, then to fiscal space, and again this would reinforce fiscal solvency.
R2 Fiscal space	Reinforcing loop	The increase in fiscal space would lead to a decrease in the difference between the interest rate and economic growth (the interest payment growth may become smaller relative to the economic growth rate) and to a decrease in fiscal space. In the causal loop diagram shown below, this is depicted as $r - g$.
R3 Debt limit	Reinforcing loop	The increase in the debt limit may lead to a decrease in default probability and a decrease in risk premium, which will normalise the actual growth rate.
B1 Actual growth rate	Balancing loop	The increase in actual growth rate would lead to an increase in fiscal space, which would create a more attractive investment climate and would help to resolve the fiscal solvency issue through innovative development. As a result, the ratio of debt/GDP would decrease. The effect on the primary multiplier is positive, as well as the effect of the former one on the actual growth rate.
B2 Primary balance multiplier	Balancing loop	The increase in primary balance multiplier would lead to an increase in fiscal space and then to a decrease in $r - g$, which leads to an increase in debt/GDP ratio and to an increase in primary balance multiplier through the mechanism of innovative growth.
B3 Risk premium	Balancing loop	The increase in risk premium will lead to an increase in debt limit, which lowers the interest rate and increases the risk premium.
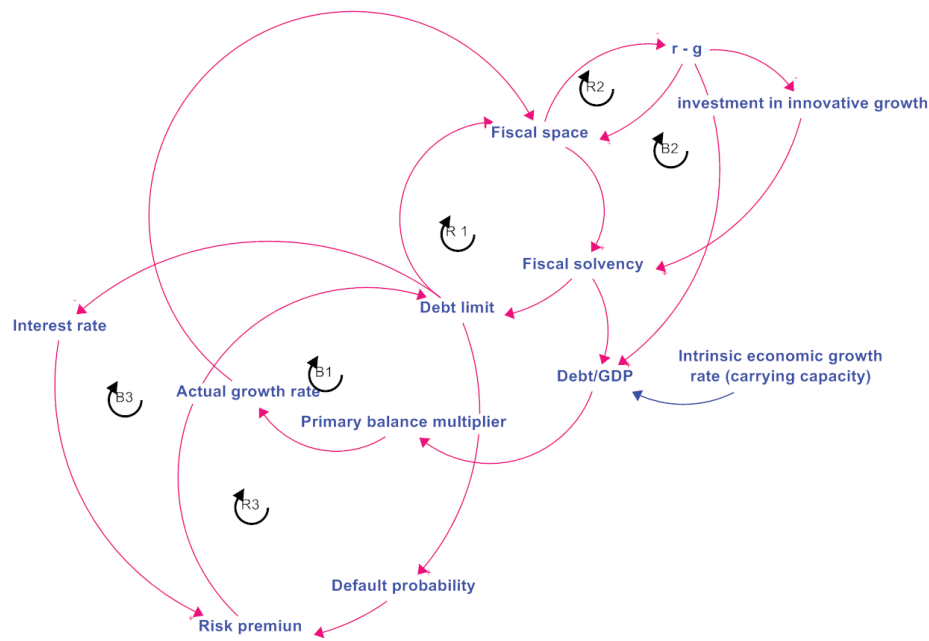
Fig. 2. Causal loop diagram (S-shaped growth case)
Source: calculated by the author

The first very basic model components:

Stock of debt and fiscal space. **Inflow of debt** (borrowing). Outflow of debt (repayment). **Parameters**: debt repayment rate, growth rate stimulated by external debt, and intrinsic economic growth rate. The *boundaries of the model* are initially outside debt and fiscal space.

Time horizon for the model is 8 years, from 2021 to 2029. The year 2021 was chosen as the last year before Russian aggression in Ukraine in 2022 and 2029 as the year of possible new debt restructuring (which provides debt relief) for Ukraine by external creditors. That is our time limitation boundary. The time step (dt) is 0.25, which also represents the boundary of the system (Table 2).

