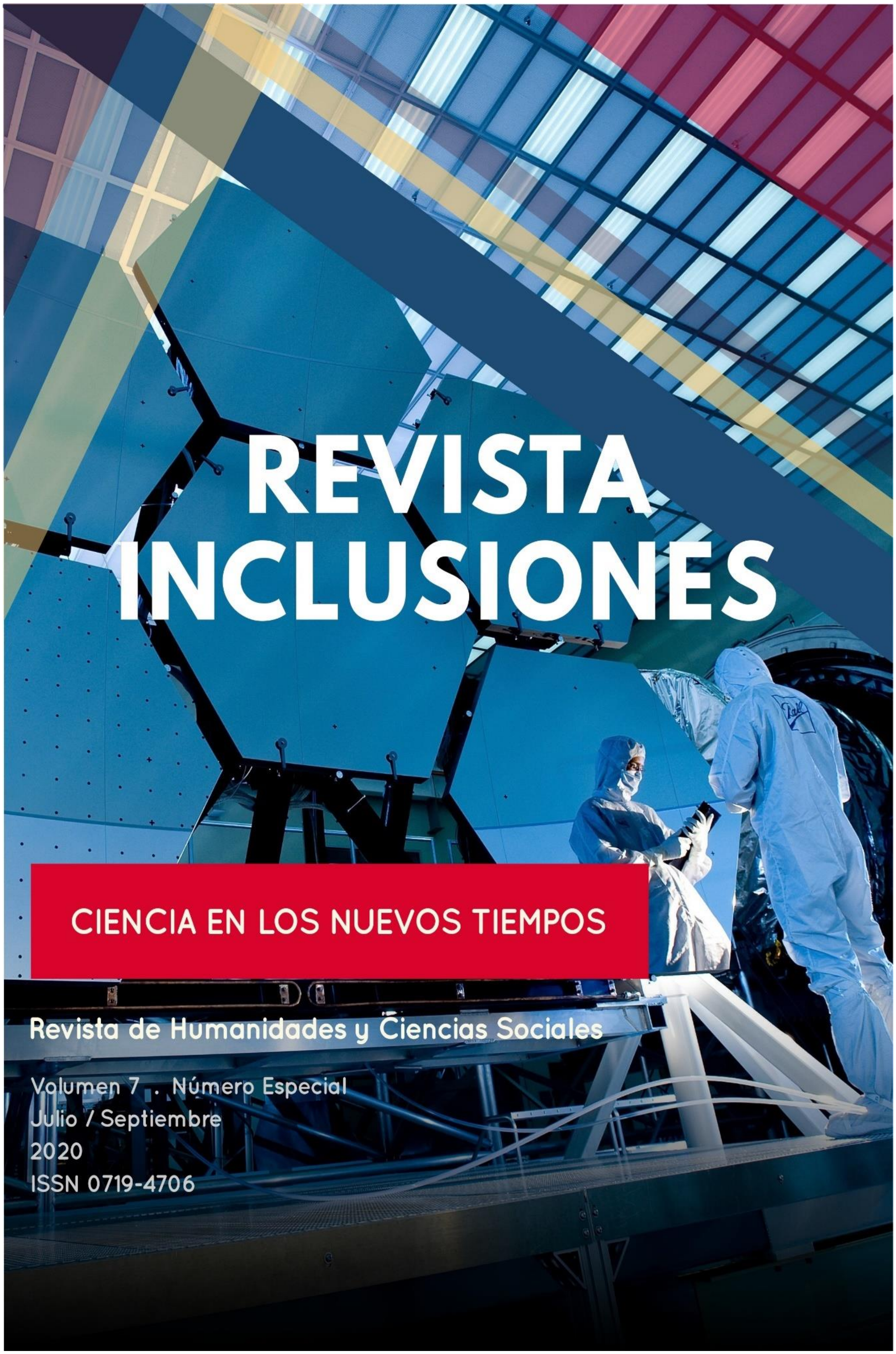
REVISTA INCLUSIONES
CIENCIA EN LOS NUEVOS TIEMPOS
Revista de Humanidades y Ciencias Sociales
Volumen 7 . Número Especial
Julio / Septiembre
2020
ISSN 0719-4706

REVISTA INCLUSIONES
REVISTA DE HUMANIDADES Y CIENCIAS SOCIALES

CUADERNOS DE SOFÍA EDITORIAL

Editorial Cuadernos de Sofía
Santiago – Chile
Representante Legal
Juan Guillermo Estay Sepúlveda Editorial

REVISTA INCLUSIONES
REVISTA DE HUMANIDADES
Y CIENCIAS SOCIALES

Indización, Repositorios y Bases de Datos Académicas

Revista Inclusiones, se encuentra indizada en:

CATÁLOGO

BIBLIOTECA UNIVERSIDAD DE CONCEPCIÓN

REVISTA INCLUSIONES
REVISTA DE HUMANIDADES Y CIENCIAS SOCIALES

CUADERNOS DE SOFÍA EDITORIAL

ISSN 0719-4706 - Volumen 7 / Número Especial / Julio – Septiembre 2020 pp. 628-640

