Artículo de investigación

Assessment methods for the reproductive potential of the population

Методы Оценки Потенциала Воспроизводства Населения

Métodos para estimar el potencial de reproducción de la población

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Abstract

The paper considers various approaches to the assessment of reasonable and reliable indicators that characterize the reproductive potential of the population embedded in the system of gender- and age-specific fertility and mortality rates. The authors demonstrate that it is impractical to use the total coefficients of natural population growth due to their dependence on population's age-sex structure, which can significantly vary over time due to the movement of demographic waves. The authors evaluate the diverse influence of demographic waves on the total fertility rates, mortality rates, and natural movement of the population in Russia in 1990-2000 and 2001-2017. It is suggested to evaluate the reproductive potential of the population by its growth rate calculated only based on the natural movement coefficients for female population younger than 50 and its modification determined on the basis of such coefficients for the male and female population of all ages. The paper provides annual estimates of these indicators for the population of Russia in 1990-2017 and states the reasons for the discrepancies in their values. On the basis of these estimates, the authors identify trends in the variability of the reproductive potential of the population in Russia during the period under review and justify the approaches to determining the directions of socio-economic policy conducive to its increase.

Аннотация

В статье рассмотрены подходы к оценке обоснованных и достоверных показателей, характеризующих сложившийся у населения потенциал его воспроизводства, заложенный в системе половозрастных коэффициентов рождаемости и смертности. Показано, что в качестве таких показателей нецелесообразно использовать общие коэффициенты естественного прироста населения вследствие их зависимости от его половозрастной структуры, которая может существенно меняться во времени (движение демографических волн). Оценено разноплановое влияние демографических волн на общие коэффициенты рождаемости, смертности и естественного движения населения России в 1990-2000 гг. и в 2001-2017 гг. Предложено оценивать потенциал воспроизводства населения по его предельному темпу роста, рассчитываемому только по коэффициентам естественного движения женщин моложе 50 лет, и его модификации, определяемой на основе таких коэффициентов мужчин и женщин всех возрастов. Приведены годовые оценки этих показателей для населения России в 1990-2017 гг., определены причины расхождений в их значениях. На основе этих оценок выявлены тенденции изменчивости потенциала воспроизводства населения

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Keywords: Demographic policy, demographic wave, indicators of the natural movement of the population, population growth rate, reproductive potential.

России в рассматриваемом периоде и обоснованы подходы к определению направлений социально-экономической политики, способствующей его повышению.

Ключевые слова: Потенциал воспроизводства, показатели естественного движения населения, предельный темп роста населения, демографические волны, демографическая политика.

Resumen

El artículo considera enfoques para la evaluación de indicadores razonables y confiables que caracterizan el potencial de reproducción de la población, integrados en el sistema de tasas de fertilidad y mortalidad por edad sexual. Se muestra que no es práctico utilizar los coeficientes generales de crecimiento de la población natural como indicadores debido a su dependencia de su estructura de edad y sexo, que puede variar significativamente con el tiempo (el movimiento de las ondas demográficas). Se estima la influencia diversa de las ondas demográficas en las tasas generales de natalidad, mortalidad y el movimiento natural de la población de Rusia en 1990-2000. y en los años 2001-2017 Se propuso evaluar el potencial de reproducción de la población por su tasa de crecimiento marginal, calculada solo por los coeficientes de movimiento natural de las mujeres menores de 50 años, y su modificación, determinada sobre la base de dichos coeficientes de hombres y mujeres de todas las edades. Se dan estimaciones anuales de estos indicadores para la población de Rusia en 1990–2017, se determinan las razones de las discrepancias en sus valores. Sobre la base de estas estimaciones, se identifican las tendencias en la variabilidad del potencial de reproducción de la población rusa en el período que se examina y se justifican los enfoques para determinar las orientaciones de la política socioeconómica conducente a su aumento.

Palabras clave: Potencial de reproducción, indicadores de movimiento natural, tasa máxima de crecimiento de la población, olas demográficas, política demográfica.

Introduction

The development and justification of a set of socio-economic measures to ensure the transition of Russia and its regions from the protracted population decrease to its steady growth regime must take into account the objective regularities describing the variability of reliable estimates of the demographic reproduction process intensity in changing life conditions (Hanewald 2011; Gerland et al. 2014; Tikhomirova & Sukiasyan 2014; Elizarov 2014).

