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I. O. Zagoruiko, L. O. Petkova**MODELLING OF THE EVOLUTION OF AN AGGRESSIVE TOTALITARIAN REGIME:
A GEOMETRIC APPROACH**

The article is devoted to the methodology of modelling the evolution of an aggressive totalitarian regime. The methodology is grounded on macroeconomic functions and their geometric reflection. Several models are built and analyzed in the article, such as socio-political, military-economic and socio-economic evolution of totalitarian society; evolution of labour potential; goods' net exports and production capacity of the country with a variable level of statization of the economy; changing economic potential during the war between a large totalitarian country and a small democracy country.

The nowadays totalitarian regime (similar to the previous one) is based on the statization of the economy and the manipulation of information. The statization isn't total now, but the means of manipulation have improved significantly. The authors have suggested that the reduction of repression in a totalitarian country is not a sign of its liberalization. The economic growth leads to the impoverishment of the population, and economic crises – to its loss of skill in quasi-market circumstances. Together they strengthen the regime's social base. High prices for low-tech goods increase the level of statization of the economy and, consequently, reduce the country's productive potential. Specialization in low-tech exports puts it in a "trap of statization", where the positive trade balance becomes impossible to even with lower levels of government regulation. Deteriorating global conditions for trade in low-tech goods create a situation of uncertainty when the level of statization can both fall and rise. The excess of maximum allowable losses over the minimum possible losses of a large totalitarian country becomes the "trigger" for open aggression. The fundamental asymmetry like the losses for the military-and-economic potential of a large totalitarian country and a small democratic country is the peculiarity of the clash between them.

Keywords: *Russian aggression against Ukraine, war economy, totalitarian society, statization, income distribution, production function, economic potential, net exports, high technology.*

Introduction. The transformation of the Yalta-Potsdam system of international relations caused by the destruction of the bipolar world and the movement towards multipolarity hasn't received proper institutional and political approval yet. The formation of new world order for more than four decades is taking place with the intensification of a growing number of uncertainties. Threats to the world order became asymmetric and they haven't the time or geographical frameworks. International terrorism and nuclear war are the most well-known of these threats.

The tragic events of the Russian-Ukrainian war and the consolidation of the international community's response to the unprecedented military aggression of the Russian Federation through a set of economic, political and military measures allow determining the trend of new world order. From the idea of J. Rosenau of "post-international politics" with chaos, identity distortion, reorientation of traditional ties of authority and loyalty, the world returns to the basic laws of international systems – the dependence of actor's behaviour on the structural characteristics of the system (S. Troyan, 2016). The transformation of security-based concepts and structures expected throughout the post-bipolar period is returning to confrontational structures. The instruments of strong sanctions deterrence (primarily economic) and significant geopolitical constraints have to be used in addition to traditional mechanisms.

The world requires unequivocal political leadership, moreover, the current crisis conditions are mobilizing the leading countries to be more than only guarantors of global security due to their economic and military potential. The leading role of the United States, Britain, and Poland (especially in the context of the EU's common position) has to be noted in consolidating the international response to Russian aggression. This is an excellent example of the complex partnership between old and new actors at the global level. Intensive multilateral diplomatic efforts of the leading countries, backed by the dynamics of the diversity of economic sanctions, are aimed at maximizing the unification of the world's efforts to achieve peace.

The full-scale Russian aggression against Ukraine has clearly shown that the aggressive nature of totalitarian regimes is the main threat to human existence. This unprovoked aggression demonstrates the perniciousness of the policy of "pacifying" the aggressive totalitarian regime ("understanding" the leader and

"looking into his eyes", following the imposed "neutrality", etc.). A new concept of combating current military, regional and global threats is being formed around the world. The key component in it is the economic component, which requires detailed justification.

The analysis of the recent publications. Some economic, technological, and social aspects of the war were considered in "prewar" English-language literature. Many papers have examined the academic issues of implications for economic growth in democracies that has military expenditure and technology [4, 6, 10, 18, 30, 34]; impact on external debt [8, 21, 26] and the civilian sector [28, 35]; economic consequences of the Islamic Revolution and war between Iran and Iraq [15]. The statistical analysis of the macroeconomic consequences of wars in underdeveloped countries was conducted in the article of the International Monetary Fund officers N. Novta and E. Pugacheva (2021). They deduced that nowadays (compared to the 1990s), the number of countries affected by the war is lower, but the number of wars is rising and they occur in relatively large economies. Moreover, this rising has negatively weighed on GDP (both regional and global) [25, p. 1].

China and non-governmental terrorist organizations were considered the main threats to the United States and other democracies [7, 17, 23, 32]. The interesting graphical interpretation of the evolution of military capability and vulnerability of states and terrorists in the information age demonstrated by E. O. Goldman and L. J. Blanken (2006) [17, p. 8]. An article devoted to the importance of the Israel issue about determining how the new peace agreement starts a new peace process and doesn't continue the old one was published by Y. Kapshuk (2021) [19].

The threat from Russia was considered only in certain publications. For example, researchers from the Humboldt University of Berlin J. Bluszc and M. Valente (2022) devoted their article to estimating the economic losses of hybrid wars based on the Ukraine example [5]. Researchers from Greece E. Economou and N. Kyriazis (2022) noted about well-documented that the stock market of Russian energy companies does not affect geopolitical uncertainty [11, p. 29]. This conclusion is consistent with the issues of some Sino-Pakistani experts about the weak link between Russia's military spending and geopolitical risks and their recommendations for converging regional interests through "peaceful settlement of disputes". The obtained results for Russia, Israel and Brazil are allowed to conclude the following. First, there is a very weak and insignificant linkage between DE (defence expenditure) and GPR (geopolitical risk). Second, DE is mostly determined by the national political system and its input on labour employment. For these reasons, state and international security can be guaranteed with peaceful negotiations where regional interests become a consensus [20, p. 42].

The researchers from Canada P. L. Ghazalian and M. Hammoud (2021) concluded that more developed countries with more educated populations and democratic systems are also more peaceful. Vice versa, countries with significantly unequal income distribution and significant natural resources are less peaceful [16, p. 509]. A similar view is held by the British researcher P. Nelson (2021). He noted that the low level of consumption in poor countries pushes people to start a civil war because they lose little from changes in the economic and political system [24, p. 533].

