Methods of Justification of Effective Demographic Policy

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Abstract. The article considers approaches to justification of effective courses of demographic policy, that ensures the shift from depopulation to a regime of sustainable growth of population in Russia and its regions. These approaches are based on estimates of indicators, which objectively characterize determined by the observed values of sex and age-specific fertility and mortality rates the potential of population self-reproduction, regardless of its gender and age structure, and on the identification of patterns of this potential in the current living conditions using econometric methods. As such indicators, we consider marginal and standardized population growth rates, determined on the basis of age-specific fertility and mortality rates of females of age not older than 49 years and age-specific natural movement rates for male and female population, respectively.

The paper presents results of the study, which indicate that the shift to a sustainable population growth in Russia in the future is mainly associated with an increase in the fertility rate, the necessary conditions of which are a significant increase in income and the strengthening of incentive measures.

Keywords: population growth rates, fertility, mortality, living conditions, socio-economic policy, econometric modeling.

1 Introduction

The ongoing since the beginning of the 90s of the last century demographic crisis in Russia, characterized by an excess of mortality over fertility and, as a consequence, a reduction in the population and labor resources, not only negatively affects the country's economic development and living standards, but also threatens its existence as a single state. In this case, the problems of developing a justified demographic policy, that can ensure sustainable self-reproduction of the population in the Russian Federation and its regions over a long period of time, are actualized. Such policies, if necessary, must take into account the patterns of natural movement, which are formed under the influence of changing living conditions, including used in the country measures to stimulate fertility and reduce mortality [1, 2, 3].

These patterns can be identified by analyzing the trends of reliable and objective estimates of indicators of the intensity of population natural movement in the past, carried out, for example, by econometric modeling methods [4, 5, 6]. In this regard, we note that as such indicators it is incorrect to consider the general fertility, mortality

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and natural growth rates, due to their dependence not only on age-related indicators of natural movement, characterizing the population's potential for self-reproduction, but also on its sex and age structure, which in Russia varies significantly over time (the phenomenon of demographic waves). In particular, the natural population decline in Russia in the period 1990-2003, amounting to approximately 800-900 thousand people per year, was largely due to a significant, compared with 1989, decrease in the proportion (and number) of people at age 20-40 and an increase in the proportion of people of older age groups. This resulted in the period 1990-1999 to a significant decrease in the total fertility rate from 13.4‰ to 8.3‰, and an increase in the overall mortality rate from 11.2‰ to 14.7‰. Taking the levels of age-specific fertility and mortality rates, observed in 1999, and maintaining the age structure of the population in 1989, the total fertility rate in the country would be 9.3 ‰, and the mortality rate – 13.0‰ [7, 8]. The data presented indicate, that the unfavorable phase of the demographic wave, that occurred during this period, contributed to a significant decrease in the natural growth rate of the Russian population in 1999 to minus 6.4‰, versus minus 3.7‰, which could have occurred with the age and sex structure of the population of 1989.

On the contrary, in the period from 2006 to 2015, a favorable phase of the demographic wave was observed in the age structure of the Russian population, which was characterized by an increase in the proportion (and number) of females aged 20-34 and relative stabilization after 2010 of the proportion of people aged over 50 years at the level about 34%. These shifts in the age structure of the population, along with an increase in age-specific fertility rates of females and a decrease in sex and age-specific mortality rates in almost all age groups of males and females, led to the fact that in 2013-2015 the values of the total fertility and mortality rates were 13.3‰ and 13.1‰, respectively, and, thus, the natural increase exceeded the zero level. However, after 2015, the demographic wave phase, unfavorable for population growth, again formed on the age structure of the population of Russia, and its natural increase again became negative, which was to some extent also due to a decrease in age-specific fertility rates.

2 Methods

In a situation of significant influence of demographic waves on the population growth rate, it is advisable to express the regime of its natural reproduction by indicators, that depend only on age-specific fertility and mortality rates, the set of which characterizes the demographic potential available for the corresponding year. Such indicators include the marginal growth rate of population, its standardized counterpart, calculated on a basis of a constant standardized sex and age structure, and the population net reproduction rate (NR) [9, 10, 11].