METHODS USED TO JUSTIFY STRATEGIES OF ACHIEVING THE EXPANDED POPULATION REPRODUCTION

Dr. Nikolay Tikhomirov
Plekhanov Russian Economic University, Russia
ORCID ID: 0000-0002-0282-1553
nik.tikhomirov.46@mail.ru
Dr. Tatiana Tikhomirova
Plekhanov Russian Economic University, Russia
ORCID ID: 0000-0003-3149-7673
t_tikhomirova@mail.ru

Fecha de Recepción: 03 de abril de 2020 – **Fecha Revisión**: 11 de mayo de 2020

Fecha de Aceptación: 21 de junio de 2020 – **Fecha de Publicación**: 01 de julio de 2020

Abstract

Approaches and methods for solving the problems of justifying the directions and measures of the socioeconomic policy that contribute to the transition of the population in some European states and Russia from the established depopulation mode to sustainable reproduction have been discussed in this article. The indicators that are independent of the age and sex population structure have been proposed; they are the indicators that objectively and unambiguously describe the reproduction mode established in the current period and predetermined only by the levels of the age and sex birth and death rates. The main attention among them is paid to the marginal and standardized population growth rates. The methods for assessing these indicators and the characteristics of their sensitivity to changes in age and sex rates of natural motion ratios have been described. The prevailing importance of the age-specific fertility rate growth in comparison with the reduction in the death rate for the transition to the expanded population reproduction has been justified. The methods have been proposed for estimating the growth of the age-specific fertility rates, which ensure the transition of the population from the current reproduction mode to the expanded mode.

Keywords

Population growth rates – Indicators of the natural population motion – Demographic waves

Para Citar este Artículo:

Tikhomirov, Nikolay y Tikhomirova, Tatiana. Methods used to justify strategies of achieving the expanded population reproduction. Revista Inclusiones Vol: 7 num Especial (2020): 628-640.

Introduction

According to some experts in Russia and a number of European countries, the transition from the protracted depopulation mode to the sustainable expanded population reproduction can be made through the formation of living conditions in accordance with the general socioeconomic policy of the state, which contributes to an increase in the birth rate and a decrease in the death rate[1]. In general, the methodology for justifying such conditions should be based on the results of solving the following problems:

– determination of the indicators that objectively describe the state of the natural population reproduction process and its mode developed in the period under study;

– identification of the characteristics of the birth and death rates that are the most significant in terms of the productivity impact on the intensity of this process; and

– justification and estimation of the necessary changes in the living conditions of the population, which allow to achieve the levels of these characteristics corresponding to the sustainable expanded reproduction mode.

The opinions of demographers about the indicators of the natural population reproduction were divided. They proposed to consider either the general natural growth rate or the absolute population growth (including migration)[2]. The authors believe that these indicators do not quite adequately describe the state of the natural demographic process, which can negatively influence the justification and effectiveness of strategies to achieve the main goal of managing the population reproduction – a stable population growth rate secured by high levels of the age-specific fertility rate and low age-specific death rate. In Russia, this is associated with the significant dependence of the real population growth both on demographic waves and on migration processes, in the face of which it is difficult to distinguish the objective estimates of its reproduction potential predetermined only by the age-specific natural motion ratios. The demographic waves are described by the time-varying ratios of numbers and shares of the population in different age groups. Their existence in Russia is mainly explained by losses of a significant contingent of the population at the age of 20 – 40 and low birth rate during the 1941 – 1945 war. They significantly influenced the estimates of the general reproduction rates of the country's population both during the acute demographic crisis in the late 90s of the last century, and in the early 2000s, when this crisis began to weaken. For example, if the age structure of the population of 1989 had been preserved, described by a high proportion of women aged 20 – 34, the value of the total natural growth rate in Russia would have been minus 3.7 ‰ in 1999. However, the actual value of this ratio was minus 6.4 ‰, due to a significant reduction in their share in the 90s following the demographic wave[3]. On the contrary, the return of the fertility favorable phase of the demographic wave in 2000 – 2010 contributed to the growth of the total birth rate in these years by 20 – 40 % compared with its levels caused by the values of the age-

[1] V. N. Arkhangelsky; A. E. Ivanova y L. L. Rybakovsky, Rezultativnost demograficheskoy politiki Rossii (Moscow: Econ-Inform, 2016); V. F. Kobanov y L. L. Rybakovsky, Demograficheskoye nastoyashcheye i budushcheye Rossii (Moscow: Econ-Inform, 2012); G. N. Karelova y L. L. Rybakovsky, Stabilizatsiya chislennosti naseleniya Rossii (vozmozhnosti i napravleniya demograficheskoy politiki) (Moscow: Publishing House of the Center for Social Forecasting, 2001) y P. Gerland, "World population stabilization unlikely this century", Science. Vol: 346 num 6206 (2014): 234 – 237.

[2] L. L. Rybakovsky, 20 let depopulyatsii v Rossii (Moscow: Econ-Inform, 2014), 231.

specific fertility rates that took place in this period. The positive migration balance significantly restrained the reduction in the population of Russia after 1990. Its total value for 1991 – 2005 exceeded 7.7 mln people, which allowed to compensate for about two thirds of demographic losses caused by a decrease in the birth rate and an increase in the death rate during this period.

In particular, the net reproduction rate is well-known in demography as an indicator that is independent of these transient phenomena. However, the content of this indicator – the average number of girls who were born by a woman in a lifetime and lived to their mother's age at the time of birth for the given age-specific fertility and death rates – does not clearly describe the reproduction potential of the population. The marginal and standardized population growth rates are more suitable for this[3].