We classify the variables by groups (exogenous, endogenous, excluded).

The above-mentioned variables are now included in the new stock and flow. The expanded version with three stocks is presented below (Fig. 3).

The diagram consists of four component stocks: fiscal space, national external debt, debt restructuring (this is especially relevant for Ukraine, which restructured its debt in 2024), and government accounts stocks included in the analysis based on (Wheat, 2017). In the context of Ukraine's overwhelming dependence on external financial resources, external debt forms the national fiscal space, which in turn is reduced by outflows to the external debt stock. The complexity of interrelationships between parts of the model does not allow us to provide full goodness of fit, so we limit our research to partial goodness of fit. It is expected that the fiscal space will stabilize due to the active innovation policy of the state, despite its prolonged contraction over an extended period of time (Fig. 4).

Table 2. **Model boundary chart for a model of debt repayment**

Exogenous	Endogenous	Excluded
Intrinsic economic growth rate	Public debt	Unexpected shocks
Growth rate stimulated by external debt	Fiscal space	Other than lagged debt systemic determinants of the primary balance
Actual growth rate	Debt growth	Age dependency ratio
Debt repayment rate	Primary balance multiplier	Future age dependency ratio
	Debt restructuring	Expected return on sovereign debt
	Debt outflow – restructuring	
	Debt/GDP	
	Innovative development	

Source: calculated by the author

Fig. 3. Expanded four stocks and flow diagram
Source: calculated by the author based on (Wheat, 2017)

Fig. 4. Part of the general model, taken for goodness-of-fit analysis
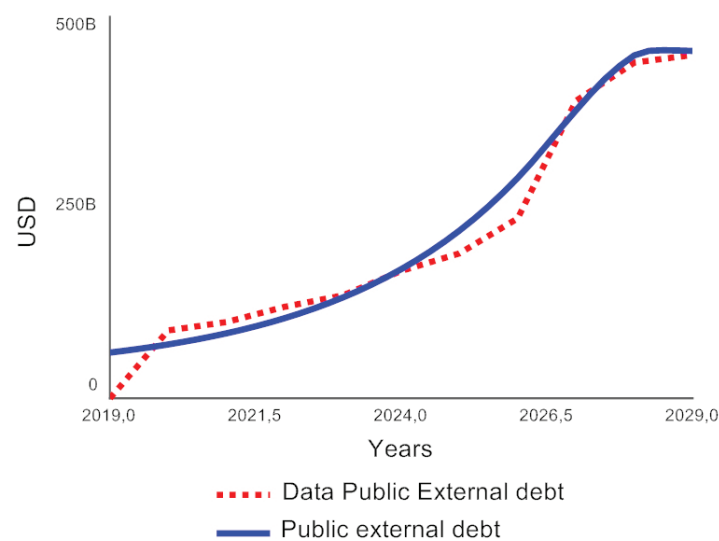*Source:* calculated by the author

Fig. 5. Goodness-of-fit results
Source: calculated by the author

The adequacy of the model was verified using the method of iteration and data selection (Fig. 5).

The result of the adequacy check indicated a rather significant gap between the modeled data and the real system in the period from 2024 to 2027. During this period, we can observe the process of post-war reconstruction of the Ukrainian economy, which may cause a significant exceedance of the debt burden over the economic potential of the Ukrainian economy. Economic stabilization may occur starting in 2027, which means real economic recovery and a gradual reduction in the debt burden, which is reflected in a greater adequacy of the modeled data to the real data in the period from 2027 to 2029 (Table 3).

These are the final values of goodness of fit. The correlation is 0.988, which means that we've been doing a statistical test that would be reliable. R-squared explains 97% of the variation. We can also look at how that error is decomposed and to what extent it has the same mean structure. Three components (U^m – mean square error due to bias, U^s – unequal variance, U^c – unequal covariance) should always add up to one. Most of the error is unequal variance.

Conclusion and suggestions for further research. The result of the conducted scientific research was the establishment of a regularity of the relationship between sovereign debt and fiscal space. The conducted goodness of fit between real statistical data (observed data) and modeled data indicates a sufficient level of closeness in the relationship.