The marginal growth rate (GR) is calculated for a specific year and represents the population growth rate over a certain period (usually five years), which will be established in the long run, provided that the age-specific fertility and mortality rates of females under 50 in annual or five-year age groups, respectively, on the basis of which its value is estimated, will remain at the level of the year under consideration. In an algebraic sense, this indicator represents the largest root (Perron root) of the characteristic equation of the matrix of age-specific coefficients of natural movement (annual or five-year) of the population. Accordingly, based on annual coefficients, the marginal population growth rate for a year is estimated, and on the basis of five-year ones, for five years. However, due to the block structure of this matrix, its value is estimated only by the block of coefficients of natural movement of females under 50 years old. Taking this into account, its characteristic equation can be represented as follows:

$$\lambda^r - \theta \cdot \sum_{i=m+1}^{r} \lambda^{r-i} b_i \cdot \prod_{j=1}^{i-1} p_i = \lambda^r - \lambda^{r-m-1} \cdot \theta \cdot b_{m+1} \cdot p_1 \cdot ... \cdot p_m + \\ + \lambda^{r-m-2} \cdot b_{m+2} \cdot p_1 \cdot ... \cdot p_{m+1} + ... + \theta \cdot b_r \cdot p_1 \cdot ... \cdot p_{r-1} = 0 \tag{1}$$

where λ is the root of the characteristic equation; θ is the proportion of girls among newborns (in average 0.488); b_i is the fertility rate in i-th age group of females, which corresponds to the age interval from $(i-1)\tau$ to τ years old, $\tau = 1$ or 5 years; p_j is the survival rate of females of j-th age group from $(i-1)\tau$ to τ years (the probability of transition from $(i-1)$-th to i-th age group), which is determined on the basis of age-specific mortality rates q_j as $p_j = 1 - q_j$.

The indices $i = \overline{m+1, r}$ characterize the fertile age groups of females (as a rule, at the ages of 15 to 49 years).

Net reproduction rate (NR) is a quantitative measure of the replacement of the maternal generation with the daughter. It determines the average number of daughters, born to a female in a lifetime and survived to the age of the mother, under considered values of the age-specific fertility and mortality rates of females under 50 years old. In an algebraic sense, this indicator is defined as the sum of the coefficients for unknown λ^{r-i}, $i = \overline{m+1, r}$ on the right side of the characteristic equation (1):

$$NR = \theta \cdot b_{m+1} \cdot p_1 \cdot ... \cdot p_m + \theta \cdot b_{m+2} \cdot p_1 \cdot ... \cdot p_{m+1} + ... + \theta \cdot b_r \cdot p_1 \cdot ... \cdot p_{r-1} \tag{2}$$

Note that when evaluating these indicators, the fertility rate of boys and the mortality of the entire male and female population over 49 years old are not taken into account.

The standardized growth rate (SGR) for each year is estimated by the difference between the general standardized fertility (STFR) and mortality rates (STMR) of the entire population, calculated by its standardized age structure and fixed in that year the fertility and mortality rates for female and male age groups. Its expression has the following form [12]:

$$SGR_t = 1 + STFR_t(\bar{x}) - STMR_t(\bar{x}) \tag{3}$$

where $STFR_t(\bar{x})$ and $STMR_t(\bar{x})$ are the standardized general fertility and mortality rates, calculated according to the following expressions, respectively:

$$STFR(\bar{x}) = \sum_{k=1}^{2} \sum_{i=m+1}^{r} b_{ki} \cdot x_{1i}, \quad STMR(\bar{x}) = \sum_{k=1}^{2} \sum_{i=1}^{M} q_{ki} \cdot x_{ki}, \tag{4}$$