C. S. Saba (2021) grounded that in the mathematical theory of war economics the different models can be used. These are organizational policy models (Lucier model), arms race models (Richardson model) and neoclassical models in which the state maximises a social welfare function [31, p. 52]. The Marxist tradition is followed by A. Y. Elveren (2018, 2021). He analyzed the relationship between military expenditure and the rate of return based on Marx-Foley's modified model of capital reproduction [12, 13, 14]. Based on the supply and demand model, J. P. Dunne (2000) with co-authors suggested that the reduction of military expenditures will improve macroeconomic indicators [9, p. 573; 3, p. 553]. The conclusions of P. Balcaen (2022) from the Belgian Royal Military Academy are the opposite. He built with co-authors a game-theoretic model of "hybrid threats" for western liberal democracies. They mentioned that using relatively cheap "hybrid threats" is due to new technological developments and the growing linkages between different countries [2, p. 26]. S. Auray and A. Eyquem (2017) analyzed the impact of world wars on the macroeconomic dynamics of the United States, the United Kingdom, Germany and France and identified multipliers of government expenditures and military losses, using the dynamic general equilibrium model. The obtained results allowed forming conclusions about state-dependence and the size of public expenditures output multipliers and losses of the welfare caused by war [1].

The articles of the American Foreign Policy Research Institute stand out from this list of econometric and mathematical works. The motto on the website of this institute: "A Nation Must Think Before it Acts". Thus, A. Roland (2009) expressed the opinion that new military technologies only "open the door", but do not determine who will pass through them [29]. W. Lamping (2022), a graduate student at the Naval War

College, drew attention to the ancient Russian tradition of using "historical" arguments to justify wars of aggression after the beginning of the full-scale invasion of Ukraine [22].

The concise and meaningful description of the evolution of economic losses of war in history given the T. Pettinger in his blog, posted on 24.02.22 on Economics Help.org. The author notes the following. First, modern warfare is very expensive. Second, the modern world is heavily dependent on national wealth, which in turn depends on international trade. The country waging an illegal war, such as Russia in 2022, could face painful economic sanctions. Third, since the XIX century, nationalism has become a powerful force, so the occupying army will have to face resistance from the people of the country. The author of the blog refers to the British author N. Angell, who warned that in the XX century the war would lead only to net economic losses. His book "The Great Illusion" was published in 1909. He mentioned that past wars (until the twentieth century) mostly lead to economic gain, while nowadays – only significant economic losses [27].

Formulation of the problem. The presented review of scientific (and some journalistic) literature testifies to certain "gaps" both in the subject and in the methodology of modern research. On one side, the analysis of the war economy was conducted due to the possibility of the totalitarian regime's aggression, rather than its inevitability. On the other, a noticeable shift in econometric methods and models allowed to obtain quantitative results, but left "behind the scenes" some fundamental features of a totalitarian society, such as the aggressiveness of its population; a low value of one's own life, and the more of someone else's life; the peripheral value of market incentives due to the statization of the economy; historical inertia of totalitarianism.

The purpose and logic of the study. The proposed study attempts to reflect the social, economic and military evolution of the totalitarian regime via the most generalized functions. The authors focus on the rationale and geometric interpretation and leave the algebraic analysis and statistical verification of the proposed models for future investigations. According to the chosen goal, the proposed study moves from more general models of the socio-political and military-economic evolution of the totalitarian regime to models of its macroeconomic dynamics. The study was finalized with the model of changing economic potential during the war between a large totalitarian country and a small democracy country.

The model of socio-political evolution of totalitarian society. The model consists of two functions, in which the scale of repression in a totalitarian society depends on the levels of conformism and hostility towards others. Both functions are declining, as the growth of each of these values allows the government to reduce the scale of repression. As the same repressive apparatus aimed at population support of the domestic and foreign policies of the totalitarian regime, the linkage between conformism and xenophobia was established. The gradual movement from the industrial to the information society reduces the maximum acceptable scale of repression, which is reflected as the compression of the graphs of both functions vertically (Figure 1). However, the informatization of the society increases the government's ability to manipulate the population's minds.

