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SOVEREIGN DEBT AND POST-WAR UKRAINIAN ECONOMIC GROWTH – SYSTEM DYNAMICS APPROACH

The aim of the article is to examine the post-war national economy, notably overburdened with significant war expenditures and the effects of sovereign debt restructuring in a wartime period. The research uses system dynamics modelling methods, operates with S-shaped growth, overshoot and collapse dynamic patterns. The oscillation patterns of behaviour have been used to demonstrate the scenario options of possible external debt minimization.

The dynamic hypothesis about non-linear behaviour of post-war debt trajectory has revealed the intrinsic growth rate in debt-dependent economy and the inflection point of no return to stable economic growth without radical decision of sovereign debt cancellation. The direct consequence of a negative solution for debt cancellation would be the unpredictable, even chaotic fluctuations of national economic growth rate. Baseline simulation to prove the results of research has been provided. The embedded "dependent-economy" type of macrostructure does not allow to overcome the critical debt overhang level and needs a new national model with appropriate policy to stabilize the economy. Performance of post-war debt repayment depends mostly on an innovative fund, which can be created by export abilities in the framework of post-war recovery plan. The results of the research may be applied by national authorities responsible for macroeconomic debt policy. The obtained results of the study allow us to draw a conclusion about the impossibility of developing the national economy within the framework of the existing economic structure of the developing country. The debt trap, which cannot be eliminated, does not allow to develop the national innovative economy and ensure economic growth and development.

Keywords: sovereign debt and debt restructuring, national inventories, debt-to-GDP ratio, Russian war of aggression, postwar economic growth, system dynamics, overshoot and oscillation inventories curve.

JEL classification: E37, F34, F35, G28, H63

Introduction and research problem. According to Brzoska (1983) "the key factor determining the fall in GDP through the growth of external debt is military spending." The dynamic problem is in devastating exponential growth of external debt, triggered by Russian aggression in February 2022, which may "eat out" the lion's share of national income with further possible overshoot in reaching the (economic)goal and collapse. The overshoot is triggered by the desired short-run strategic goal to win the war against Russia with appropriate concentration of all possible economic resources in the military and defence sphere, with further critical debt overburden and collapse of the national economy without external aid. Until the national economy is contained by external debt, there is a risk of the former one to collapse suddenly with a simultaneous sudden stop of external financing.

Recent publications analysis. The analysis of publications is aimed to find the research gap to carry out the scientific analysis. The structure of our literature review consists of some literature layers on sovereign debt restructuring, war and post-war macroeconomic performance and sovereign debt default. Most of the revealed research are focused on the problem statement rather than problem solution and perceive primarily negatively sovereign debt restructuring and affirm that sovereign debt restructuring cannot stop the outflow of developing countries financial resources in a form of annual interest payment, which creates a high risk of economic collapse during frequent sovereign debt restructuring. In (Plieshakova et al., 2022) the issue of the critical debt overhang in Ukraine along with national debt security was considered. In (Gorodnichenko et al., 2022) "Kyiv approach" of handling non-performing loans (NPL) as "the voluntary out-of-court restructuring" is opposed to "Korean fundamentally market approach to handle NPL." In the same research paper, the necessity of "Brady bonds as a part of debt restructuring" appears to be complementary to Eurobonds. The sovereign debt restructuring vector of scientific research has received a practical embodiment in (Bogdan, 2023),

who asserts that it is "necessary to increase the share of grants in external finance structure to reduce the risk of debt crisis and to work out the issue of post-war debt restructuring." In the review study of (Das et al., 2012) the far-reaching review of sovereign debt restructuring has been conducted along with (Megliani, 2015) where the important issue of sustainability exclusion in a period of sovereign debt restructuring has been brought up.

At the same time, despite the considerable number of scientific publications devoted to sovereign debt restructuring, the holistic (systemic) representation of the debt restructuring problem has not been widely distributed. The fundamental ideas of debt representation in dynamic modelling are presented in (K. Yamaguchi & Y. Yamaguchi, 2021).

System dynamics approach to this issue was considered by (Lewis, 2013), where the holistic problem of "stability restoring after severe macroeconomic shocks" has been identified and the solution in a form of "causal underlying structures for identification of debt spillover over banking sector" with appropriate sensitivity and testing has been proposed.