The conducted research allows recommendations to the national government on determining the financial position of the country, diagnosing and managing macroeconomic policy to achieve long-term fiscal sustainability with the elements of innovational development.

Further modeling will be aimed at eliminating the problem of unequal variance, in particular, considering interactions in the framework of regression analysis. Adding interactions between variables to the model to account for their unequal influence on the result may resolve the issue. System analysis requires the study of endogenous relationships, and it is necessary to investigate how the interaction between external financial and trade flows occurs. Utilizing a gravity model within the context of system dynamics holds considerable importance for various reasons, especially in the

Table 3. **Final values fit**

Public external debt fit. "Correlation. XsimXobs"	0.988
Public external debt fit. R-squared	0.976
Public external debt fit. MSE	495E18
Public external debt fit. U^m	0.102
Public external debt fit. U^s	0.0287
Public external debt fit. U^c	0.87

Source: calculated by the author, based on (Ukraine: National debt. Statista.com, 2024)

analysis of intricate systems and their interactions in domains such as economics, international trade, and sovereign lending.

One of the key principles for the successful post-war development of the national economy is its foundation on innovation-driven growth, along with the corresponding development of innovative strategies. For this, the implementation of such strategies in financial debt and fiscal management is essential.

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ФІСКАЛЬНИЙ ПРОСТІР, СТІЙКІСТЬ БОРГУ ТА ПЕРЕХІД ДО ІННОВАЦІЙНОГО ЗРОСТАННЯ В УКРАЇНІ: ПІДХІД СИСТЕМНОЇ ДИНАМІКИ

Метою статті є оцінювання унікальних характеристик боргу державного сектору за допомогою підходу системної динаміки та проведення аналізу відповідності під час та після війни в Україні. Сформульовано пропозиції щодо можливого післявоєнного економічного та фінансового відновлення в контексті співвідношення боргу до ВВП, стабільності фіскального простору з переходом до моделі зростання, орієнтованої на інновації. Використано інструменти динамічної системи для аналізу та перевірки даних, зокрема Stella Architect Software.

Результати дослідження. Вказано на наявність S-подібної моделі зростання державного боргу відносно ВВП, що свідчить про необхідність для уряду запровадити ініціативи із започаткування політики боргового вільного економічного зростання для досягнення мети довгострокової незалежної економічної політики шляхом фіскальних реформ, оптимізації податкових надходжень та інновацій для стимулювання механізмів конкурентоспроможності. Доведено, що стратегії реструктуризації боргу можуть впливати на державні фінанси, що згодом позначиться на загальному фінансовому стані і стабільності уряду. Важливо, щоб уряди ретельно оцінили можливі варіанти та розробили комплексні стратегії реструктуризації боргу, які враховують як найближчі, так і довгострокові фінансові цілі. Ігнорування заходів щодо подолання неприйнятного рівня боргу може призвести до фінансової кризи, впровадження заходів жорсткої економії та негативного впливу на соціальні послуги та суспільний добробут.

У статті зроблено висновок, що державний зовнішній борг, фіскальний простір і загальна економічна спроможність як елементи державної політики, що базується на переході до інноваційної моделі зростання, є ключовими елементами для сприяння економічній стабільності та зростанню за одночасного управління ризиками, пов'язаними з державним зовнішнім боргом та обмеженнями фіскальної спроможності. Результати дослідження можуть бути корисними для уряду України в реалізації фіскальної політики з елементами боргової стійкості та інноваційного розвитку. Реалізація цих стратегій в управлінні фінансовою заборгованістю та фіскальними питаннями є головним завданням, яке буде виконано в подальших дослідженнях.

Ключові слова: фіскальний простір, боргова стійкість, національний борг / ВВП, реструктуризація боргу, економічний потенціал, системна динаміка, S-подібне зростання, адекватність моделі, боргова залежність, інноваційне зростання.

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