Methods

The marginal population growth rate is determined for each year as the largest eigenvalue (Perron root) of the matrix of the age-specific fertility and death rates (annual or five-year) observed this year, as a result of solving its secular equation obtained from the condition that the following determinant is equal to zero:

$$|A_t - \lambda \cdot E| = 0, \qquad (1)$$

where A_t is the matrix composed of the age-specific natural motion ratios observed in year *t*; λ is the unknown root of the secular equation; and *E* is the unit matrix.

In general, matrix *A* with the $n \times n$ size has *n* roots, and the desired solution is the largest of them, which describes the population growth rate (for a year or a five-year period, respectively, depending on the age structure under consideration: annual or five-year) in the long term under the assumption that the values of the age-specific natural motion ratios remain unchanged. As such, the value of this indicator does not depend on the current age structure of the population and can be used as a characteristic of its reproduction potential in the year *t* under study, incorporated in the totality of the values of the natural motion ratios recorded this year.

The standardized growth rate can be estimated for the population structure selected as a standard one (constant or reduced to the current period), according to the following expression:

$$\lambda_{SRt} = 1 + STBR_t - STDR_t, \qquad (2)$$

where λ_{SRt} is the standardized growth rate in year *t*; and $STBR_t$ is the standardized total birth rate in year *t*, estimated as follows:

[3] N. P. Tikhomirov, "Identifikatsiya i upravleniye rezhimom vosproizvodstva naseleniya", Sociological studies Vol: 6 num 386 (2016); N. P. Tikhomirov y T. M. Tikhomirova, "Otsenka i upravleniye potentsialom vosproizvodstva naseleniya Rossii", Federalism Vol: 3 num 95 (2019); A. Jindrová, "Dimensionality reduction of quality of life indicators", Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis Vol: 60 num 7 (2013) y N. Tikhomirov; T. Tikhomirova y A. Sukiasyan, "Assessment methods for the reproductive potential of the population", Amazonia Investiga Vol: 8 num 21 (2019)

$$STBR_t = \sum_{i=1}^{n} b_{it} \cdot x_i, \quad (3)$$

$STDR_t$ is the standardized total death rate in year *t,* estimated as follows:

$$STDR_t = \sum_{i=1}^{n} q_{it} \cdot x_i, \quad (4)$$

b_{it} is the birth rate in the *i*-th age group of the population in year *t* (its value differs from zero only in fertile age groups of women); q_{it} is the death rate in the *i*-th age group of the population in year *t*; and x_i is the share of the *i*-th age group in the total population.

When a standardized age structure of the population represented by vector $\bar{x} = (x_1, \ldots, x_n)$ with ratio $\sum_{i=1}^{n} x_i = 1$ is formed, it is important to ensure the condition of its independence from demographic waves. Due to this, it is impossible to use a vector obtained from the current composition of the Russia's population of any year as such a structure because a certain phase of the demographic wave is present in it. The marginal structure of the population $\bar{x}_t$ is independent of any of its phases and corresponds to the marginal rate of population growth λ_t, estimated from a vector-matrix equation as follows:

$$A_t \cdot \bar{x}_t = \lambda \cdot \bar{x}_t. \quad (5)$$

Any permanent structure independent of demographic waves can be used as a standardized structure for all years *t*, where the shares of the neighboring age groups of both men and women are related by the ratio that determines the age-specific patterns of retirement of men and women in year *t:*

$$x_{i+1} = (1 - q_i) \cdot x_i, \quad (6)$$

where q_i is the population death rate in the *i*-th age group in the period under study, $i = \overline{1, n}$.

It must be noted that both the marginal and standardized growth rates have certain disadvantages. In particular, in accordance with the block structure of the matrix of the age-specific natural motion ratios *A*, the value of the marginal growth rate is determined only by the birth rate of girls and the death rate of women aged under 50, excluding the birth rate of boys and the death rate in other age and sex groups. The birth rate of girls in each age group amounts to 48.8 % of the birth rate of all children on average.

The standardized growth rate depends on the population structure chosen as the standard. At the same time, the obtained estimates of these indicators for the population of Russia for 2000 – 2018 differ slightly. The five-year estimates of the standardized growth rate for 2000 – 2018 for the population structures that correspond to the patterns of their age-specific death rate during these years turned out to be about 3 – 4 % higher than their ultimate alternatives, or 0.03 – 0.04 higher in absolute terms. These differences are shown on Figure 1.