The main requirement for such assessments is an adequate expression of the reproductive potential of the population inherent in the system of its gender- and age-specific indicators of fertility and mortality (Jindrová et al. 2013; Tikhomirov 2016). Such well-known demographic indicators as total fertility, mortality and natural population growth rates do not satisfy this requirement, as their values depend not only on the gender- and age-specific characteristics of the natural movement but also on the population's age-sex structure for the period of their assessment. In Russia, this kind of structure is characterized by a significantly uneven distribution of numbers (proportions) of age-specific groups of male and female population, changing over time in the process of generation replacement. This phenomenon is known as "demographic wave movement".

Demographic waves can significantly distort the characteristics of the intensity of the population reproduction process due to its gender- and age-specific indicators. In particular, the unfavorable phase of the demographic wave in 1990-1999 characterized by a significant decrease in the proportion of the population aged 20-40 years in Russia and an increase in the proportion of people of the older age groups as compared to 1989 contributed to a significant deterioration in the total natural movement coefficients. The observed value of the total fertility rate for this period decreased from 13.4‰ to 8.3‰, the mortality rate increased from 11.2‰ to 14.7‰, and the natural increase rate thus decreased from more than 2‰ to a negative value of minus 6.4‰. At the same time, while maintaining the population's age-sex structure in 1989, i.e. in the absence of a demographic wave, and with the levels of gender- and age-specific fertility and mortality rates registered in 1999, the total fertility and mortality rates in that year would have been

9.3‰ and 13.0‰ respectively, which predetermines the level of natural increase of minus 3.7‰ (i.e. 2.7‰ higher) (Rybakovsky 2008).

On the contrary, in the period from 2006 to 2015б the new phase of the demographic wave was characterized by shifts favorable for population growth in its age-specific structure, associated with an increase in the number and proportion of female population aged from 20 to 34, cessation of growth, and stabilization after 2010 of the proportion of age groups older than 50 years at about 34%. These shifts, along with an increase in the age-specific fertility rates and a decrease in the age-specific mortality rates during this period, led to fairly significant positive changes in the total fertility and mortality rates, the values of which in 2013-2015 on average equaled 13.3‰ and 13.1‰ respectively. As a result, the levels of the total natural growth rate in Russia in 2013-2015 exceeded the zero mark for the first time after 1989. However, starting from 2016, the processes of the natural movement of the Russian population are again beginning to be accompanied by an unfavorable phase of the demographic wave. According to the available estimates, due to the decline in the female population aged 20-34 years in the age-specific structure of the country's population, the total fertility rate may drop to about 10‰ by 2025, even with a slight increase in its age indicators. At the same time, the expected decrease in age-specific mortality rates with a slight increase in the proportion of older age groups in the country's population will help stabilize the total mortality rate in 2020-2025 on average at around 12.5‰. As a result, the total natural population growth rate in Russia will decline again after 2016 and will reach minus 2.0-2.5‰ by 2025 (Rybakovsky 2014).

The standardized total fertility rates, mortality rates, and natural growth, which are estimated for each year on the basis of a constant population's age-sex structure and current values of gender- and age-specific natural movement indicators, are independent of the influence of demographic waves. Standardized total coefficients of natural movement are quite convenient when comparing the intensity of the reproduction process of the state (region) population in different periods of time. Their temporal (for example, annual) sequences are generally suitable for identifying the emerging patterns in the variability of this process. However, their current values do not quite adequately characterize the reproductive potential of the population, since they depend not only on the age and gender indicators of fertility and mortality but also on the population structure usually unrelated to them and selected as the standard one. To a certain extent, this can distort the estimates and trends in the variability of the reproductive potential of the population (Lee & Carter 1992; Chi & Zhu 2008; Tikhomirova & Gordeeva 2017).

Methods

The population reproduction intensity estimates obtained only on the basis of gender- and age-specific natural movement indicators are independent of the population structure. These include, in particular, the population growth rate (GR) and the gross reproduction rate (GRR). These methods are based on the representation of the process of demographic population reproduction by a vector-difference equation of the following form (Tikhomirov 1984):

$$y_{t+1} = G_t \cdot y_t, \qquad (1)$$

Where $y_t = (y_1, y_2, \dots, y_n, y_{n+1}, y_{n+2}, \dots, y_{2n})'$ is the column vector of the number of age-specific groups of the female and male population at time *t*; G_t is the matrix of values of age-specific fertility rates of the female population and mortality of the male and female population in the period (*t*, *t* + 1) expressed in the following form:

$$G_t = \begin{bmatrix} 0 & \dots & 0 & b^t_{1,m+1} & \dots & b^t_{1,r} & 0 & \dots & 0 & 0 & \dots & \dots & \dots & 0 \\ p^t_1 & 0 & 0 & \dots & \dots & \dots & \dots & \dots & 0 & 0 & \dots & \dots & \dots & 0 \\ 0 & p^t_2 & 0 & \dots & \dots & \dots & \dots & \dots & 0 & 0 & \dots & \dots & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & \dots & \dots & \dots & \dots & p^t_{n-1} & p^t_n & 0 & \dots & \dots & \dots & 0 \\ 0 & \dots & 0 & b^t_{2,m+1} & \dots & b^t_{2,r} & 0 & 0 & 0 & 0 & \dots & \dots & \dots & 0 \\ 0 & 0 & 0 & \dots & \dots & \dots & \dots & \dots & 0 & p^t_{n+1} & 0 & \dots & \dots & 0 \\ 0 & 0 & 0 & \dots & \dots & \dots & \dots & \dots & \dots & \dots & p^t_{n+2} & 0 & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & 0 & 0 & \dots & \dots & p^t_{2n-1} p_{2n} \end{bmatrix}, \qquad (2)$$

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where the $j = \overline{1, n}$ indices refer to the female population age groups and $j = \overline{n+1, 2n}$ to the male population age groups; *n* and 2*n* are the indices of the last age groups of the female and male population, which include the population over a certain age, for example, 70 years and older; b_{1j}^t and b_{2j}^t are the values of fertility rates of girls and boys, respectively, in the $j = \overline{m+1, r}$ female age group in the interval (*t*, *t* + 1), the $\overline{m+1, r}$ indices, as a rule, cover the age from 15 to 49 years. In practice, it is often believed that:

$$b_{1j}^t = \theta \cdot b_j^t \text{ and } b_{2j}^t = (1-\theta) \cdot b_j^t, \qquad (3)$$

where b_j^t is the fertility rate of the female population of the age group *j* in the interval (*t*, *t* + 1) and θ is the proportion of girls among newborns, usually equal to 0.488; p_j^t are the coefficients of survival up to a point in time (*t* + 1) of the female or male population belonging at the moment *t* to the corresponding age group *j* (transition coefficients from age group *j* to group *j* + 1). That said, we take into account that the female and male population who have lived up to the moment $(t + 1)$ and are in the groups *n* and 2*n* respectively, at the moment *t* remain in the same groups. This condition is taken into account by the location of the p_n^t coefficients on the main diagonal, while all other survival coefficients are located under the main diagonal.

In practical studies, the duration of the period (*t*, *t* + 1) is usually one or five years, which is predetermined by the initial statistical information collected, as a rule, for one-year or five-year age-specific population groups.

The growth rate, which is proposed to be used as an assessment of the population demographic reproductive potential in the period (*t*, *t* + 1) of the considered time interval $t \in (1, T)$ is the Perron root (the largest eigenvalue) of the positive definite matrix G_t. This figure theoretically means that, provided that the elements of the matrix $G_t = G$ remain unchanged in the long term, in the limit as $T \to \infty$, the population reproduction process will be determined by the following equation:

$$y_T = \beta_1 \cdot \lambda_1^{T-t} \cdot z, \qquad (4)$$

according to which, for each individual time period in the future, the population will change with the pace λ_1 and its structure *z* will remain constant; λ_1 is the Perron root of the matrix *G*; *z* is the eigenvector of the matrix *G*, corresponding to its Perron root, whose elements characterize the proportion of the *j*th age group of the female and male population in the total population, so that $\sum_{j=1}^{2n} z_j = 1$; β_1 are the coefficients at the vector *z* in the decomposition of the original vector $y_t = y_0$ in the system of eigenvectors of the matrix G_t. Thus, for a five-year population structure, λ_1 characterizes the population growth rate over 5 years, and for a one-year one for a year. Note that these indicators are related by the following relation $\lambda_1(1) = \sqrt[5]{\lambda_1(5)}$, where the period duration (*t*, *t* + 1) is indicated in brackets.