Unsolved part of the problem. The research gap in literature review has shown the lack of publications, which are dealing with the endogenous approach to sovereign debt restructuring. The structure of the Ukrainian national economy is dangerously oriented towards the reinforcing of external debt, triggered by military expenditures. The system with exponentially growing debt, which relies primarily on external financing is exogenously opened and is ought to create in the short run the endogenous mechanism of self-regulating in the form of a balancing loop. Otherwise the system may take the form of the "bell-shaped" overshoot and collapse. The issue of the article is to redirect the decision-making process of the debt regulation from primarily external global form to national, internal one.

Research goal and questions. The importance of the problem must be considered from an empirical and theoretical point of view. *Empirical aspect.* The dynamics of overshoot and collapse of the debt burden caused by war burden is still poorly understood in science and practice. The core idea here is the possible expansion of internal macroeconomic financing to repay the external debt with appropriate extension of the safe level of the debt carrying capacity. *Theoretical aspect.* The external debt management dominance in national debt solution creates the exogenous type of model. At the first stage "there is not much 'management'" we can do because the model is too open and dependent on the international creditors to create the independent national debt policy (Barlas, 2002). To change the situation, we need to reveal the hidden internal forces to be able to close the loop and create the endogenous dynamic model.

Main findings. External borrowing has a contradictory effect on economic growth: sovereign debt can be a driver of economic growth up to a certain critical debt overhang or to serve as a constraint to it. Minimum or zero level of debt creates minimum limitation to economic growth. Using (Ford, 1999) terminology, we will call the growth rate without debt limitation *intrinsic growth rate.* Intrinsic growth rate in debt-dependent economy applies when the external debt absorbs relatively small part of the national "liabilities assets." But as the external debt becomes deeply embedded into national economic structure, it absorbs a larger and larger share of national economic space. The latter one may shrink to the minimum, or even collapse. The independent economic reproduction approaches the minimum. There is an inflection point, which cannot be crossed, because the actual economic growth rate becomes less than intrinsic growth rate. In this case the growth rate multiplier of sovereign debt will lower radically the actual growth rate over time and sovereign debt needs restructuring in one form or another.

One of the basic steps to solve the problem is its dynamic definition (articulation). We formulate it as: "Why Ukraine's macroeconomic system creates the problem of remaining in the state of vicious external debt circle?" and "Why the sovereign debt restructuring in war time may deteriorate the national economic well-being after the war?"

Time horizon: we should consider the problem at least for 30 years into the future, starting from the time of Russian military aggression into Ukraine in February 2022, which is determined by a difficult period of post-war recovery of a partially destroyed national economy burdened by overhanging debt. The roots of the problem are at least in 1992, with the beginning of the rapid growth of Ukraine's external debt.

List of the variables, which are contributing to the problem, are presented lower, in the aggregated causal loop diagram. From them we distinguish national inventories, wartime expenditures and sovereign debt as the key stock factors, which accumulate time, create delay, and need to be regulated via systems of flows.

Reference behaviour (Figure 1) is built upon key variables, which are above mentioned in the list of variables. Inventories and sovereign debt have been converted into debt-to-GDP ratio. We associate national inventories (national wealth) with the capacity for economic growth and development.