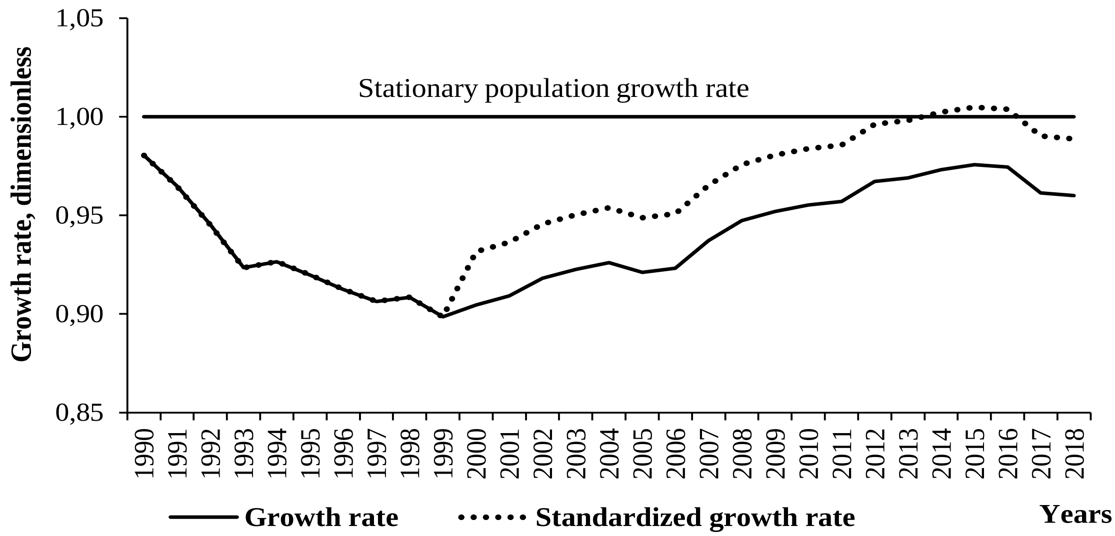

Figure 1
Five-year population growth rates and standardized population growth rate
in Russia in 1990 – 2018

Compared to the marginal growth rate, its standardized alternative grows due to the birth rate of boys and falls due to the death rate of men of all ages and women aged over 50. In addition, differences in the estimates of these indicators may be explained by the specifics of their assessment methods. In general, it can be concluded that the estimates of both indicators with a certain degree of accuracy describe the potential available to the population in year *t* and the corresponding reproduction mode. Their values greater than one correspond to the expanded reproduction mode, those equal to one correspond to the stationary population mode, described by its constant number, and those less than one correspond to the depopulation mode. The patterns of the population reproduction potential variability at different time periods can be judged according to the values of these indicators estimated over successive years.

The two other tasks of justifying the socioeconomic policy for the transition to expanded population reproduction set forth in this article can be solved using the growth rates under study. The most effective areas of impact of the policy measures in terms of ensuring population growth can be justified based on the rates of their elasticity according to the birth and death characteristics.

The growth rate elasticity by the age-specific fertility and death rates of women is determined using the following expressions, respectively:

$$E_{\frac{\lambda}{b_i}} = \frac{\Delta\lambda}{\Delta b_i} \cdot \frac{b_i}{\lambda},\ E_{\frac{\lambda}{q_i}} = \frac{\Delta\lambda}{\Delta q_i} \cdot \frac{q_i}{\lambda}. \qquad (7)$$

It was shown in work[4] that the ratio of these rates for the marginal growth rate, the values of which were in the depopulation zone, was approximately as follows:

[4] N. P. Tikhomirov, T. M. Tikhomirova, "Otsenka i upravleniye potentsialom vosproizvodstva naseleniya Rossii", Federalism Vol: 3 num 95 (2019).

$$\frac{E_{\frac{\lambda}{b_i}}}{E_{\frac{\lambda}{q_i}}} = \frac{b_i}{q_i}, \qquad (8)$$

where b_i was the fertility rate of girls in the *i*-th age group of women, and q_i was the death rate of women in the *i*-th age group.

It can be proved that relation (8) is accurately fulfilled for the standardized growth rate using expressions (2) – (4), but for the birth rates of all children.

In particular, it follows from relation (8) that the increase in the birth rate significantly exceeds the decrease in the death rate in terms of the impact on the population growth rate in groups of women of the fertile age. This result is verified by substituting the observed values of the corresponding birth and death rates in its right part. In particular, the elasticity of the marginal growth rate for the girls' birth rate is more than 50 times higher than its elasticity in the death rate in the age group of women aged 20 – 24 in Russia, while the ratio between the elasticity rates is more than 40 times in the age group of 25 – 29, and ~ 17 times higher than in the age group of 30 – 34. Accordingly, the ratios of elasticity of the standardized growth rate in terms of the birth rates of all children and the death rate of women in these age groups are more than twice higher.

The predominant influence of the birth rate as compared to the death rate on the natural reproduction rate is also confirmed by the results of simulation modeling of the sensitivity of the marginal growth rate to changes in the entire set of age-specific fertility rates of girls and death rates of women aged under 50 in Russia. It was noted in[5] that an increase in this indicator with an increase in the birth rates by a certain percentage was more than 30 times higher than its growth ensured by a decrease in the death rates by the same percentage.

More accurate estimates of the contributions of the growth in the age-specific birth and death rates to the change in the population reproduction potential, determined by its marginal growth rate, can be obtained from the following equation:

$$\frac{x_1^2}{\sum_{i=1}^{r} x_i^2}\left(\sum_{i=m+1}^{r} \Delta b_i \cdot \lambda^{-i} \cdot \prod_{j=1}^{i-1} p_j + \sum_{i=2}^{r} \Delta p_{i-1} \cdot p_{i-1} \cdot \lambda^{-2(i-1)} \cdot \prod_{j=1}^{i-2} p_j^2\right) = \frac{\Delta\lambda}{\lambda}, \qquad (9)$$

where λ is the marginal population growth rate for a year or a five-year period in the reference year; b_i and p_j are the birth rate of girls and the female ageing factor in the *i*-th and *j*-th age groups (annual or five-year, respectively) of women aged under 50 in the reference year; $\Delta\lambda$, Δb_i, and Δp_j are the increments of the marginal growth rate, birth rate of girls, and female ageing factor in the age groups of women aged under 50, respectively; x_1 and x_i are the shares of the first and *i*-th age groups in the structure of the female population aged under 50 in the reference year, provided $\sum_{i=1}^{r} x_i = 1$ and $i = \overline{m+1, r}$ are the indices of fertile age groups of women.

