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Mathematical modeling of long-term economic and financial security of the state in the context of demographic decline

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Abstract
The article presents mathematical modeling of long-term economic and financial security of the state in the context of demographic decline based on the definition of indicators of demographic decline, which are an effective tool for preventing critical situations and achieving the goals of safe development.
Key words: economic security, demographic decline, demographic indicators, normalization.

1 Introduction

An important prerequisite for the economic, intellectual, and political development of any country is the demographic factor as an independent component of the foundation on which society rests, being an element of the root system that feeds the entire social tree. Demographic factor reflects the relationship between the rates and proportions of social development with the quantitative and qualitative characteristics of the population (its number, sex-age, and family structures, as well as the dynamics of birth, mortality, migration, health condition, resettlement, vocational education structure, etc.) [1].

In recent years, drawing conclusions about the economy condition of an individual state on the basis of the calculation of various international ratings and indices has become increasingly popular. Today, international institutions are calculating about 30 general indicators, which are used by governments and business leaders to form better economic policies and institutional reforms [2, 3].

This trend has certain drawbacks: the attitude of the international community, foreign investors, and individual citizens to the state depends on the objectivity and reliability of the conducted calculations that can give this process a subjective character. Therefore, it is very important to scientifically ground and apply in practice the long-term economic and financial security (LTEFS) index of the state, which would reflect the domestic economy condition, help to track trends in its change, and could be successfully used instead of existing international ratings and indices.

In addition, in case of decrease of international index, leadership of the state would be able to defend the real trends in the development of the economy and assess the factors that contributed to this. The absence of the LTEFS index leads to the appearance in the mass media, analytic and expert communities, as well as political forces of diverse and often contradictory information about the development trends of the state economy, the pace of economic growth, and social protection of the population.

At that, demographic processes are the most important ones in ensuring sustainable development of the country, while the demographic problems should be analyzed as paramount to the interests of the country. The significance of the population and its demographic potential is especially important in modern conditions, where intelligence becomes the main driver and determining factor of development. Therefore, any lack of human resources in both quantitative and qualitative aspects is both a domestic and a foreign policy problem [4].

Today, the problem of demographic decline is very relevant for Russia due to the demographic hole that arose due to the catastrophic decline in the birth rate of the late 90-ies.

Taking into account the above mentioned, the purpose of the present article is to justify scientific and methodological approaches to mathematical modeling

of the long-term economic and financial security of the country in the context of demographic decline.

2 Methodological foundation for the definition of demographic decline indicators

The LTEFS index of the state should be understood as a macroeconomic indicator that characterizes the current condition of the state economy.

To study the condition of the LTEFS, it is necessary to develop a system of criteria and indicators that reflect the status of the economic system depending on the threats of demographic decline.

The population is the subject and at the same time the main driving force of all social developments, while modern parameters of its reproduction represent basic determinant which influences both rates and proportions of economic progress, as well as opportunities and priorities of human development in the country. At the same time, certain demographic indicators can be considered as final criterial indicators of effectiveness of both socio-economic and human development. These include, first and foremost, birth and mortality rates.

Birth rates, as a human development characteristic, accumulate the influence of a wide range of factors of human life-sustaining activity, namely socio-psychological, economic, socio-cultural, and many other activities, and reflect the possibility of self-actualization of the individual in one of the most important spheres of human life, which is motherhood/fatherhood.

Mortality rates are also an integrated characteristic of the conditions in which human life and development take place. They accumulate the influence of the medical and social welfare conditions in the country, working conditions, environmental situation, etc.

When constructing LTEFS indicators, the main requirements are their availability and simplicity of calculation in order to give local authorities ability to assess the LTEFS at the regional level.

The formation of a set (list) of indicators is carried out according to the principles of representativeness (the most significant indicators affecting the LTEFS level are considered), reliability (selected indicators should adequately reflect the condition of the security component), and information availability (calculation is based on official statistical data and public expert assessments).

Each of the components of population reproduction is of vital importance, and the disruption of the normal functioning of any of them (reduced fertility, increased mortality, reduced life expectancy, etc.) can lead to a violation of the level of LTEFS.

The formation of the LTEFS demographic indicators' system is characterized by a number of methodological and practical reservations:

- there is a problem consisting in selection of vital socio-demographic indicators of society development, the thresholds of which must be determined; however, giving reasons of the choice is extremely difficult;

- it is not easy to prove why this or that set of indicators will create the preconditions for the objective characteristic of the "key" points of socio-demographic development;

- since the demographic system is inherently organic rather than mechanical, the precise definition of critical values of demographic indicators is problematic; usually they are obtained by inductive method, through expert assessments, based on historical experience, as well as social and demographic conditions, and therefore specific thresholds of socio-demographic indicators are mainly of subjective nature [5].