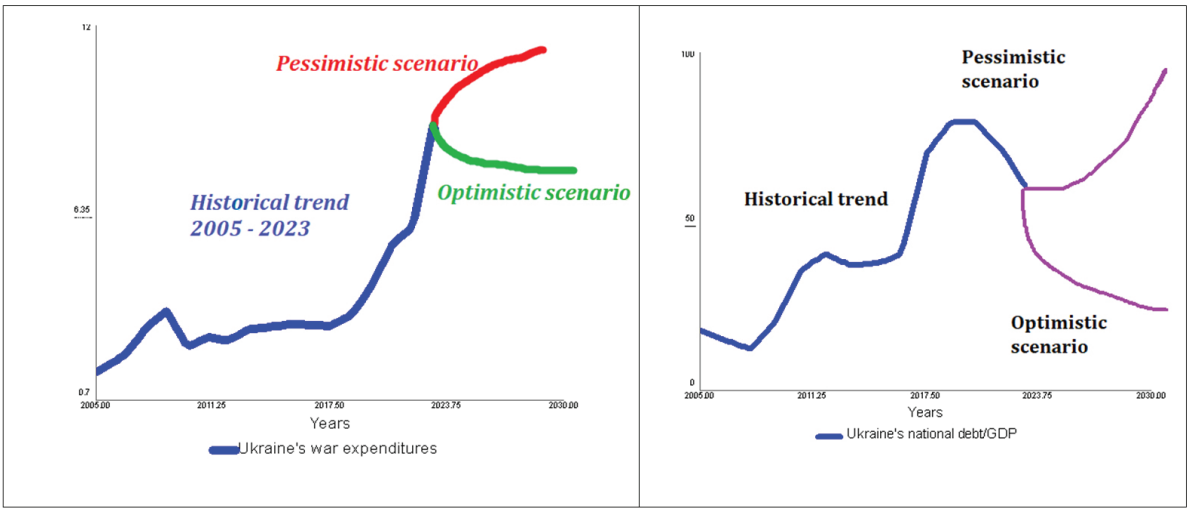

Fig. 1. Reference mode for inventories and debt/GDP in Ukraine
Source: built by author, based on (www.statista.com, 2005–2023)

Looking ahead, our optimistic scenario under the condition of debt writing off corresponds to the 5 runs sensitivity analysis with declining sovereign debt after the end of the war.

Figure 2 presents causal links, aggregated into corresponding balancing and reinforcing loops, and reveals the logic of the reference mode presented above. The represented mental model helps to recreate the basic wartime and post-war logic of sovereign debt overhang over the national economy. The presented causal loop presents the evidence of the strategic influence of investor climate improvement on national economic security which also depends on the ability to manage effectively with the funds received. In particular, the reorientation of high technologies from war expenditures for peaceful purposes in a form of National Investment Fund creation ensures the transition to new technological stage of national development under the condition of effective and transparent management of funds.

Debt trap (B1). The reinforcing loop has been created based on (Pettis, 2001) which claims the existence of "exchange rate crisis, precipitated by inflationary monetary policy," which is inevitable after the war. In this scientific work it is also stated that "dependency on primary export leads to overvaluation of national currency and will slow the economic growth." The consequences are a threat of the debt trap and decreasing of external borrowing to support the national economy. "The expected exchange rate (along with interest rate differentials) is a cause of capital movement" (Pettis, 2001). The negative side effect of primary export dependency in Ukraine has been aggravated by possible devaluation of the Ukrainian hryvnia in 2023 and the rise of global food price, accelerated by war in Ukraine. The devaluation of national currency results in postponing (delay effect) the strategic decision of sovereign debt repayment and increases their absolute volumes, denominated in the currency

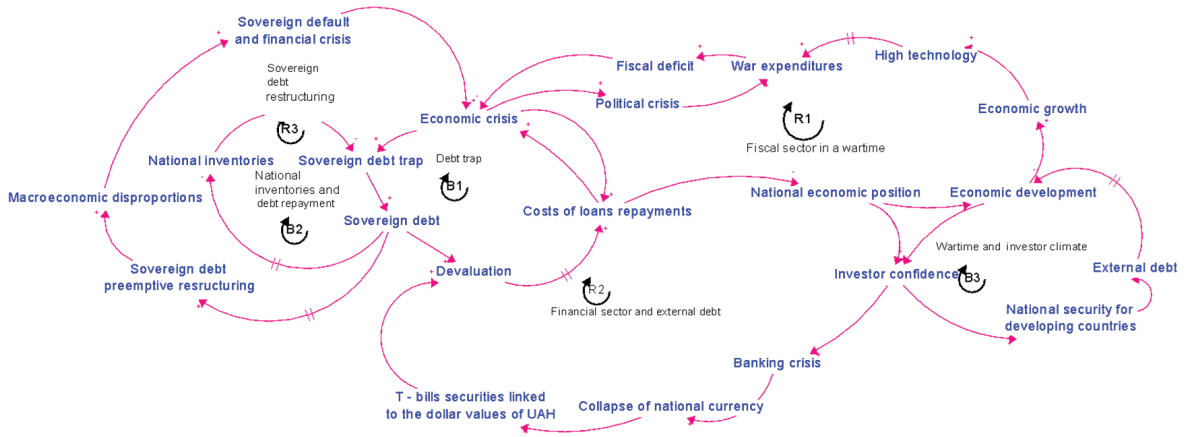

Fig. 2. Aggregated causal loop diagram
Source: built by author based on literature review

of the creditor country. For today the possibility of a currency crisis in Ukraine is buffered by a well functioned local monetary regime.