For a standardized growth rate, the alternative of expression (9) has simpler form:

[5] N. P. Tikhomirov, T. M. Tikhomirova, "Obyektivnyye otsenki effektivnosti demograficheskoy politiki", Environmental Economics num 5 (2008).

$$\Delta\lambda = \sum_{i=m+1}^{r} x_{1i} \cdot \Delta b_{1i} - \sum_{i=1}^{M} \sum_{k=1}^{2} x_{ki} \cdot \Delta q_{ki}, \quad (10)$$

where x_{1i} and x_{2i} are the shares of the *i*-th age groups of women and men in the total population; b_{1i} is the birth rates for all children in the *i*-th age group of women; q_{ki} is mortality rates for women ($k = 1$) and men ($k = 2$) in their *i*-th age groups, respectively; and *M* is the index of the last age group.

The specifics of solving the problems set forth in this article will be further considered by the example of a stricter indicator of the population reproduction mode – the marginal growth rate. This will serve as a certain guarantee for obtaining more reliable results[6,7].

The first term in parentheses of expression (9) determines the contribution of the age-specific fertility rate growth to the change in the marginal growth rate, while the second term in parentheses determines the contribution of the death rate, given that $\Delta p_i = -\Delta q_i$, where Δq_i is the absolute value of the death rate growth in the *i*-th age group of women. In particular, it was found using expression (9) that an increase in the marginal five-year growth rate of the Russian population from 0.905 in 2000 to 0.975 in 2016 had been determined by an increase in the age-specific fertility rate by almost 90 % – mainly in the age groups from 25 to 40. The sum of the increments in the values of these five-year rates, defined in this case as the ratio of the number of girls born over five years by five-year age groups of women, i.e., women aged 25 – 29, 30 – 34, and 35 – 39, to the population of the corresponding groups, exceeded 0.3 over the period under study.

In practice, the five-year birth, death, and ageing rates per individual can be estimated based on their annual values reflected in the statistical reporting per mille, according to the following expressions:

$$b_i(5) = \frac{b_i(1) \cdot 5}{1000},\ p_i(5) = 1 - q_i(5) = 1 - \frac{q_i(1) \cdot 5}{1000}, \quad (11)$$

where $b_i(5)$, $p_i(5)$, and $q_i(5)$ are the five-year birth, ageing, and death rates per individual in the five-year age groups for a five-year period, respectively; $b_i(1)$ and $q_i(1)$ are the birth and death rates in the five-year groups, determined annually per 1,000 people.

The values of the birth rates remained nearly unchanged in other fertile age groups of women for the 16 years under study. Moreover, the values of these rates, as well as their growth, were insignificant in the age groups of 15 – 19 and over 40, while their levels were on average at 0.22 for girls and a little above 0.44 for all children in the group of 20 – 24 over all 16 years, demonstrating the complete insensitivity to the constantly improving living conditions in the country in this period. According to demographers, such insensitivity is explained by changes in the nature of the demographic behavior of the population associated with an increase in the age of marriage, as well as delays in the birth of a child until reaching an acceptable level of the wealth conditions and for career reasons[8].

---

[6] A. Jindrová, "Dimensionality reduction of quality of life indicators", Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis Vol: 60 num 7 (2013).
[7] N. Tikhomirov; T. Tikhomirova y A. Sukiasyan, "Assessment methods for the reproductive potential of the population", Amazonia Investiga Vol: 8 num 21 (2019).
[8] V. N. Arkhangelsky, Tendentsii i perspektivy rozhdayemosti v Rossii: Demograficheskiye perspektivy Rossii (Moscow: Econ-Inform, 2008) y L. L. Rybakovsky, Osobennosti sovremennoy demograficheskoy situatsii: Demograficheskiye perspektivy Rossii (Moscow: Econ-Inform, 2008).

All these results indicate that the way out of the demographic crisis in Russia is primarily ensured by an increase in the birth rate. However, in any way, this does not deny the need to justify and implement measures to reduce the death rate and the related increase in life expectancy in the practice of managing public development, which are the main goals of the state policy. The issues of justifying such a policy and evaluating the results of its implementation were considered in[9]. However, it should be borne in mind that, apparently, even achieving significant results in this direction only will not be enough for Russia to achieve the expanded population reproduction mode.

Based on the portion of expression (9) relating to the birth rate of girls,

$$\frac{x_1^2}{\sum_{i=1}^{r} x_i^2}\left(\sum_{i=m+1}^{r} \Delta b_i \cdot \lambda^{-(i-1)} \cdot \prod_{j=1}^{i-1} p_j\right) = \Delta\lambda, \qquad (12)$$

the necessary increments of its age rates, which ensure that the indicator λ exceeds a unit threshold, can be approximately estimated (without taking the death rate into account).