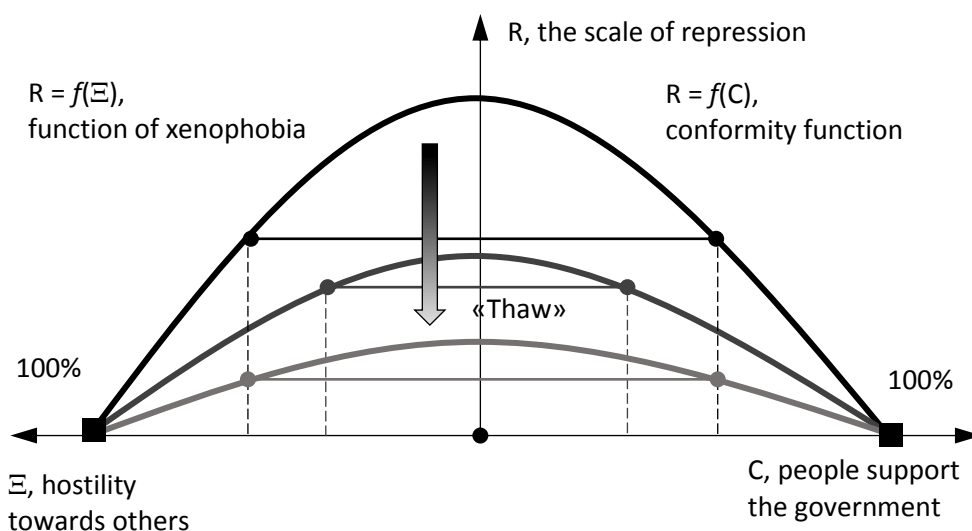


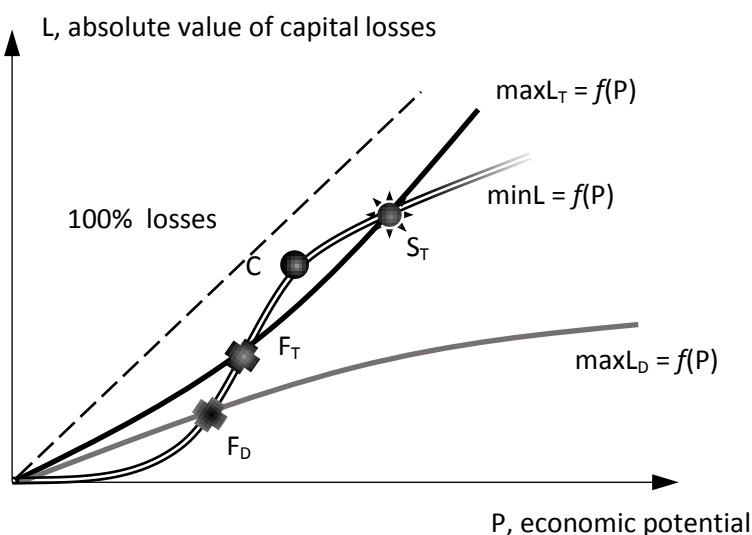
Figure 1 – Stages of socio-political evolution of totalitarian society

Source: The model is developed by I. O. Zagoruiko

As a result, the totalitarian regime consistently goes through states: 1) a state of brutal suppression of the population with a high level of conformism and xenophobia (terror and Holodomor during Stalinism); 2) the state of the regime softening with the declining the support for authorities and aggression (Khrushchev's Thaw and Brezhnev's Detente); 3) the state of point repression with the restoration of a high level of conformism and xenophobia (the period of Putinism).

The model of military-economic evolution of totalitarian and democratic society. The model consists of three functions losing the economic potential of the country due to armed conflict with an approximately equal enemy. The maximum allowable losses functions are increasing for both societies. However, for a democratic society, these losses grow more slowly than the potential, and for a totalitarian society – faster.

The s-like curve in Figure 2 reflects the minimum possible losses. The shape of this curve is determined by the ratio of the effectiveness of the destruction and protection means. At the initial stage of military-technical progress, protection means have a passive form and are less effective than destruction means. In the second stage of military-technical progress, the defence becomes active, and the ratio in the effectiveness of these means changes to the opposite. As a result, with increasing economic potential, the minimum possible losses increase first rapidly and then slowly. The bisector in Figure 2 limits the range of allowable and possible losses.



$\max L_D$, $\max L_T$ – maximum allowable losses of a democratic and totalitarian society in case of armed conflict;
 $\min L$ – the minimum possible losses; F_D , F_T – points of the aggression cessation for democratic and totalitarian society;
 C – the crossover point from the dominance of destruction means to the dominance of protection means; S_T – the point of resumption of totalitarian society open aggression

Figure 2 – Stages of military-economic evolution of a totalitarian and democratic society

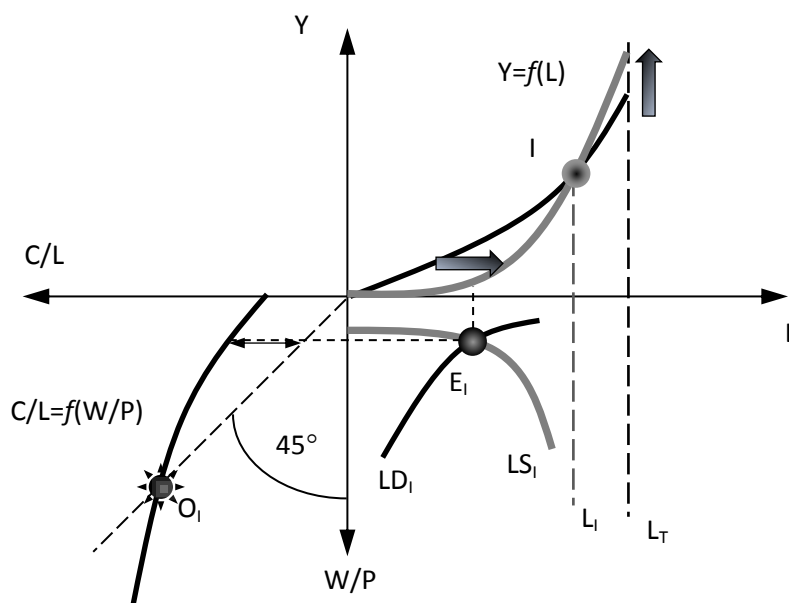
Source: The model is developed by I. O. Zagoruiko

Under this model, a democratic society goes through two stages of development: 1) the stage of territorial expansion, due to the excess of the maximum allowable losses over the minimum possible (the period of colonial wars); 2) the stage of economic expansion (the period after the end of the colonial wars to the present). An excellent example of the balance between the minimum possible and maximum allowable losses is the Crimean (Eastern) War of 1853–1856 when information about military losses negatively affected the public opinion of European countries and deterred the Allies from final victory.

Totalitarian (or authoritarian) society goes through three stages: 1) the stage of open territorial expansion; 2) the stage of hidden territorial expansion; 3) the stage of restoration of open territorial expansion. In the first stage, due to technological backwardness, authoritarian and totalitarian societies actively use the export disinformation about their condition and intentions (Panslavism in the nineteenth and "internationalism" in the twentieth century). In the second stage, the export of terrorism is added to this instrument (such as support for the "revolutionary" and "people's liberation" movements), and then it is

followed by the export of corruption. All these three instruments are the criminal use of the free movement of information, labour and capital in democracies.

The model of socio-economic evolution of a quasi-market totalitarian country. The model consists of the following functions: functions of the personal income distribution (Lorentz curve in absolute value); consumption functions; neoclassical functions of labour demand and supply (Figure 3). Unlike the "classical" totalitarian society with a command-and-control economy, this society has all the external attributes of a capitalist economy, such as commodity, currency and stock markets, as well as the labour market. This country differs from democracies in the leading role of quasi-private monopolies controlled by individual officials dependent on the will of the leader. As a result, market incentives for technological progress are significantly weakened. Corruption is rampant in the country and the system of social protection and professional training of the population is inefficient.