where b_{ki} are fertility rates of girls $(k = 1)$ and boys $(k = 2)$ in i-th female age group; q_{ki} are mortality rates of females $(k = 1)$ and males $(k = 2)$ in i-th age group; x_{ki} are normalized proportions of female and male age groups in the standardized structure of population, represented by a vector $\bar{x} = (x_{11},..., x_{1M}, x_{21},..., x_{2M})$, that satisfies the following ratio:

$$\sum_{k=1}^{2} \sum_{i=1}^{M} x_{ki} = 1 \tag{5}$$

When assessing SGR, the problem arises of choosing a standardized age structure of the population, which should not depend on demographic waves. As such a structure, one can consider the marginal structure of the population, corresponding to the Perron root of the matrix of age-specific coefficients of its natural movement [10, 12], or a structure, formed taking into account the patterns of retirement of females and males, predetermined by the values of their age-specific mortality rates, examples of which are given in the work [12]. For Russia, it is inexpedient to use as such a structure the real population structure of any year, for example, 1990, 2000, 2010, since each of them has a particular phase of the demographic wave.

Using the marginal GR and standardized population growth rates of SGR and NR, it is simple enough to identify the mode of demographic reproduction in the current period. Values of these indicators, exceeding the value 1, correspond to the expanded population reproduction regime, equal to 1 – to the stationary population regime, less than 1 – to depopulation.

Estimates of marginal and standardized growth rates may vary slightly. Compared to the marginal growth rate, its standardized counterpart is increasing by taking into account the fertility rate of boys and decreasing due to the mortality rate of males of all ages and females older than 50 years old. In addition, certain differences in the values of these indicators may be due to the specific features of the methods for their assessment.

3 Results

Estimates of the five-year marginal and standardized growth rates for Russian population in certain years of the 21st century, obtained on the basis of the corresponding fertility and mortality rates, observed in these years, indicate that the first indicator is still slightly less than the second, as presented in Table 1.

Table 1. Marginal and standardized population growth rates for Russia in 2008-2016.

Years	GR	SGR
2008	0.947	0.993

2010	0.955	0.999
2014	0.973	1.005
2016	0.975	1.005

It sounds interesting to consider the patterns of the reproduction regime of the population of Russia and its regions, united in the framework of three homogeneous by their characteristics regional clusters, in the 21st century as an example of a five-year marginal growth rate, which is a more stringent indicator of the intensity of this process compared to its standardized analogue (see Table 2).

With respect to NR, note that its variability is characterized by greater dynamism (see Table 2). In addition, the content of this indicator does not adequately reflect the intensity of the population reproduction process. As a result, NR is less convenient when analyzing its patterns.

Table 2. Marginal indicators of the population reproduction regime of Russia and its regional clusters for 2000-2019.

Year	2000	2003	2006	2009	2012	2015	2018	2019
Russia in a whole								
Five-year growth rate	0,9045	0,9226	0,9232	0,9520	0,9673	0,9757	0,9600	0,9586
Annual growth rate	0,9801	0,9840	0,9842	0,9902	0,9934	0,9951	0,9919	0,9916
Five-year NR	0,5640	0,6269	0,6267	0,7448	0,8169	0,8593	0,7681	0,7553
Five-year marginal growth rate by clusters								
Cluster 1	0,9223	0,9406	0,9407	0,9675	0,9855	0,9925	0,9713	0,9685
Cluster 2	0,9049	0,9245	0,9254	0,9550	0,9715	0,9777	0,9564	0,9537
Cluster 3	0,8922	0,9100	0,9099	0,9364	0,9509	0,9616	0,9423	0,9394

Among the regions, 4 outliers were also identified, which are significantly different from the clustered administrative entities according to the laws of the process under consideration. The composition of regional clusters is presented in Table 3.

Table 3. Composition of homogeneous and outlier in terms of the marginal growth rate in the period 2000-2019 clusters of Russian regions.