In particular, in order to move from the value 0.975 of this indicator, which was estimated in Russia in 2016, to the value 1.01, which describes the expanded natural reproduction mode with an increasing population in the future by 1 % every five years, a total increase in the five-year birth rate of girls by women aged 25 – 39 must be ensured at the level of 0.16 – 0.20 (depending on the ratio of increments in individual age groups), which corresponds to an increase in the total birth rate of all children at the level of 0.32 – 0.4. This result was obtained for the option of expression (12) after substituting the five-year parameters of reproduction of the female population of the country observed in 2016 into it:

$$0.17 \cdot (\Delta b_6 \cdot 1.11 + \Delta b_7 \cdot 1.13 + \Delta b_8 \cdot 1.15) = 0.035.$$

The directions of the socioeconomic policy and the associated measures and costs that provide such increments in the age-specific fertility rates, with a certain degree of justification and accuracy, can be established and estimated using the econometric modeling methods[10]. Such methods allow to identify patterns in the dynamics of the birth rates in the period under study, which were formed under the influence of the factors describing the living conditions. The power model is an example of such dependencies:

$$y_t = \alpha_0 \cdot z_{1t}^{\alpha_1} \cdot z_{2t}^{\alpha_2} \cdot \ldots \cdot z_{kt}^{\alpha_k} + \varepsilon_t, \qquad (13)$$

where y_t is the value of birth rate under study in year *t*; z_{jt} is the value of the *j*-th living factor in year *t*; α_j is the model rates, which are estimated by the known – in this case, nonlinear – methods (for example, the least square method and the maximum likelihood method), using the observed values of variables y_t and z_{jt} over the past years, these rates

[9] K. Hanewald, “Explaining mortality dynamics: The role of macroeconomic fluctuations and cause of death trends”, North American Actuarial Journal Vol 15 num 2 (2011); T. M. Tikhomirova y N. P. Tikhomirov, “Otsenka rezultativnosti programmy materinskogo kapitala v regionakh Rossii”, Federalism Vol: 1 num 97 (2020) y T. M. Tikhomirova y V. I. Gordeeva, “Assessment of health care cost-effectiveness considering a reduction in population health loss”, Journal of Pharmaceutical Sciences and Research Vol: 9 num 11 (2017): 2204 – 2211.

[10] G. Chi y J. Zhu, “Spatial regression models for demographic analysis”, Population Research and Policy Review Vol: 27 num 1 (2008).

are constant estimates of the elasticities of the dependent variable y_t with respect to changes in the corresponding factors $z_{1t},\ldots,z_{kt}$; andε_t is the model error in year *t*; $t=\overline{1,T}$.

The per capita income of the population, child support payments from the state, provision with a living space, social tension indices estimated by the number of murders, suicides, and crimes per 100,000 people, state of the healthcare system, and other indicators can be considered as factors in such models. The composition of factors directly included in the model can be refined and specified with due consideration for the nature of their interconnections with each other and with the dependent variable y_t by statistical (in particular, correlation) methods.

The attempts to build a model of type (13), which linked the levels of the age-specific fertility rates in female age groups of 25 – 29, 30 – 34, and 35 – 39 and their sum with the above listed factors based on the early information for 2000 – 2018 available in Russia, yielded almost the same results in terms of both the composition of factors and the nature of their influence on the rates under study. These results were expected to a certain extent, given the similar nature of the patterns in the dynamics of the indicators of the age-specific fertility under study in the period of 2000 – 2018 in Russia. The charts of their variability are presented in Figure 2.

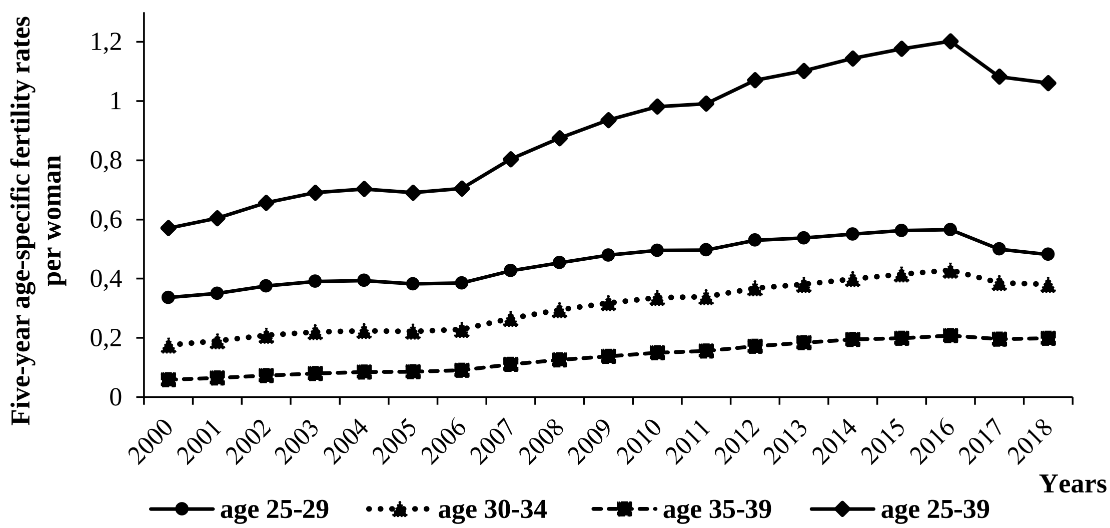

Figure 2
Five-year age-specific fertility rates in Russia in 2000 – 2018
per woman of the corresponding age