Y – personal income; C – consumption; L_T – total population; I – point of stable income; L_I – the number of impoverished population; C/L – per capita consumption; W/P – real wage rate; O_1 – the point of impoverished population zero savings; LS_1 , LD_1 – labour supply and demand curves; E_1 – the equilibrium point of impoverished population labour market

Figure 3 – Consequences of economic growth in a quasi-market totalitarian country

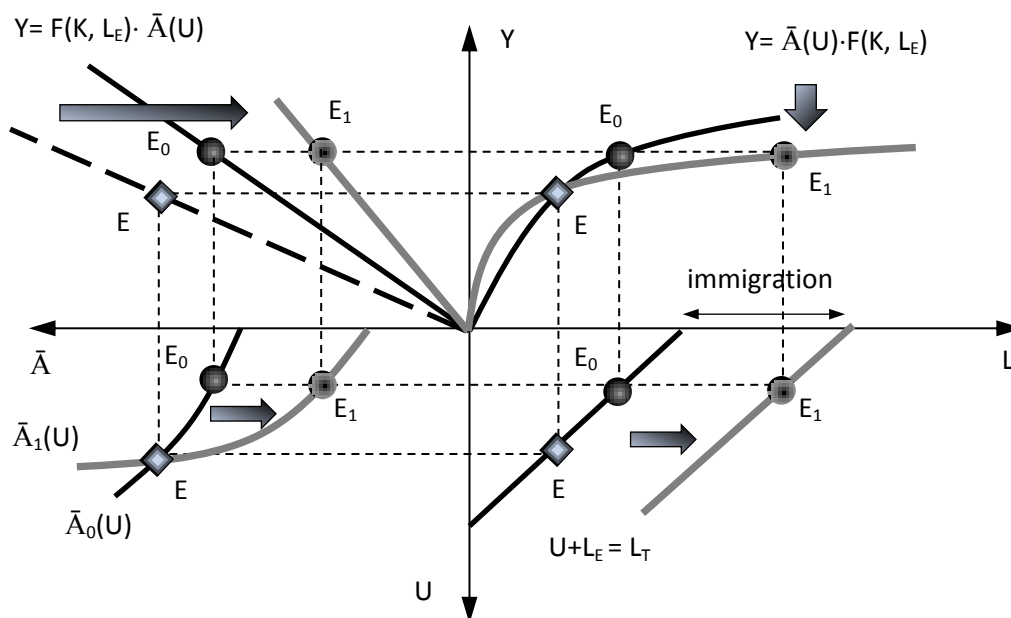
Source: The model is developed by I. O. Zagoruiko

In such a country, economic growth leads to an increase in income inequality. As a result, part of the population begins to receive lower incomes and forms a separate segment of the labour market. Generally, less-skilled workers tend to be poorer. The demand for their work does not grow and the equilibrium rate of real wages is set at a low level due to the conditions of technological changes. According to Keynes's basic psychological law, consumption is declining less than real income. In the situation shown in Figure 3, the impoverished part of the population comes into the negative savings zone, where $W/P < C/L$. Through insufficient state support, these segments of the population are forced to increase debts, beg or become criminals. They are becoming a convenient tool for the policies of the totalitarian regime due to the uncertainty of their status.

The model of evolution of labour potential of a totalitarian country with a medium quasi-market economy. The model consists of the production function and the balance of the division of the total labour force of the country into working L_E and unemployed U. The volume of national production in this model is the product of two functions – the function $F(K, L_E)$, which reflects the influence of the volumes of factors involved in the production and the function $\bar{A}(U)$, which reflects the statistical distribution of workers by labour productivity. The function $F(K, L_E)$ is linearly homogeneous and corresponds to the law of diminishing returns. For the function $\bar{A}(U)$ the law of increasing return is fulfilled: $\partial \bar{A} / \partial U > 0$, $\partial^2 \bar{A} / \partial U^2 > 0$.

This property can be explained as follows. When the number of employees decreases, firms primarily lay off less skilled and less industrious workers. Consequently, the mean employee productivity is growing. When the number of employees increases, firms hire worse and worse workers and the mean productivity of employees decreases.

The geometric interpretation of this model is presented in Figure 4. In the upper right quadrant are graphs of the production function for different periods, in the upper left – its beams. In the lower-left quadrant are graphs of the function $\bar{A}(U)$, in the lower right – graphs of labour balances.



Y – the volume of national production; $\bar{A}(U)$ – the function of mean labour productivity; L_T – the total labour force;
 L_E – the number of employed; U – the number of unemployed; K – the amount of involved capital;
 E – points of the economy state

Figure 4 – Consequences of long-term unemployment in a totalitarian country with a medium quasi-market economy

Source: The model is developed by I. O. Zagoruko

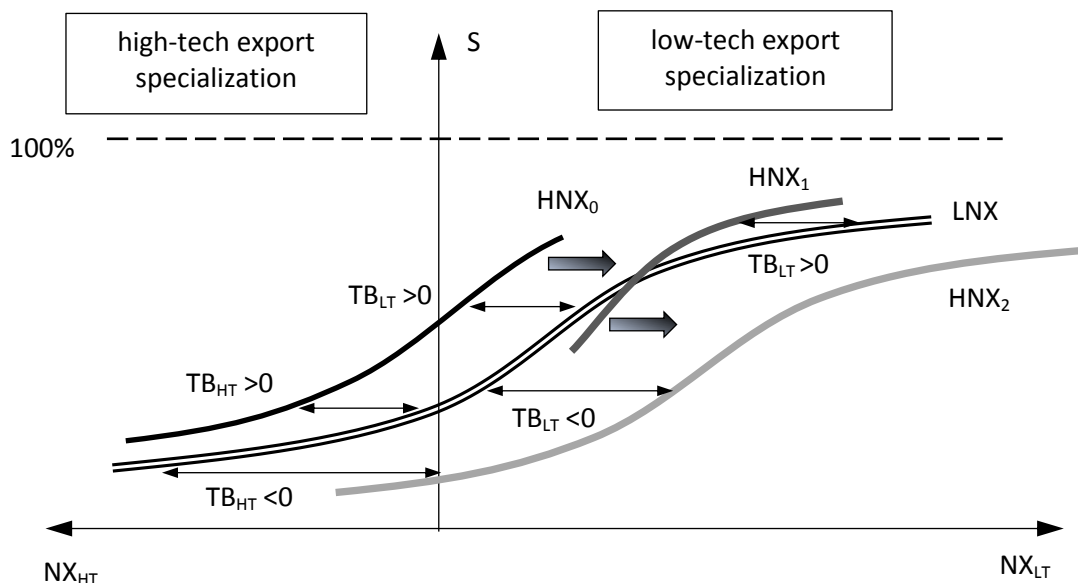
The country's economy is at point E_0 in the initial period. The economic crisis is leading to lower production and higher unemployment. The economy is moving to point E . In the upper left quadrant, this is reflected by turning the production function beam counterclockwise. In the lower-left quadrant, the economy moves along the curve $\bar{A}_0(U)$, in the lower right – along the line of labour force balance.