From expression (4), it follows that the indicator λ_1 can be used as an identifier of the population reproduction mode in each period (*t*, *t* + 1) of the considered time interval $t \in (1, T)$. Its values which are less than one, $\lambda_1 < 1$, correspond to the depopulation mode; the values above one $\lambda_1 > 1$ to the mode of population growth; equal to one $\lambda_1 = 1$ to the stationary population regime, which is characterized in the limit as $T \to \infty$ and an invariable matrix *G* of its constant number.

For definiteness, we assume that the interval (*t*, *t* + 1) is 5 years. With this in mind, the population composition vector *y* (expression (1)) with *n* = 15 in the first and sixteenth groups combined the male and female population aged 0-4 years, respectively, in the second and seventeenth groups aged 5-9, etc., in the fifteenth and thirtieth at the age of 70 years and older. Fertile groups of the female population characterized by non-zero coefficients b_j have $j = \overline{4{,}10}$ indices. At the same time, since official statistics usually gives annual values of natural movement indicators for five-year age groups per 1,000 people, for a five-year period, their respective estimates can be approximately calculated on the basis of the following expressions:

$$b_j(5) = \frac{b_j(1) \cdot 5}{1000}, \ldots\ p(5) = 1 - q_j(5) = 1 - \frac{q_j(1) \cdot 5}{1000}, \qquad (5)$$

where we indicated in brackets with appropriate coefficients the duration of the period to which they correspond.

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The value λ_1 is determined from the characteristic equation obtained from the condition that the following determinant equals zero:

$$|G - \lambda \mathrm{E}| = 0, \qquad (6)$$

where *E* is the identity matrix.

A special feature of equation (6) is the fact that in order to compile it, it suffices to use only the upper left square of the matrix *G* containing the parameters of the natural movement of the female population under 50 years old. This result directly follows from the block structure of the matrix *G*.

By resolving the determinant of this square on the elements of its upper row, we obtain the characteristic equation of the matrix *G* in the following form:

$$\lambda^r - \theta \sum_{i=m+1}^{r} \tau^{r-i} \, b_i \prod_{j=1}^{r-1} p_j = 0, \qquad (7)$$

where index $i = \overline{m+1, r}$ refers only to fertile groups of the female population.

The largest root of equation (7) is the Perron root, i.e. growth rate. Here we would like to remind that the expression

$$\theta \sum_{i=m+1}^{r} b_i \sum_{j=1}^{r-1} p_j = \theta (b_{m+1} \cdot p_1 \dots p_m + b_{m+2} \cdot p_1 \dots p_{m+1} + \dots + b_r p_1 \dots p_{r-1}) = \mathrm{GRR} \qquad (8)$$

is called the population gross reproduction rate in demography. Its value determines the quantitative measure of the replacement of the maternal generation by a child or in other words — the average number of daughters born by a woman in her entire life and living to the age of the mother that she had at the time of their fertility.

It is known that to satisfy the conditions $\lambda_1 > 1$, $\lambda_1 = 1$, $\lambda_1 < 1$, it is sufficient that the corresponding relations satisfy gross reproduction rate. In this regard, this indicator can also be used as an identifier of the population reproduction mode.

It is easy to see that the growth rate and gross reproduction rate indicators have one drawback: in identifying the population reproduction mode, they do not take into account the specific mortality patterns of the entire male population and senior groups of the female population. In other words, in two population groups, with the same fertility and mortality rates of the female population under the age of 50, but with different mortality rates in all other age groups, the values of growth rate and gross reproduction rate will be the same.

To eliminate this shortcoming, the population growth rate should be adjusted for unaccounted mortality rates and fertility rates for boys. Note that the gross reproduction rate is not subject to such an adjustment because of its content. We denote this adjusted population growth rate as SMGR. Its value can theoretically be estimated using the total fertility and mortality rates, calculated on the basis of the normalized coordinates of the limit eigenvector *z* of the matrix *G* corresponding to its Perron root. This vector for the source data of each period (*t*, *t* + 1) satisfies the relation:

$$G \cdot z = \lambda_1 \cdot z \qquad (9)$$

and its coordinates are normalized.
For a five-year population structure, the values of the total fertility (TFR) and mortality (TMR) rates are defined respectively as:

$$\mathrm{TFR} = \sum_{j=4}^{10} b_j \cdot z_j, \qquad (10)$$

$$\mathrm{TMR} = \sum_{j=1}^{30} (1 - p_j) \cdot z_j = \sum_{j=1}^{30} q_j \cdot z_j, \qquad (11)$$

Where z_j is the proportion of the *j*th fertile age group of the female population in the population structure; b_j is the fertility rate in the *j*th group of the female population; $q_j = 1 - p_j$ is the population mortality rate of the *j*th age group in the period under review.