National inventories and sovereign debt repayment (B2). National inventories reduction, caused by sovereign debt crisis and economic crisis (loop B1), is a "critical warning signal" for maximum sovereign debt threshold achievement and necessity for a new macroeconomic policy, aimed at substantial external debt reduction. Our opinion differs from (Moore, 1989), who asserts the "perfect foresight with neutral public debt" and almost instant "inventories intertemporal adjustment" with appropriate risk aversion. We believe in a substantial time delay between sudden sovereign debt shock, agents (sovereign debt policymakers) decisions to minimize it and national inventories adjustment to cover by faster rate of GDP growth the economic losses, caused by above mentioned shock. Sovereign debt accumulation makes the delay in national inventories increasing almost impossible since the newly created national wealth will be used to cover the existing debt and its service, and not to economic development.

Wartime and investor climate (B3). It is asserted in (Azam & Feng, 2015) that "military conflict exacerbates both the external investors' confidence in national markets reliability and the risk of losing the long-run economic development, triggered by external debt threatening increasing, implicitly and explicitly caused by military escalation." The Ukrainian economy is splitted by the dilemma of post-war national security sustenance, sovereign debt repayment and economic growth and development. The positive impact of the increase in military spending on the dynamics of economic growth can be observed in the case of high-tech technologies spillover into the civilian sectors of the economy and transition to a new technological paradigm of development. The positive effect of military spending on sovereign debt should be overlapped at a faster rate of GDP growth. It is also obvious that increasing external debt will postpone the national economic development.

Fiscal sector in a wartime (R1). A trigger mechanism of external debt accumulation are the wartime expenditures, amplified by new technologies spillover over the economic sector (Brzoska, 1983; Azam & Feng, 2015). In the situation with Ukraine, the negative situation is reinforced by the lack of real breakthrough technological innovations aimed at updating the defence-industrial complex, and by predominant military products import, though military investment is not the optimal way to allocate the national resources. The economic crisis deepens the problem of payment of external debts and worsens the national economic position, which inhibits economic development and negatively affects the prospects of economic growth. At the same time global financial market shocks in 2023 may critically exacerbate the financial and economic problems in Ukraine. The possible delay in high technologies implementation may reduce the fiscal deficit, though at the same time will lead to national security level decreasing.

Financial sector and external debt (R2). According to (Pettis, 2001) the devaluation increases the costs of loan repayment which deteriorates the national economic position and investor confidence and deepens crisis, which may lead to a collapse of national currency with an effect of T-bills securities to the dollar values of UAH downgrading with a new round of national currency devaluation. There is a reinforcing loop of national currency devaluation, which makes the process of sovereign debt repayment more difficult. The sovereign debt restructuring is needed. Debt repayments postponed by Eurobonds may substantially save national budget expenditures. At the same time *(Sovereign debt preemptive restructuring (R3))* is a leading cause of the delayed macroeconomic disproportions, exacerbating the possible debt trap risk, risk of sovereign default and economic crisis with further political crisis and possible social and political unrest and even military escalation. The risk of sovereign default of Ukraine's economy has substantially increased since the beginning of Russian aggression in February 2022. Correlation is being tracked between sovereign debt restructuring, sovereign debt crisis and a threat to political stability. "Debt restructuring is a cause and the indicator of financial distress and increasing of sovereign risk, which may lead to the necessity of even larger debt restructuring" (Pettis, 2011), may be fatal to the national economic system and takes the form of reinforcing by war negative effect in the long-run. On the other hand, international investors are increasing confidence in the local economy after debt restructuring, though it may also deepen the external financial dependence. As a result, there is a collision of opposite tendencies — the balancing loop (B3) with the reinforcing one (R1). Predominance of the reinforcing power over balancing (in this case) leads to unpredictable chaotic consequences. At the same time, the predominance of the balancing loop gives the economy, which is in a difficult post-war economic situation, a chance for survival and development.

1. The debt issue resolution gives the national economy the chance to "release" economic resources for economic development and growth.

2. "Release" from debt dependence allows the economy for a new model of economic development.