Through the weakened market incentives, the crisis is dragging on. Workers who stay at work become more experienced and their productivity increases. Vice versa, the unemployed are disqualified and morally degraded during this time. The curve $\bar{A}(U)$ becomes more elastic. Respectively, in the upper right quadrant, the graph of the production function is deformed. As a result, after overcoming the crisis, the economy can no longer return to its former state. There is a medium-sized totalitarian country with a small enough working population (Figure 4). Due to these features for restoring the pre-crisis production, the country's authorities will be forced to allow the immigration of labour from other countries. The beam of the production function in the upper left quadrant will rotate clockwise, and the line of the working function balance in the lower right quadrant will shift to the right. The economy will move to point E_1 .

The model of the country's net exports of goods with a variable level of the economy statization.

In this model, the country exports and imports two types of goods – low-tech LT and high-tech HT. The level of the economy statization has a positive effect on net exports of low-tech goods and a negative effect on net exports of high-tech goods.

The geometric interpretation of this model is presented in Figure 5. In the left half of this figure, net exports of high-tech goods are positive, and low-tech is negative. In the right half of the figure conversely, net exports of high-tech goods are negative and low-tech exports are positive.



NX_{LT} – net exports of low-tech goods; NX_{HT} – net exports of high-tech goods; S – the level of the economy statization; TB_{HT} – the surplus of the country's trade balance with positive net exports of high-tech goods; TB_{LT} – the surplus of the country's trade balance with positive net exports of low-tech goods; LNx – the net export curve of low-tech goods; HNx – the net export curve of high-tech goods

Figure 5 – Long-term consequences of the country's specialization in the export of low-tech goods

Source: The model is developed by I. O. Zagoruiko

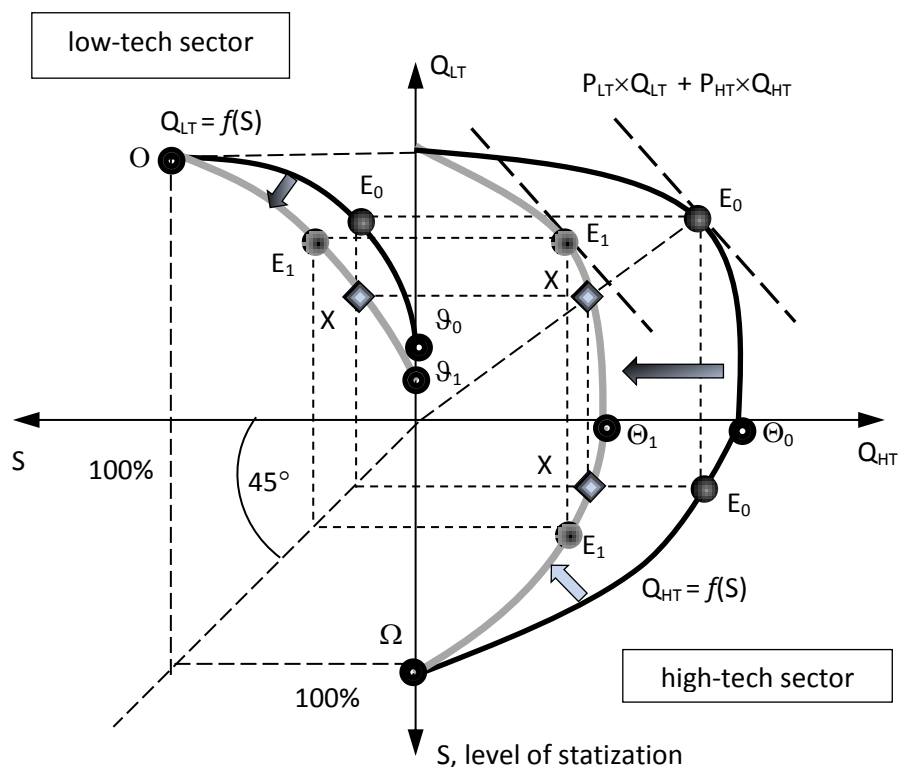
The net export curve of high-tech goods HNx_0 is located to the left of the net export curve of low-tech LNx goods in the initial period. As a result, at any level of the economic statization, the country will have a positive trade balance. If, for various reasons, the country chooses to specialize mostly in the export of low-tech goods, then in the next period its ability to export high-tech goods is reduced. This is reflected by shifting the HNx curve to the right geometrically. As a result, the country falls into the trap of economic statization. Now the trade surplus is achievable only with a high level of economic statization, growth in exports of low-tech goods and imports of high-tech.

The situation becomes worse with the insufficiency of capital imports (or their irrational use). The HNx curve continues to move to the right and doesn't intersect the LNx curve. A positive trade balance becomes impossible at any level of the economic statization.

The model of a country's production capacity with a variable level of the economy statization.