Cluster	Russian regions
Cluster 1	Jewish Autonomous Region, Chukotka Autonomous Okrug. Regions: Amur, Astrakhan, Vologda, Irkutsk, Kurgan, Orenburg, Sakhalin, Tyumen. Republics: Bashkortostan, Kalmykia, Komi, Mari El, North Ossetia-Alania, Khakassia, Udmurtia.

	Territories: Transbaikal, Perm.
Cluster 2	Regions: Arkhangelsk, Kemerovo, Kirov, Kostroma, Magadan, Novgorod, Novosibirsk, Omsk, Pskov, Sverdlovsk, Tver, Chelyabinsk. Republics: Adygea, Kabardino-Balkarian, Karachay-Cherkess, Karelia, Tatarstan, Chuvash. Territories: Altai, Kamchatka, Krasnodar, Krasnoyarsk, Primorsky, Khabarovsk.
Cluster 3	Moscow, St. Petersburg. Regions: Belgorod, Bryansk, Vladimir, Volgograd, Voronezh, Ivanovo, Kaliningrad, Kaluga, Kursk, Lipetsk, Moscow, Murmansk, Nizhny Novgorod, Oryol, Penza, Rostov, Ryazan, Samara, Saratov, Smolensk, Tambov, Tomsk, Tula, Ulyanovsk, Yaroslavl. Republics: Mordovia. Territories: Stavropol.
Outlier regions	Regions: Leningrad. Republics: Altai, Buryatia, Dagestan, Ingushetia, Sakha (Yakutia), Tuva.

The data, presented in Table 2, indicate that in Russia and in all its regional clusters the trends in the marginal growth rate were the same. Moreover, the values of this indicator in the second cluster practically coincided with the average Russian ones. Intercluster differences in its values can be explained by the difference in the levels of age-specific fertility rates, due to regional characteristics of demographic behavior and lifestyle of the population. In particular, in the regions of the first cluster, which are characterized by higher values of the indicator under consideration, the levels of fertility rates in the most "prolific" age groups of women from 20 to 34 years during the entire period under review were approximately 20% and 30% higher than in the second and third, respectively. Differences in the values of age-specific mortality rates for both females and males in the regions of Russia during the period under review were less significant.

The data, given in Table 2, also indicate, that during the period under review both in Russia and in most of its regions the regime of expanded reproduction of the population was not achieved. Moreover, after 2015, the marginal growth rate in these regions and in Russia as a whole began to decline again. At the same time, in some regions of the country included in the first cluster or classified as outlier, this regime, characterized by a marginal growth rate greater than 1, was nevertheless observed in the period under review up to 2017. In particular, in the Republics of Tuva, Altai and Ingushetia, this excess has occurred since 2007, in the Republics of Sakha (Yakutia) and Buryatia – from 2012-2013, in the Kurgan and Tyumen regions – from 2013-2014. This is largely due to the fact that these regions are characterized by high proportion of the rural population, the marginal growth rate of which in Russia was much higher than that of the urban population, again due to higher fertility (see Fig. 1).

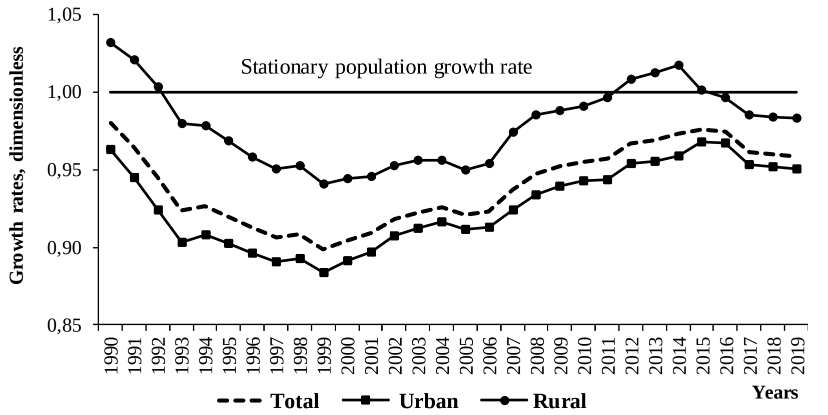

Fig. 1. Five-year growth rates of rural, urban and total population in Russia in 1990-2019