As the difference between these indicators for each period $(t, t+1)$, the natural population growth rate (NPGR) can be calculated:

$$\mathrm{NPGR}_t = \mathrm{TFR}_t - \mathrm{TMR}_t, \qquad (12)$$

taking this into account, the adjusted population growth rate is defined as:

$$\mathrm{APGR}_t = 1 + \mathrm{NPGR}_t. \qquad (13)$$

As an alternative to the adjusted population growth rate APGR, it is possible to offer its modified analog (MGR) calculated on the basis of the normalized structure w, determined only by the mortality (survival) rates of the age-specific groups of the female and male population. The shares of these groups, with the exception of the latter with $n = 15$, in such a structure, are defined by the following expressions, respectively:

$$w_j = p_1 \ldots p_{j-1} \cdot w_1, \; j = \overline{2,14}, \quad w_j = p_{16} \ldots p_{j-n-1} \cdot w_{16}, \; j = \overline{17,29} \qquad (14)$$

where p_j characterize in this case, the survival rates in both female $j = \overline{1,14}$ and male $j = \overline{16,29}$ groups. When determining the first coordinate w_1 for the female population and sixteenth w_{16} for men, one can proceed from the ratio between the number of girls born to boys (0.488 to 0.512).

The growth rate for the structure of the vector w is also calculated by expressions (6) — (9) with accuracy to coordinate z_j replacement by coordinates w_j, $j = \overline{1,30}$.

Results

Estimates of the reproductive potential of the population in Russia during the period from 1960 to 2017 obtained on the basis of the considered options for its indicators, the population growth rate (marginal, adjusted and modified), bear quite significant differences. First of all, we note that the APGR growth rate adjusted for mortality of the entire male and senior female population and the fertility rate of boys, is not a completely correct indicator, especially when the population is decreased, i.e. at $\lambda_1 < 1$. This is due to the fact that the normalized coordinates of the eigenvector z of the Perron root λ_1 (with the exception of the latter) in both female and male population are related by the following ratios, respectively [189] (Tikhomirov 1984):

$$\begin{cases} z_j = \lambda_1^{-(j-1)} \cdot p_1 \ldots p_{j-1} \cdot z_1, \; j = \overline{2, \mathrm{n}-1}, \\ z_j = \lambda_1^{-(j-n-1)} \cdot p_{j+1} \ldots p_{j-n-1} \cdot z_{n+1}, \; j = \overline{n+1, 2n-1}, \end{cases} \qquad (15)$$

from which it follows that with $\lambda_1 < 1$ the proportion of older age groups among the female and male population, they can even increase (with a significant decrease in λ_1), which contradicts the natural laws of the generational change process.

When $\lambda_1 > 1$ from relations (15) it follows that the proportions of the older age groups decrease more than is predetermined by the mortality rates, although the general patterns of generation change are not violated. The differences between the marginal structure z and its analogue w, determined only by age-specific mortality rates, are illustrated in Figure 1, describing the distribution of the Russian population in the five-year age-specific groups of the female population and male population in 1999, when the value of the five-year growth rate amounted to 0.899.

[189] The values of the coordinates of this vector with indices $j = n$ and $j = 2n$ are determined by more cumbersome expressions.