The country's economy consists of two sectors LT and HT in this model. These sectors produce respectively low-tech and high-tech goods. The output of each type of goods depends on the level of the economy statization – S . The economy statization has a positive effect on the production of low-tech goods and a negative effect on the production of high-tech goods: $\partial Q_{LT} / \partial S > 0$, $\partial Q_{HT} / \partial S < 0$. For the positive effect of the economic statization, the law of diminishing returns applies $\partial^2 Q_{LT} / \partial S^2 < 0$, for the negative impact of the economic statization, the law of increasing losses applies: $\partial^2 Q_{HT} / \partial S^2 < 0$. Thus, there is a negative functional linkage with the growing marginal rate of transformation between the outputs of the two types of goods: $\partial Q_{HT} / \partial Q_{LT} < 0$, $\partial^2 Q_{HT} / \partial Q_{LT}^2 < 0$. The geometric interpretation of this model is presented in Figure 6. The upper left quadrant shows the curve of low-tech goods production, and the lower right – high-tech goods production. The points projection of these curves in the upper right quadrant forms the curve of the production capacity of a country with a variable level of economic statization. The points of intersection of the low-tech curve with the vertical coordinate axis and the high-tech curve with the horizontal axis are the states of a completely liberal economy.

The conditions of foreign trade in the initial state E_0 show that the country benefits from producing more low-tech goods. As a result, in the next period, its production potential reduced in both sectors to a greater extent in the sector of high-tech goods. This is indicated by a shift to the left of the point Θ and a shift down the point ϑ geometrically. In this case, the points O and Ω don't move.



P_{LT} , Q_{LT} – world price and production of low-tech goods; P_{HT} , Q_{HT} – world price and production of high-tech goods;
 S – the level of the economy statization; E_0 , E_1 – points of initial and subsequent state at the low relative price of high-tech goods; X – point of sustainable level of the economy statization; Θ_0 , Θ_1 – points of the maximum output of high-tech goods in a completely liberal economy; ϑ_0 , ϑ_1 – points of the minimum output of low-tech goods in a completely liberal economy; O – the point of the maximum output of low-tech goods in a fully statized economy; Ω – the point of minimum production of high-tech goods in a fully statized economy

Figure 6 – The impact of the coefficient of international trade on the level of the economy statization

Source: The model is developed by I. O. Zagoruiko

Depending on the value of the international exchange rate in the new period, the level of the economic statization may increase, fall or not change.

Under stable conditions of foreign trade, the level of the economy statization increases – the country falls into a state of equilibrium E_1 (Figure 6). This can be explained by the interaction of two pairs of effects. On the one side, the effect of shifting the low-tech curve exceeds the effect of reducing the output of these goods. On the other, the effect of reducing the output of high-tech goods exceeds the effect of shifting the high-tech curve. As a result, the output of both types of goods is reduced, but the country will produce relatively more low-tech goods.

The situation, when the proportions of production and the level of the economy statization don't change is possible too. This state corresponds to point X , in which the conditions of foreign trade are less favourable for the production of low-tech goods.

The model of changing the military and economic potential of the country during open aggression. The Solow model has been chosen as the basis of the proposed model, supplemented by the following assumptions:

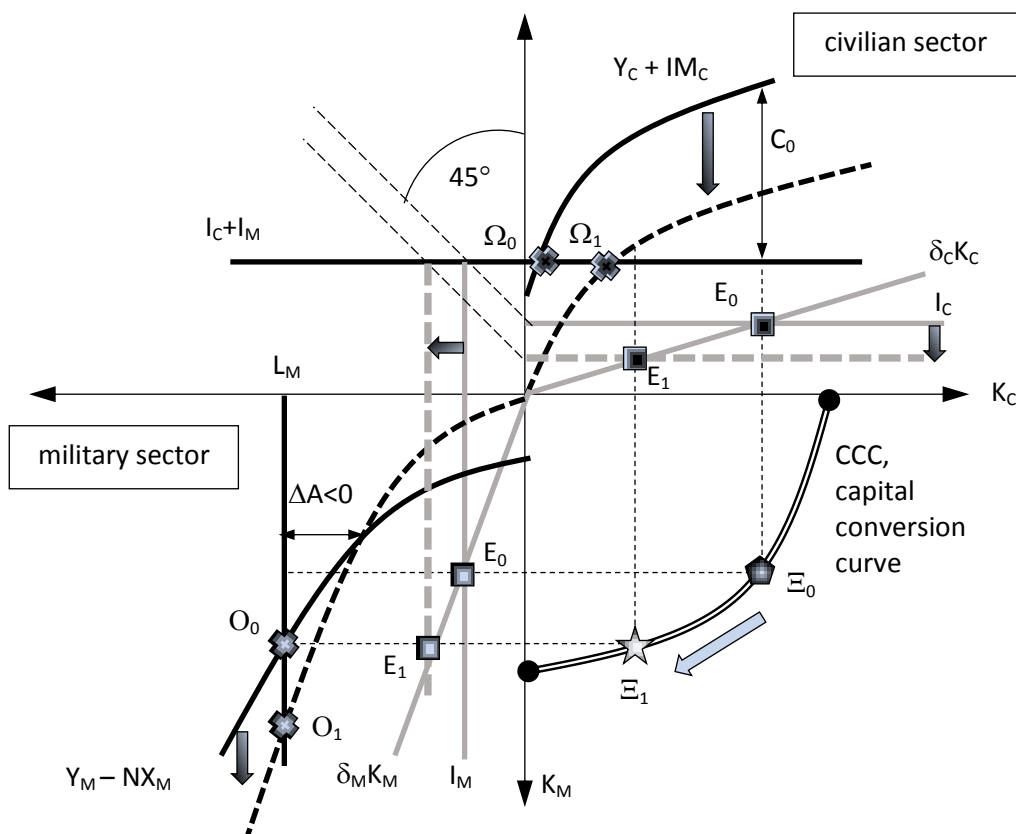
1. The country's economy consists of two sectors – civilian and military.
2. In each sector, the supply of finished goods consists of its output Y and imports of IM , which contains two parts – a variable that is proportional to output, and a constant consisting of critical products.
3. The net supply of the sector is lower by the amount of EX exports and military losses L , which do not depend on the amount of output and capital.
4. The investment amount I in each sector does not depend on the amount of capital and output.
5. Civilian sector creates fixed assets for itself and the military sector.

6. The disposal of capital consists of a variable part that is proportional to its volume K , and a constant part Λ , which forms as a result of war.

7. The country can redistribute existing fixed assets between the two sectors. The efficiency of this redistribution decreases with the increase of its scale.