The main reason for the growth of this indicator of the self-reproduction regime in Russia in the period 2000-2015, in our opinion, was the increase in average per capita incomes of the population by an average of 10% per year until 2008 and by 3-4% in the further, to 2014. After 2005, the growth of this indicator was also due to the measures, introduced in the country to stimulate the birth rate and, above all, the payments of federal and regional maternal capital. In particular, only for 2011-2016 the amount of family and maternal benefits, paid in Russia, increased at current prices by more than 60% (from 464.4 billion rubles to 747.8 billion rubles). In comparable prices, the growth of this indicator is estimated at about 35%. To a certain extent, the growth of this indicator was also due to a decrease in mortality due to an increase in health care expenditures and an improvement in the social situation in the country [13, 14, 15]. In particular, health care expenditures in 2011-2016 amounted to 3.2-3.6% of GDP, while in 1995-2000 together with expenditures on physical education and sports, they did not exceed 2.2% of GDP.

At the same time, from the point of view of increasing population growth rates, a decrease in mortality is a significantly less effective factor compared to an increase in the fertility rate. This is evidenced by the ratio of the coefficients of elasticity of the marginal growth rate to changes in age-specific indicators of fertility rates of girls and mortality both in certain age groups of females at childbearing age and throughout the female population under the age of 50. As shown in [12], in the depopulation area, i.e. when GR <1, the ratio of the absolute values of these elasticities in a separate group of females at childbearing age is approximately determined by the following expression:

$$\frac{El(\lambda_1)/b_{1i}}{El(\lambda_1)/q_{1i}} \approx \frac{b_{1i}}{q_{1i}} \qquad (6)$$

where $El(\lambda_1)/b_{1i}$ and $El(\lambda_1)/q_{1i}$ are the elasticities of the marginal growth rate by the fertility rate of girls b_{1i} and mortality of females of i-th age group q_{1i} respectively.

Note that in accordance with expression (3), a similar ratio of elasticity indicators of a standardized growth rate in terms of fertility and mortality rates for females of the i-th group is exactly equal to its right side.

Putting into expression (6) the values of the coefficients of natural movement of females at childbearing age, observed in the period 2000-2019 in Russia, it is easy to verify, that the relative increase in the marginal growth rate of the country's population due to an increase in the fertility rate of girls by a certain percentage in the age group of females at age 20-24 years old is more than 50 times higher, than due to the same decrease in mortality. In the age group of females at age 25-29 years old, the ratio between these coefficients is about 40 times, in the group of 30-34 years old it is about 17-20 times. This conclusion is also confirmed by the results of simulation modeling of marginal growth rate depending on changes in the totality of age-specific fertility rates of girls and mortality rates for Russian females not older than 50 years old. These results indicate that the growth of this indicator, due to an increase in the birth rate by a certain percentage, is more than 30 times higher than its growth due to a decrease in the death rate by the same percentage.

The fact that an increase in the living standards of the population of Russia is the main condition for increasing the rate of its natural self-reproduction, is also indicated by the decrease in its marginal values, that began after 2015, apparently due to a significant reduction in incomes per capita in the country, which led to a decrease in the fertility rate. In particular, the five-year population growth rate in Russia decreased by 2019 compared to 2015 from 0.976 to 0.959. In the urban population, it decreased from 0.968 to 0.951 and in the rural population, from 1.001 to 0.983. Note that, compared to 2015, by 2019, the average income per capita of the population of Russia decreased by more than 10%. Moreover, a slight increase in the size of federal and regional maternal capital could not compensate for the negative impact of lower incomes on the growth rate of the Russian population during this period [15].