With reference to the above mentioned, 6 indicators of the demographic decline, representing the indicators of natural reproduction of the population, were selected from the whole set of possible indicators to model the LTEFS of the country in the context of the demographic decline:

1. The indicator of the population's vitality;
2. Total birth rate;
3. Mortality rate of the population aged 16-59 years;
4. Supermortality index of males aged 16-45 years;
5. Mortality rate of children under 1 year, %
6. Natimortality rate, %

For assessment, we propose to define three levels of indicator values: achievable, optimal, and threshold levels of indicators.

At that, the achievable and optimal indicator values are those, which evidence the favorable conditions for LTEFS.

The advantage of the proposed approach is that achievable and optimal values can be used in the development of a long-term strategy for the country's development. The proposed threshold indicators characterize the limiting critical values below which the demographic crisis occurs.

In the course of determining the demographic indicators of the LTEFS and their limiting values, it is necessary to take into account that in practice there is no well-established defined threshold, beyond which the system will immediately suffer a crisis.

Offering the indicator values, we divided them into stimulants and disincentives depending on their impact on the threat of demographic decline.

In our case, the first two indicators selected for normalizing (the indicator of the population's vitality and the total birth rate) are stimulants, while the last four are the disincentives.

3 Modeling LTEFS of the country in the context of demographic decline

To bring all the mentioned LTEFS indicators to comparable values, we move from absolute and relative values to the normalized values of indicators which vary from 0 to 1.

Vector of primary features $[x_1, x_2,..., x_m]$ is

replaced by the vector of normalized values [z_1, z_2,..., z_m]. At that, the integrated index is calculated using weighted sum method according to the formula:

$$I = \sum_{i=1}^{n} a_i z_i \ \sum a_i = 1, 0 \le a_i, z_i \le 1 \ (1)$$

where a_i is the weighting coefficients, which determine the contribution of the i-th normalized value of the indicator into the integrated index.

When calculating the integrated index of the LTEFS, two methodological approaches can be used to normalize the demographic indicators.

In accordance with the first methodological approach, normalizing is carried out according to the formula:

$$Z_{i1} = \begin{cases} \frac{x_i}{x_{opt}} \text{ if } x_i \text{ is stimulant, than } z_{i1} = 1 \\ \text{at } x_i = x \\ \frac{x_{opt}}{x_i} \text{ if } x_i \text{ is stimulant, than } z_{i1} = 1 \\ \text{at } x_i = x_{opt} \end{cases} \quad (2)$$

In this case, if the current values of the indicator exceed x_{opt} (or are below x_{opt}), which is the norm, then normalized values of z_{i1} will be greater than unit, which violates the accepted assumptions (1).

$$Z_{i,2} = \begin{cases} (x_i - x_b^{min})/(x_{th}^{min} - x_b^{min}) & x_b^{min} \le x_i < x_{th}^{min} \\ ((x_i - x_{th}^{min}) + x^*_{min}(x_{opt}^{min} - x_i)) / (x_{opt}^{min} - x_{th}^{min}) & x_{th}^{min} \le x_i < x_{opt}^{min} \\ 1 & x_{opt}^{min} \le x_i \le x_{opt}^{max} \\ (x^*_{max}(x_i - x_{opt}^{max}) + (x_{th}^{max} - x_i)) / (x_{th}^{max} - x_{opt}^{max}) & x^B_{opt} \le x_i < x^B_{th} \\ (x_b^{max} - x_i)/(x_b^{max} - x_{th}^{max}) & x^B_{th} \le x_i < x^B_b \end{cases} \quad (3)$$

Outside the interval [x^l_b, x^u_b] the normalized values are equal to zero. Thus, according to the second method, indicators are normalized based on 5 different scales.

Moreover, second method implies artificial coarsening of normalized indicator within the range of optimal values (equating to 1) and outside the threshold values (equating to 0), that is, there is a discontinuity of the first kind, which violates the continuity of the function representing the LTEFS indicator, and makes it impossible to use it in the optimization procedures employing gradient methods when determining the sensitivity coefficients of the criterion with respect to the change in the controlled parameters (indicators).

It is proposed further to define the generalized integrated index of the LTEFS as the arithmetic mean of the values calculated by the two methods of normalization:

$$I_j = (I_{j,1} + I_{j,2})/2 \ (4)$$

Depending on the results obtained, we propose the following grading of the "safety – danger" boundaries [6]:

1. The condition characterized by the absolute LTEFS that exists in case of the absence of a demographic decline and value of the LTEFS indicators, which are equal to or exceed the threshold values.