The proposed model is presented in two versions in this article. In the case of a large totalitarian country with a semi-closed economy, the only type of military loss is the armaments losses. In the case of a small democracy with an open economy, these losses are compounded by losses of civilian products L_C and losses of capital in both sectors Λ_C , and Λ_M .

The change of the potential of a large totalitarian country. The large totalitarian country with a commodity economy is described in Figure 7. This country exports raw materials that are not included in the final output of Y_C , and weapons that reduce the net supply of goods in the military sector by the amount of EX_M . However, it imports the civilian and military products it needs. Assume that in the initial state Ξ_0 investment in each sector of this country is equal to the disposal of capital. As a result of the attack on a small democratic country, the aggressor suffers military losses L_M and its cache of weapons A are reduced. The totalitarian country is abandoning arms exports and changing the structure of investment and available capital in favour of the military sector aimed at the compensation of these losses. These changes aim to achieve a new state Ξ_1 , in which the capital reserves of both sectors K_C , K_M and cache of weapons A are replenished at the same rate as they are spent. However, due to sanctions from large democracies, imports of military and civilian products are blocked. As a result, the new state of equilibrium of cache of weapons O_1 becomes unavailable with any redistribution of capital, and current consumption is sharply reduced.



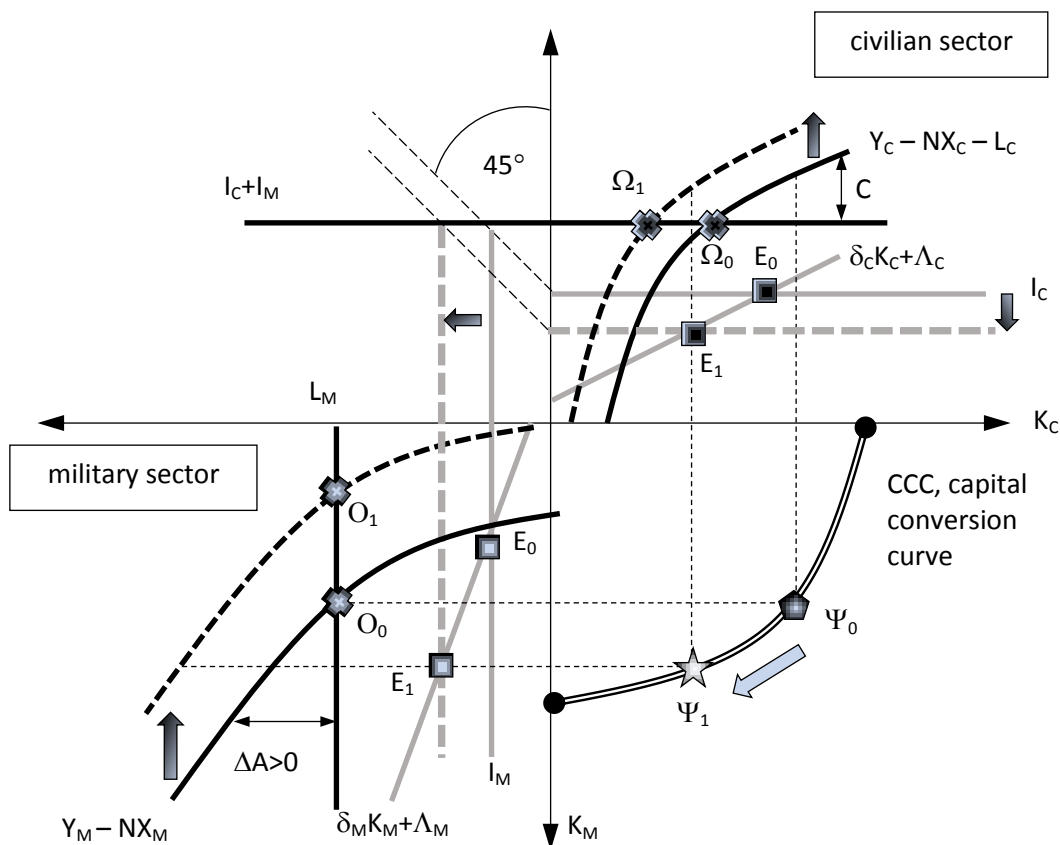
Y – output; L – military losses of output; NX – net exports of goods; IM – import of goods; C – consumption; I – investments; K – the amount of capital; δ – the rate of capital disposal; ΔA – increase in the cache of weapons; E – point of stable capital reserves; Ω – point of zero consumption; O – point of the stable cache of weapons

Figure 7 – The change of the potential of a large totalitarian country with a semi-closed commodity economy

Source: The model is developed by I. O. Zagoruiko

The change of the potential of a small democracy. The small democracy with an industrial and agricultural economy is described in Figure 8. Unlike a totalitarian country, its net exports of finished civilian products NX_C are positive. As a result of unexpected aggression, the country finds itself in a state of

Ψ_0 , in which capital stocks in both sectors are declining. However, the cache of weapons can be kept stable. The democracy abandoned arms exports and changed the structure of investment and available capital in favour of the military sector aimed on strengthening of its defence. These changes aim to achieve a new state Ψ_1 , in which the capital reserves of both sectors K_C , and K_M are replenished at the same rate as they are spent, and the armament stock A is growing. The country continues to fight and receives additional weapons from partners because the cache of weapons was kept stable in the initial phase of the aggression. This allows to further increase the cache of weapons A . In addition, the partners of a democratic country partially compensate for the losses of civilian products.



Y – output; L – military losses of output; NX – net exports of goods; C – consumption; I – investments; K – the amount of capital; Λ – military losses of capital; δ – the rate of disposal of capital; ΔA – increase in the cache of weapons; E – point of stable capital reserves; Ω – point of zero consumption; O – point of the stable cache of weapons

Figure 8 – The change of the potential of a small democracy with an open industrial and agricultural economy

Source: The model is developed by I. O. Zagoruiko

Other versions of the military-economic potential model can be used to analyze the change in the potential of small democracies due to the possible aggression of totalitarian regimes (China against Taiwan or Iran against Israel). Thus, when modelling the economic consequences of the hypothetical Sino-Taiwan war, it should be considered that 1) net exports of final civilian products of a totalitarian country are positive, and dependence on imports of final products of both sectors is much less; 2) in the first phase of the war, a small democratic country will not be able to independently maintain its own cache of weapons and reduce the cache of weapons of the aggressor; 3) the democratic world will not be able to completely block the imports of a large totalitarian country with an open industrial economy, instead, it will use its exports as a tool to combat possible sanctions.