4 Discussion

The mentioned patterns in the dynamics of the marginal growth rate of the Russian population in the period 2000-2019 are quite well explained by econometric models. In particular, one of their most reliable ones, characterized by a determination coefficient above 99%, has the following form:

$$y_t = 0.523 \cdot x_{1t}^{0.035} \cdot x_{2t}^{0.130} \cdot x_{3t}^{0.008} \cdot x_{4t}^{-0.029} \quad (7)$$

which indicates, that the increase in the marginal growth rate of the Russian population y_t is associated with improved living conditions in the country, expressed in terms of average income per capita x_{1t} (rubles/person, in 2016 prices), living space per inhabitant x_{2t} (m2/ person), and the number of crimes per 100 000 of persons

x_{4t}, as well as state-stimulating payments by the state for the maintenance of one child aged 0-17 years x_{3t} (rubles/child in 2016 prices).

It should be noted that from expression (7) it follows that the elasticity of the marginal growth rate in terms of housing conditions is almost four times higher than in terms of average income per capita, and 16 times higher than in terms of state payments for child support. However, given that the housing conditions in the country are largely determined by the incomes of the population, their increase, apparently, is the main condition for entering a regime of sustainable expanded demographic reproduction. It should be noted that this result to a certain extent also depends on the social tension in the country, reflected in the model (7) as the crime rate, with a decrease in which the marginal rate of population growth also increases.

Note that a definite confirmation of the validity of expression (7) is almost complete coincidence with it, up to a constant factor, of its analogues, describing the patterns of marginal population growth rates in the considered period in the reference regions of the formed clusters.

The importance of increasing age-specific fertility in overcoming the demographic crisis in Russia is evidenced by an econometric model that describes the patterns of its level in the age groups of females at ages 25-39 years old, established in 2000-201. under the influence of the same factors. The equation of this model, also characterized by a coefficient of determination above 98%, has the following form:

$$b_t(25-39) = e^{-6.65} \cdot x_{1t}^{0.27} \cdot x_{2t}^{1.58} \cdot x_{3t}^{0.08} \cdot x_{4t}^{-0.22} \qquad (8)$$

where $b_t(25-39)$ is total fertility rate of Russian females at ages 25-39 years old in a year t.

Note that the birth rate in the group of 20-24-year-old females in the country during the period under review did not respond to changes in living conditions and remained at a constant average annual level of about 90‰. According to demographers [7, 8], this is due to changes in the conditions of family formation associated with increasing the age of marriage, delaying the birth of the first child until a certain level of material security and career status is achieved.

Based on models (7) and (8), it can be concluded, that the shift to the expanded self-reproduction regime of the Russian population is possible by 2030 with an increase in the average monthly income of the population by about 50-60% compared with their levels in 2019, which is equivalent to an increase in these indicators of about 3-4% per year. It is assumed that income growth will contribute to a certain improvement in the living conditions of the population.

The results presented, no way indicate the inappropriateness of the implementation of policies aimed at reducing mortality and the resulting increase in life expectancy of the population, which are the most important social goals of any developed society. However, the achievement of these goals cannot bring as tangible results in terms of ensuring high population growth rates as increasing the birth rate. To a certain extent, this is also associated with significantly smaller physiological reserves in reducing mortality in developed countries, compared to fertility rate reserves.

5 Conclusion

The results of the study suggest, that the intensification of depopulation of the Russian population in the last decade of the last century was due, firstly, to a significant deterioration in the standard of living and social situation in the country in the absence of any significant measures to stimulate fertility by the state, and, secondly unfavorable for the fertility and mortality rates the phase of demographic wave, that faced at that time. It is the fertility rate increase in the country that should be considered as the main goal of the demographic policy in Russia, which provides shift to the sustainable self-reproduction of its population in the long term, and the main conditions for this growth in the current period, apparently, are to increase the standard of living of the population, including and by strengthening material support for low-income families with children.

A decrease in mortality, in contrast to an increase in fertility, does not bring significant results in terms of increasing population growth rates. However, this fact cannot be regarded as a denial of the feasibility of efforts, aimed to reducing mortality and increasing the life expectancy of the population, which are one of the most important goals of the development of society.

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