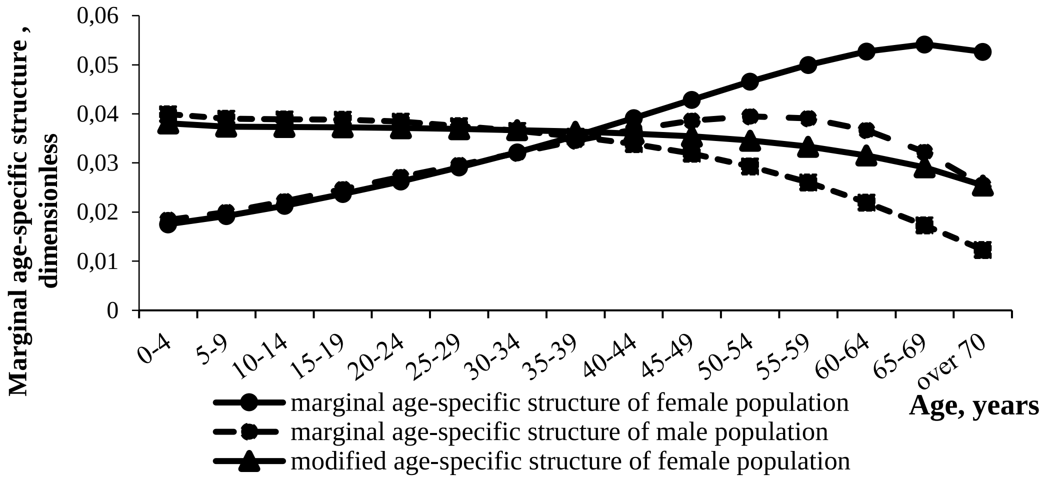

Fig. 1. Marginal and modified age-specific structure of the male and female population in Russia in 1999

Expression (15) and the marginal age-specific structures of the Russian population for 1999 shown in Figure 1 clearly indicate the inexpediency of using the APGR indicator as an indicator of the reproductive potential of the population due to its incorrectness. The difference between the growth rate and its modified analog is illustrated by the data in Table 1 obtained using the annual statistics of natural movement coefficients recorded in official statistics in the five-year age-specific groups of females and males for the period between 1960 and 2017.

Table 1: Estimates of population reproductive potential in Russia from 1960 to 2017, at five-year marginal and modified growth rates*

Years	In 5 years		Annual		Components of the five-year MGR				
	GR, λ	MGR	GR, λ	MGR	MFRM	MFRF	MMRM	MMRF	MCPNG
1960	1.028	1.043	1.006	1.008	0.048	0.045	0.029	0.020	0.043
1987	1.009	1.030	1.002	1.006	0.042	0.039	0.030	0.020	0.030
1999	0.899	0.986	0.979	0.997	0.022	0.021	0.034	0.023	-0.014
2015	0.976	1.018	0.995	1.004	0.034	0.031	0.029	0.019	0.018
2017	0.961	1.013	0.992	1.003	0.030	0.028	0.027	0.018	0.013

* Abbreviations used in the table:

MFRM and MFRF are modified fertility rates for the male and female population, respectively,
MMRM and MMRF are modified mortality rates for the male and female population, respectively,
MCPNG is modified natural growth rate.

The data presented in Table 1 generally indicate that estimates of the reproductive potential of the population for reproduction in Russia determined by the values of modified growth rates, calculated on the basis of the entire age and gender-specific structure and the corresponding set of age-specific fertility and mortality rates, exceed, and in some years quite significantly, their analogs represented by marginal growth rates.

Discussion

Here we would like to review the main reasons for the discrepancies in the estimates of the population growth rate in Russia and its modified analog. First of all, we would like to note that the excess of modified growth rate estimates over growth rate estimates can be caused by taking into account the fertility rate of boys in modified growth rate, which is slightly higher than that of girls, which also largely neutralizes the mortality rate of the entire male and female population of older age groups considered in modified growth rate. On the other hand, a simplified method for estimating five-year age-specific mortality rates could contribute to an underestimation of their levels, albeit insignificant. According to our estimates, this decrease should not be more than 1% of the level of each coefficient, which practically could not lead to such significant discrepancies in the estimates of the considered options for the growth rate of the Russian population. In our opinion, the main reason for such discrepancies are errors in the estimates of age-specific mortality rates (especially for men) presented in statistical digits, in the direction of their underestimation. This, in particular, is indicated by the differences in the growth rate values under consideration in 1960, 1987, 1999, 2015 and 2017. In 1960, the five-year modified growth rate value exceeded its growth rate equivalent by only 0.015 points (1.043 against 1.028), in 1987 — by 0.021 (1.030 against 1.009), and in 1999 — by almost 0.09 points. In 2015, the discrepancy between these indicators amounted to 0.041 and in 2017, it increased to 0.062. The ratios between the average values of these indicators in 1960 were 1.008 to 1.006; in 1987 — 1.006 to 1.002, in 1999 — 0.997 to 0.979, in 2015 — 1.004 to 0.995 and in 2017 — 1.003 to 0.992. At the same time, we note that the total mortality rates used in estimating the five-year modified growth rate increased in 1999 compared with the other considered years not too much.