That is, the normalization of indicators should be carried out based on the maximum (for stimulants) or minimum (for disincentives) indicator values, rather than based on the optimal values.

In accordance with the second methodological approach to normalization, the range of possible values of each indicator is divided into 5 intervals according to the levels of indicator values:
(x_b^{min}, x_{th}^{min}), (x_{th}^{min}, x_{opt}^{min}), (x_{opt}^{min}, x_{opt}^{max}), (x_{opt}^{max}, x_{th}^{max}), (x_{th}^{max}, x_b^{max}),
where: X_b^{min}, x_b^{max} are the demographically attainable boundary values of indicators;

X_{th}^{min}, x_{th}^{max} are the threshold values of demographic decline indicators, i.e. the values that should not be exceeded;

X_{opt}^{min}, x_{opt}^{max} are the optimal values of the demographic indicators.

Values x_b^{min}, x_{th}^{min}, x_{opt}^{min}, x_b^{max}, x_{th}^{max}, x_{opt}^{max} are determined by expert evaluation method, while the value of normalized indicator in the points x_b^{min} (x^*_{min}) and x_b^{max} (x^*_{max}) is also determined by this method, or is taken equal to 0.5 that brings a certain share of subjectivity and requires additional substantiations.

Normalization by the second method is carried out by the formula:

2. Normal condition of the LTEFS, which exists in case of a weak and short demographic decline, where the levels of some indicators begin to fall below the thresholds, while others are just approaching them.

The threat to LTEFS arises from the functional disruption of the demographic system, and depending on the scale and depth of the demographic decline, the condition of danger can be characterized as:

3. The pre-crisis level of LTEFS arises with the growing scale of the threats of demographic decline, but their impact is weak, and thus the threats and their consequences can be regulated.
4. The crisis condition of the LTEFS, where the threats of demographic decline become larger, longer and deeper; it is difficult to control or partially offset them, while the consequences have significant impact on the demographic system functioning.
5. Critical condition, where there are significant violations in the reproduction of the population, the demographic system itself is not able to cope with the imbalance and requires management and

adjustment from the external environment.

6. A catastrophic condition occurs in case of a long demographic decline and is determined by significant disruption of the demographic system functioning, namely the deterioration of the quality and quantity of the population. A feature of the catastrophic condition is the inability to quickly return to a safe condition.

Conclusion

In consequence of the study we have developed a system of demographic indicators of LTEFS, which is an effective tool to prevent critical situations and achieve the goals of safe development. It can serve a basis when developing measures to prevent the threats and risks of demographic decline, as well as for planning and programming of activities of public authorities.

The conducted normalization of demographic indicators is developed taking into account three criteria, namely, achievable, optimal, and threshold values of indicators. Achievable and optimal indicators should be used in social and economic planning.

The integrated index of LTEFS was calculated using the arithmetic mean calculated by two methods of indicators' normalization.

References

[1] Mikheeva, A.R., 2014. Demograficheskij faktor razvitiya obshchestva: ocenki i idei [Demographic factor of society development: Estimates and ideas] [Text]. Bulletin of Novosibirsk State University. Series: Social and economic sciences, 14(2), pp. 155-161.

[2] Yaroslavtseva, O.A., 2012. Sravnitel'nye rejtingi i indeksy kak instrumenty izmereniya politicheskoj stabil'nosti [Comparative ratings and indices as measurement tools of political stability] [Text]. Bulletin of Peoples' Friendship University of Russia, Political science series, 2, pp. 103-114.

[3] Francis, Ch.M., Barker, R.J., and Cooch, I.G., 2013. Modeling demographic processes in marked populations. Proceedings of the EURING 2013 analytical meeting. Methods in Ecology and Evolution, 5, pp. 1265–1268.

[4] Rodionova, V.I., Kulikova, V.A., and Shcherbak, O.V., 2017. K probleme demograficheskoj bezopasnosti v sovremennoj Rossii [On the problem of demographic security in contemporary Russia] [Text]. Socio-demographic processes in the XXI century: Crisis, challenges, security strategies. Irkutsk pp. 47-50.

[5] Tseikovets, N.V., 2016. Bazovye trebovaniya k sistemam indikatorov nacional'noj ehkonomicheskoj bezopasnosti [The basic requirements to indicator systems of national economic security] [Text]. National Security. Nota bene, 4, pp. 532-542.

[6] Dudin, M.N., Prokof'ev, M.N., Fedorova, I.J., and Frygin, A.V., 2014. The world experience of transformation of innovative approaches to assurance of financial stability of social economic systems. Life Science Journal, 11(9), pp. 370-373.