In particular, the equation of the model describing the dynamics of the sum of the five-year age-specific fertility rates for all children by Russian women aged 25 – 39 in the period under study is as follows:

$$y_t = e^{-6.65}\cdot z_{1t}^{0.27}\cdot z_{2t}^{1.58}\cdot z_{3t}^{0.08}\cdot z_{4t}^{-0.22}. \qquad (14)$$

Its alternatives describing the dynamics of similar birth rates in five-year female age groups of 25 – 29, 30 – 34, and 35 – 39 are represented by the following expressions, respectively:

$$b_{6t}(25 \div 29) = e^{-4.86} \cdot z_{1t}^{0.22} \cdot z_{2t}^{0.92} \cdot z_{3t}^{0.06} \cdot z_{4t}^{-0.20}, \quad (15)$$

$$b_{7t}(30 \div 34) = e^{-9.64} \cdot z_{1t}^{0.29} \cdot z_{2t}^{2.01} \cdot z_{3t}^{0.11} \cdot z_{4t}^{-0.21}, \quad (16)$$

$$b_{8t}(35 \div 39) = e^{-13.69} \cdot z_{1t}^{0.51} \cdot z_{2t}^{2.59} \cdot z_{3t}^{0.10} \cdot z_{4t}^{-0.31}, \quad (17)$$

where $b_{6t}(25 \div 29)$, $b_{7t}(30 \div 34)$, $b_{8t}(35 \div 39)$, and $y_t = \sum_{i=6}^{8} b_{it}$ are the five-year values of the birth rates in female age groups of 25 – 29, 30 – 34, 35 – 39, and their sum, respectively, in year *t*; z_{1t} is the average per capita income in year *t* reduced to the prices of 2016; z_{2t} is the size of the total living space per person in year *t*; z_{3t} is the child support payments from the state in year *t*, reduced to the prices of 2016; and z_{4t} is the number of crimes in year *t* per 100,000 people; $t = \overline{1,T}$.

Discussion

All the presented models describe the dynamics of the birth rates under study with a high degree of accuracy both during their growth and fall (after 2016). They are described by high-quality indicators. In particular, the coefficient of determination for each of them exceeds 0.99, the values of the Fisher's ratio test (F-test) are in the range from 400 to 1,000 points, all the estimated ratios are statistically significant, and there is no autocorrelation in the error series. In this case, expression (14) can be considered as an averaged version of models (15) – (17), which indicate that the influence of the factors describing the living standards of the population on the birth rate increases with an increase in the age of women. In particular, the elasticity of the birth rates relative to the growth of per capita income by 1 % rises from 0.22 % in the age group of 25 – 29 to 0.51 % in the group of 35 – 39. Improvement in living conditions is even more important for increasing the birth rate in older age groups. The increase in living space per person by 1 % leads to an increase in the birth rate by about the same value in the group of women aged 25 – 29, but the same improvement in living conditions contributes to an increase in the birth rate by more than 2.5 % in the group of women aged 35 – 39.

Compared with the above indicators of the birth rate elasticity, the increase in child support payments by the state is less significant, although its changes with age are described by similar patterns. The value of the birth rate elasticity for these payments increases from 0.06 % to 0.11 % (all per 1 % of the growth in payments) when moving from the group of women aged 25 – 29 to the group of women aged 30 – 34, and remains almost unchanged in the next age group.

As the mother's age increases, the birth rate elasticity for improvement in the social situation also increases, as measured by the number of crimes per 100,000 inhabitants. In the group of women aged 35 – 39, the value of this elasticity is 0.31 %, which is 1.5 times higher than its levels in the younger groups.

The authors believe that this nature of the influence of the factors under study on the age-specific fertility rates can be due to their differences in the birth sequence structures. A significant share of newborns in the group of women aged 25 – 29 belongs to the first and second children, and it is slightly higher for the first-born ones. Moreover, the birth of the first-born is largely predetermined by the factors determining the characteristics of demographic relations in the new family, which are described by a certain independence in terms of the wealth conditions. At older ages, children of the second, third, and even fourth sequence of birth prevail among the newborns, their birth being largely planned in accordance with the wealth of the family. Moreover, compared with the size of state support to families with children, the level of their own well-being is more significant factor when deciding on the birth of another child. At the same time, state support, especially federal and regional programs of maternal capital, contribute to the birth rate to a certain extent, especially in families with low and middle incomes, as shown by the results in work[11].

The average per capita income of the population and child support spending by the state should be highlighted among the factors used in models (14) – (17). These factors, in comparison with the other two, are to a certain degree regulated and can be considered as levers of a real impact on the birth rate. Moreover, such an impact of income is not only direct, but also indirect – in particular, through the factor of provision with living space, the increase in which directly depends on the income size. The income growth is usually accompanied by a decrease in the level of social tension – in particular, the number of crimes. The negative correlation between these indicators can be traced using the corresponding data for Russia for 1990 – 2018.

In general, it can be concluded based on models (14) – (17) that it is necessary to increase per capita income level in Russia by about 40 – 50 % in order to ensure a total increase in the five-year values of the age-specific fertility rates of all children by 0.4 (respectively, the girls' birth rates by ~ 0.2), or by 33 % compared with the levels of these indicators in 2016 of 1.2 (and ~ 0.6), and, therefore, to achieve the expanded population reproduction mode with a marginal growth rate of 1.01. This result was obtained with the assumption that at least half of the increase in per capita income would be used to increase living space.