As indicated by reference mode debt/GDP, the S-shaped growth structure of it is expected to be formed after the war ending, though S-shaped growth is practically impossible without a multiplier introduction to be constructed. The procedure is the following: in the debt dynamics model we build a model of a national economy in 3 segments: external debt, war expenditures and national inventories. We build and test each stock singly and then start to connect the segments. To start modelling, we initialize the model in equilibrium state. *Equilibrium diagram* aims to provide the first dynamic testing and develop stock and flow model (Figure 3) with appropriate construction procedure.

Basic assumptions for equilibrium diagram

We want to answer the question: "What must be the initial values to reflect dynamic equilibrium?"

National capital stock (Inventories) – USD 6,392,188*10^9 in 2019. Adjustment for rapid economic growth in 2021 allows to assert an increase of it to USD 6,980*10^{12}. The war destruction in 2022–2023 caused the national inventories to shrink by approximately 40 %. The estimated reconstruction of the destroyed economy will cost no less than USD 750*10^{12}. After subtraction of it and war expenditures = USD 12*10^{12}, the National Inventories = USD 3*10^{12}.

Sovereign debt = USD 12.8*10^9. War expenditures = USD 12*10^9.

Let I = Inventories (National capital stock), Exp – War expenditures and D – Sovereign Debt. The rate of debt inflow – 0.2 and the rate of war expenditures – 0.1.

The flows must equal: D*0.2 = Exp*0.01 = I*1. We skip the intermediate calculations and obtain the following results to present the dynamic equilibrium.

D = USD 12*10^9; Exp = USD 12*10^9; I = USD 3*10^{12}. D+ Exp +I= USD 3*10^{18}.

We are placing the results of calculations into our stock, presented on Figure 3.

Stocks and flows model building. S-shaped model construction involves carrying capacity, which is economic growth rate without sovereign debt limitation. In a balanced economic system, as a debt (external resource) gets consumed, the national inventories that depend upon that resource will stabilize at a level, where the debt can regenerate each year. This will mean that as the inventories grow towards the carrying capacity, the external debt would likely increase (because of the national economy inability to expand further without external debt).

The results of stocks and flows modelling were substantially modified to compare with the previous research. In particular "Fraction occupied" has been substituted to" Inventories ratio occupied by external debt" for better reflection of the economic processes. The most fundamental change is in adding the "Sovereign debt post-war repayment/writing off" connector to "Disturbance debt inflow" by assuming the cyclical nature of the economy. Multiplier components produce different values. The product of growth rate multiplier and growth rate without sovereign debt limitation generates a new value – economic growth and debt repayment. The growth rate multiplier of the effect of economic growth on debt is defined as a graphical function converter. The horizontal axis for the graphical function will be a ratio of 2 components that have the same units. This will make the input "dimensionless." The ratio here will be = Inventories ratio occupied by debt (IRD). IRD is a ratio of two components: external debt/ total economic space. The volume of the ratio will be a number between 0 and 1. When the ratio is 0, there is no economic growth. When the ratio is 1 the debt is on the level of the carrying capacity. We assume the existence of the S-shaped form multiplier in a consequence with sovereign debt S-shaped form. A change in the generic mode is taking place with adding the converter "Sovereign debt repayment or writing it off." We hold the point of view that the cyclical fluctuations of each new wave of economic growth is accompanied by a new wave of economic growth (external debt is an engine and the limitation to growth in developing and emerging market countries). "Economic growth rate without limitation must equal the intrinsic growth rate" (Ford, 1999). As the external debt spreads across the national inventories area, it covers a larger part of the national economic area (economic space). The latter one may shrink to the minimum, or even collapse. The growth rate multiplier is on the highest level when external debt occupies the minimum economic space and decreases with the level of sovereign debt. When the ratio of economic space by debt occupation reaches 100 % the ratio of economic growth stabilizes on the minimum, close to zero level as the national economy becomes too risky to invest in. Representation of this graph confirms the scientific opinion about the importance of a moderate level of sovereign debt maintenance. We should also note that this situation is mostly unacceptable for countries with a high level of economic development, which are ready to service their external debt, which even exceeds their annual GDP.