Conclusions. As the Russian-Ukrainian war of 2014–2022 has shown, the impossibility of totalitarian (and later authoritarian) regimes is a necessary precondition for the existence and development of human civilization. The priority of further peaceful world development will be the formation of global mechanisms

for effective prevention of aggressive foreign policy of individual states and, first of all, effective monitoring and forecasting of possible threats. The study of economic, social, and political preconditions for possible escalation is the key.

This study outlines possible ways to modify traditional (primarily neoclassical) macroeconomic models. The determination of the analytical form for the proposed functions requires special econometric, sociological and military-technical research. However, even now the state of Russian society before and during the full-scale invasion of Ukraine can be chosen as a "starting point" to build more reliable indicators of the likelihood of aggression by other totalitarian countries. So far, based on the considered models, it is possible to formulate some qualitative criteria for determining the phases of the totalitarian regime evolution.

1. The model of socio-political evolution of a totalitarian society explains why reducing the scale of repression (for example, replacing concentration camps with destruction by concentration camps "re-education") is not a sign of liberalization of the totalitarian regime. At the same time, the increase in the level of support for the government and xenophobia testifies to the mental readiness of the totalitarian country population to aggression.

2. Under the model of military-economic evolution of a totalitarian society, new wars of a totalitarian regime can take place both in the phase of accelerated growth of the minimum possible losses and in the phase of slow growth. A sign of the totalitarian country's economic readiness for aggression is the excess of the maximum allowable losses for it over the minimum expected.

3. Models of socio-economic evolution and the evolution of labour potential explain the mechanism of strengthening the social base of the totalitarian regime. As a consequence of the market incentives weakness, economic growth leads to the impoverishment of the part of the population, and the increased duration and depth of economic crises lead to their disqualification.

4. The model of net exports of goods evolution emphasizes the importance of the initial decision on the nature of the country's participation in the international division of labour. The choice in favour of exporting low-tech goods and importing high-tech ones puts the country in a trap of economic statization. In the next stage, the country achieves a positive trade balance, but with a high level of economic statization and monopolization. In the final stage, a positive balance is impossible even when the level of state-monopoly regulation is reduced.

5. The importance of the proportions of international trade in goods (not necessarily legal) follows from the model of production capacity of a country with a variable level of economic statization. Maintaining high world prices for intermediate goods and goods with low added value leads (when other terms are equal) to increasing the level of the economy statization and reducing its productive capacity. The subsequent fall in these prices (or the deterioration of advanced technologies "grey" imports terms) creates a situation of uncertainty when the level of the economy statization can both fall and rise.

6. The model of the country's military and economic potential demonstrates the importance of the initial macroeconomic characteristics of both participants in the war. If the economic and military exports gap isn't critical, a small democracy can retain its cache of weapons until large-scale aid from other democracies begins.

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І. О. Загоруйко, Л. О. Петкова

**МОДЕЛЮВАННЯ ЕВОЛЮЦІЇ АГРЕСИВНОГО ТОТАЛІТАРНОГО РЕЖИМУ:
ГЕОМЕТРИЧНИЙ ПІДХІД**

Стаття присвячена методології моделювання еволюції агресивного тоталітарного режиму. Методологія базується на макроекономічних функціях та їх геометричному відображенні. У статті побудовано та проаналізовано декілька моделей, таких як: моделі соціально-політичної, військово-економічної та соціально-економічної еволюції тоталітарного суспільства; модель еволюції трудового потенціалу; моделі чистого експорту товарів і виробничої потужності країни зі змінним рівнем одержавлення економіки; модель зміни економічного потенціалу під час війни між великою тоталітарною країною та малою демократичною країною.

Сучасний тоталітарний режим (подібний до попереднього) базується на одержавленні економіки та маніпуляціях інформацією. Одержавлення нині не є тотальним, але засоби маніпуляції значно покращилися. Автори припускають, що зменшення репресій у тоталітарній країні не є ознакою її лібералізації. Економічне зростання призводить до зубожіння населення, а економічні кризи – до його декваліфікації в квазіринкових умовах. Разом вони зміцнюють соціальну базу режиму. Високі ціни на низькотехнологічні товари підвищують рівень одержавлення економіки, а отже, зменшують виробничий потенціал країни. Спеціалізація на низькотехнологічному експорті заводить її в «пастку одержавлення», де активний торговий баланс стає неможливим навіть при нижчих рівнях державного регулювання. Погіршення глобальних умов торгівлі низькотехнологічними товарами створює ситуацію невизначеності, коли рівень одержавлення може як знижуватися, так і зростати. Перевищення максимально допустимих втрат над мінімально можливими втратами великої тоталітарної країни стає «спусковим гачком» для відкритої агресії. Особливістю зіткнення між великою тоталітарною та малою демократичною країною є фундаментальна асиметрія втрат їхнього військово-економічного потенціалу.

Ключові слова: російська агресія проти України, воєнна економіка, тоталітарне суспільство, одержавлення, розподіл доходів, виробнича функція, економічний потенціал, чистий експорт, високі технології.

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Загоруйко І. О., канд. екон. наук, доцент, доцент кафедри соціального забезпечення, Черкаський державний технологічний університет
e-mail: zagoruikovanmacro@gmail.com
ORCID 0000-0003-2819-0793

Zagoruiko I. O., Ph. D. in Economics, Docent, Associate Professor at the Department of Social Security, Cherkasy State Technological University

Петкова Л. О., д-р екон. наук, професор, завідувач кафедри міжнародної економіки та бізнесу, Черкаський державний технологічний університет
e-mail: l_petkova@ukr.net
ORCID 0000-0003-4519-3726

Petkova L. O., Doctor of Economics, Full Professor, Head of the Department of International Economics, Cherkasy State Technological University