This result is also confirmed by the econometric models that do not take into account the factor of provision with living space. In particular, this model for the sum of the five-year birth rates is as follows:

$$y_t = e^{-3.48} \cdot z_{1t}^{0.58} \cdot z_{3t}^{0.08} \cdot z_{4t}^{-0.41}. \qquad (18)$$

It must be noted that model (18) also has high approximating properties. Its coefficient of determination exceeds 0.97, and the F-test is above 200 points.

Comparing the rate values in equations (14) and (18), it can be verified that the influence of factor z_{2t}describing the size of the living space on the dependent variable is largely shifted to factor z_{1t} — average per capita income. The elasticity of the dependent variable for this factor in model (18) is more than twice higher than that in model (12).

Conclusion

In conclusion, the attention must be drawn to the limited capabilities of the provided econometric models in terms of estimating the birth rates in Russia in the long term under the influence of an improving economic situation. This is due to the fact that such an influence is usually described by the decreasing efficiency, which is explained by the existence of the growth limits for the age-specific fertility rates, predetermined by stereotypes and traditions of the family formation in terms of the number of children, which

[11] T. M. Tikhomirova y N. P. Tikhomirov, "Otsenka rezultativnosti programmy materinskogo kapitala v regionakh Rossii", Federalism Vol: 1 num 97 (2020).

significantly differ among regions and nations. In this regard, it can be stated that the limits in the birth rates in such a multinational country as Russia can be considered as indicators averaged over its regions in general.

When approaching these limits, the birth rates become less sensitive to positive shifts in the economic and social areas, which corresponds to the logistic dependencies of their values on the influencing factors. However, at the present stage of restoration of the birth potential lost in Russia and most of its regions in the 90s of the past century, such limits are far from the actual values of its age-specific rates and do not significantly influence the patterns of their growth, which are approximated with a high degree of accuracy by the models presented in the article.

In the opinion of the authors, reliable results can be obtained using these models for Russia, up to the age-specific fertility rates reaching the limits of the late 80s of the last century, from which their decline began in the next decade.

Acknowledgments

The study was funded by the RFBR, project No. 20-010-00307 “Methodology for assessing population health losses and justification of improving the efficiency of healthcare systems in the regions of the Russian Federation”.

References

Arkhangelsky, V. N. Tendentsii i perspektivy rozhdayemosti v Rossii: Demograficheskiye perspektivy Rossii. Moscow: Econ-Inform. 2008.

Arkhangelsky, V. N., Ivanova, A. E. y Rybakovsky, L. L. Rezultativnost demograficheskoy politiki Rossii. Moscow: Econ-Inform. 2016.

Chi, G. y Zhu, J. “Spatial regression models for demographic analysis”. Population Research and Policy Review Vol: 27 num 1 (2008).

Gerland, P. “World population stabilization unlikely this century. Science”. Vol: 346 num 6206 (2014): 234 – 237.

Hanewald, K. “Explaining mortality dynamics: The role of macroeconomic fluctuations and cause of death trends”. North American Actuarial Journal Vol 15 num 2 (2011): 290.

Jindrová, A. “Dimensionality reduction of quality of life indicators”. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis Vol: 60 num 7 (2013): 147.

Karelova, G. N. y Rybakovsky, L. L. Stabilizatsiya chislennosti naseleniya Rossii (vozmozhnosti i napravleniya demograficheskoy politiki). Moscow: Publishing House of the Center for Social Forecasting. 2001.

Kobanov, V. F. y Rybakovsky, L. L. Demograficheskoye nastoyashcheye i budushcheye Rossii. Moscow: Econ-Inform. 2012.

Rybakovsky, L. L. 20 let depopulyatsii v Rossii. Moscow: Econ-Inform. 2014.

Rybakovsky, L. L. Osobennosti sovremennoy demograficheskoy situatsii: Demograficheskiye perspektivy Rossii. Moscow: Econ-Inform. 2008.

Tikhomirov, N.; Tikhomirova, T. y Sukiasyan, A. “Assessment methods for the reproductive potential of the population”. Amazonia Investiga Vol: 8 num 21 (2019): 558-567.

Tikhomirov, N. P. “Identifikatsiya i upravleniye rezhimom vosproizvodstva naseleniya”. Sociological studies Vol: 6 num 386 (2016).

Tikhomirov, N.P., Tikhomirova, T.M. Obyektivnyye otsenki effektivnosti demograficheskoy politiki”. Environmental Economics num 5 (2008): 85 – 87.

Tikhomirov, N. P. y Tikhomirova, T. M. “Otsenka i upravleniye potentsialom vosproizvodstva naseleniya Rossii”. Federalism Vol: 3 num 95 (2019).

Tikhomirova, T. M. y Gordeeva, V. I. “Assessment of health care cost-effectiveness considering a reduction in population health loss”. Journal of Pharmaceutical Sciences and Research Vol: 9 num 11 (2017): 2204 – 2211.

Tikhomirova, T. M. y Tikhomirov, N. P. “Otsenka rezultativnosti programmy materinskogo kapitala v regionakh Rossii”. Federalism Vol: 1 num 97 (2020).

CUADERNOS DE SOFÍA
EDITORIAL