The results of simulation analysis are coherent with reference mode, which have been presented. The amount of foreign debt increases sharply after the end of the war for about 8–10 years, which is

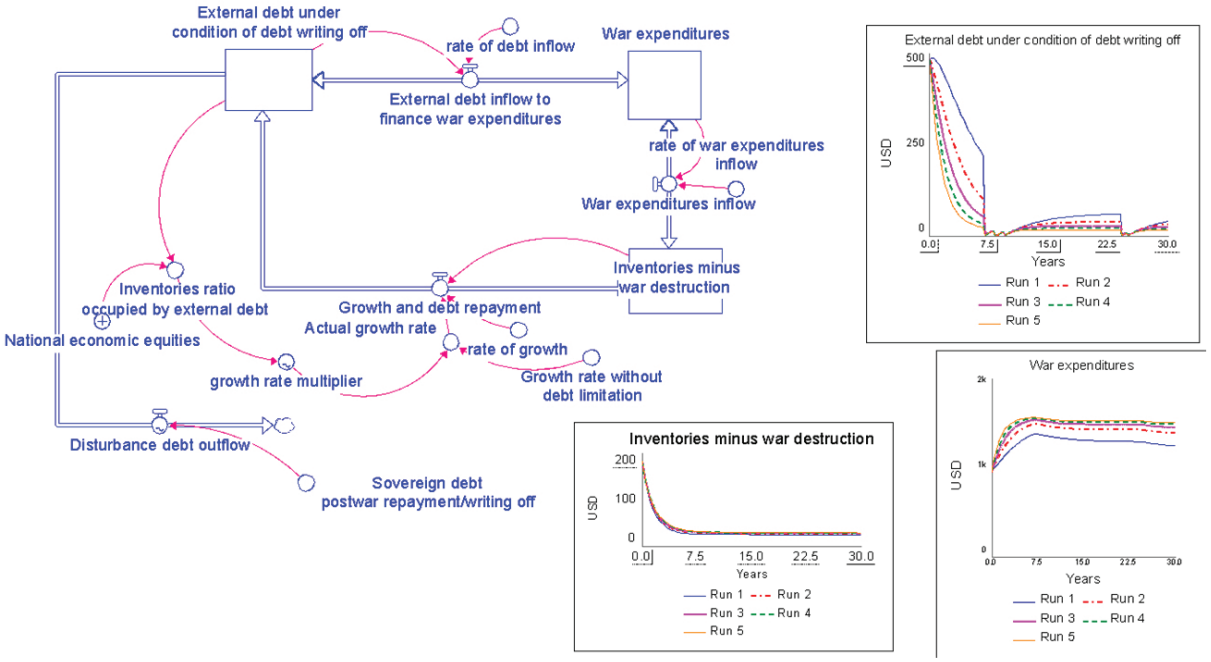

Fig. 3. Stocks and flows "sovereign debt – economic growth" modelling and simulation analysis under condition of sovereign debt writing off after the war
Source: built by the author

due to the need to restore the destroyed part of the national economy. After that, it begins to decrease and stabilize, which is caused by the effect of the fall in the rate of economic growth, caused by the impossibility of financing it with external sovereign debt, which has reached critical proportions. At the same time we are observing the gradual stabilization of war expenditures level, which even increases after the end of the war, which is due to the factor of the creation of the national military-industrial complex with its corresponding large-scale financing. War expenditures will increase for some time and then start to stabilize. We have chosen the sensitivity of the rate of debt as the core factor of influence on all three stocks in a diapason from 0.2 to 0.8 with 5 runs. The level of external debt behaviour changes proportionally to the debt rate change. There is a gap in the behaviour of military spending to compare the minimum established level of the debt rate with the rest of it. This can be explained by the non-linear growth of the debt, overburdened by budget deficit and tax load. Since the level of war expenditures directly relates not just to internal economic absorption, but also to external reserves (golden and currency reserves) outflow to finance the expenses (including war technologies procurement), the exhaustion of the last one leads to their stabilizing on some level. The sovereign debt is oscillating around the process of changing defence spending and, above all, national inventories capacity. The sharp decrease in external debt will also sharply decrease the level of national inventories. The subjunctive part of external debt on the diagram especially reflects the wishful thinking approach ("What if?") of the sovereign debt writing off at least at the beginning of 2000s. On the other hand, the sovereign debt writing off is possible after the end of the war approximately in 2023.

Conclusions and further research proposals. The results of the conducted research enter a certain contradiction with the statement about the fall of the GDP under the influence of the increase in military expenditures. The analysis carried out by the method of simulation modelling has indicated the opposite: the national economy in the short- and medium-term periods is able to maintain its economic potential under the influence of rising defence costs. However, it is fraught with a sharp drop in the rates of economic growth and national wealth in the long term.

National inventories in developing countries and in some emerging ones are embedded into the cycle of the external financing and are strongly dependent on them. The irregular oscillation of national inventories as a risky process indicates the need of policy implementation to balance the budget with the appropriate binding to balance of payments regulation (especially gold and exchange reserves outflow).

One of the main ideas of our research was to show that national economic growth without external debt is impossible. The deficit of national

savings is compensated by the inflow of external capital in the form of sovereign debt. The sharp decline in national inventories is a result of sovereign debt overburden with the corresponding debt and economic crisis. If the precautionary measures to restructure the foreign debt taken during the war do not reduce the debt burden, Ukraine risks falling into a debt default situation, which will nullify the possible positive effect of the post-war economic growth.

The high probability of global economic recession in 2023 will further deepen the economic crisis in Ukraine. The fluctuation amplitude for national inventories will increase even more to compare with Fig. 3 of the conducted research and undermine the stability of the national economic and financial system.

As the study showed, the external debt has the shape like a bell-shaped curve. The overshoot and collapse threaten the national system. The cause of the danger is in the structure of the national model, which consolidates the status of the developing country.

The study presents a system of aggregated cause and effect relationships that aggregates financial sectors with an external debt, national inventories with debt repayment, fiscal sector, and investor climate in a wartime.

We propose to shock the system via disturbance debt inflow with flexible sovereign debt post war repayment rate/writing off which helps to level out the negative effect of national inventories decrease. The disturbance flow creates the oscillation process which increases when the period for oscillation also increases. We assume the existence of damped oscillation with a lower economic growth. The run 1 of external debt of external debt writing off (Figure 3) is the largest one, which reflects the feedback effect of the causal loop diagram (Figure 2). The model without disturbance flow generates a simple S-shaped growth, which may be valid only in a short and medium run period of time.

Future studies will be oriented onto sovereign debt policy management and stocks regulations via flows. Our plans include to prove the existence of chaotic behaviour of national economic structure under the turbulence of sovereign default.

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ДЕРЖАВНИЙ БОРГ І ПІСЛЯВОЄННЕ ЕКОНОМІЧНЕ ЗРОСТАННЯ УКРАЇНИ: СИСТЕМНО-ДИНАМІЧНИЙ ПІДХІД

Метою статті є дослідження післявоєнної національної економіки, особливо перевантаженої значними військовими витратами та наслідками реструктуризації державного боргу у воєнний період.

Методи дослідження: використовуються методи моделювання системної динаміки, зокрема S-подібні динамічні моделі зростання, перевищення та колапсу. Для демонстрації сценарних варіантів можливої мінімізації зовнішнього боргу використано осциляційні моделі поведінки.

Результати дослідження. Динамічна гіпотеза про нелінійну поведінку траєкторії післявоєнного боргу виявила внутрішні темпи зростання боргозалежної економіки та переломну точку неможливості повернення до стабільного економічного зростання без радикального рішення про скасування державного боргу. Безпосереднім наслідком негативного рішення щодо списання боргу будуть непередбачувані, навіть хаотичні, коливання темпів зростання національної економіки. Було виконано базове моделювання для підтвердження результатів дослідження. Вбудована макроструктура типу «залежна економіка» не дозволяє подолати критичний рівень боргового навісу та потребує нової національної моделі з відповідною політикою для стабілізації економіки. Ефективність погашення післявоєнного боргу залежить здебільшого від інноваційного фонду, який буде створений експортними можливостями в межах плану післявоєнного відновлення.

Можливе застосування результатів дослідження: використання державними органами, які відповідають за макроекономічну боргову політику.

Висновки. Отримані результати дослідження дають змогу зробити висновок про неможливість розвитку національної економіки в наявному економічному укладі країни, що розвивається. Боргový зашморг, який неможливо усунути, не дозволяє розвивати національну інноваційну економіку та забезпечувати економічне зростання й розвиток.

Ключові слова: державний борг і реструктуризація боргу, національні запаси, співвідношення державного боргу до ВВП, російська військова агресія, післявоєнне економічне зростання, системна динаміка та імітаційне моделювання, криві перевищення та осциляції.

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