From Table 1 it follows that the modified total mortality rate, reduced to one year, which can be approximately estimated as $\frac{\mathbf{MMRM(5)+MMRF(5)}}{\mathbf{5}}$, in 1999 equaled 0.011 or 11‰, and in 1960 and 1987 about 10‰. Note that in 2017 this indicator was estimated at the level of 9.0‰ and in 2015 — at 9.6‰. At the same time, the values of real total mortality rates, estimated by the number of deaths per 1,000 people, equaled 7.4‰ in 1960, 10.5‰ in 1987, 14.8‰ in 1999, 13.0‰ in 2015 and 12.4‰ in 2017. Such a difference (more than 3‰) between real and hypothetical (estimated by age mortality rates) total mortality rates in 1999, 2015 and 2017, in our opinion, cannot be explained only by the "older" real age structures of the Russian population, compared to with their standardized variants, especially since the age structure of the 2017 Russian population differed little from its structure in 2015. Apparently, this difference was to a certain extent due to the underestimation of the age-specific mortality rates, especially of the male population.

In this regard, it appears that the marginal growth rates of the Russian population more adequately characterize its reproductive potential compared with modifications of this indicator estimated on the basis of various standardized age-specific structures, since the age-related natural movement indicators in the female population are much less susceptible to distortion.

Figure 2 reflects the patterns of variability of the five-year growth rate of the Russian population and its urban and rural settlements in the period between 1990 and 2017. It should be noted that similar patterns in the dynamics of demographic population reproduction indicators are observed in certain regions of the country, although the regional levels of this indicator are also characterized by quite significant differences.

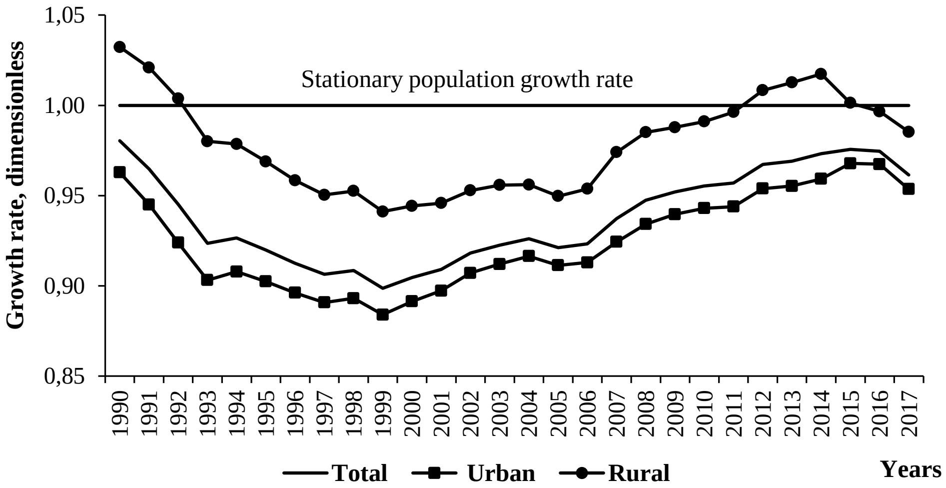

Fig. 2. Five-year growth rates of rural, urban and total population in Russia in 1990-2017.

Figure 2 indicates the existence of two multidirectional trends in the dynamics of the reproductive potential of the population in the period 1990-2017, caused primarily by a change in its living conditions. Significant reduction in average per capita real monetary income (by about 60%), a high proportion of the population with income below the subsistence minimum (20-30%), rising unemployment almost at three times and social tension in general in the absence of any significant measures to stimulate fertility and reduce mortality caused a significant reduction in the demographic reproductive potential in the country and in its rural and urban settlements in the period from 1991 to 1999. After 2000, on the contrary, the living conditions of Russian population started to improve, which had a positive effect on the reproductive potential of the population growth rate indicator that began to grow (except for 2005) and in the countryside in 2011-2015 even exceeded the value of one. The most significant increase in the five-year values of this indicator was noted in Russia in the period from 2007 to 2015 when the country began to actively implement measures to stimulate fertility. It should be noted that the value of this increase equaling about 0.05 was more than 2 times higher than the same indicator for the period from 1999 to 2006. However, after 2014, the standard of living of the population and, first of all, its real monetary income in Russia began to decline, which apparently was the main reason for the reduction of the demographic reproductive potential in the following years.

Identified patterns of the same type in the dynamics of the population growth rate in Russia and its regions, due to approximately the same changes in living conditions, indicate the possibility of using a single methodological approach to substantiating the fields of socio-economic policy that promote the transition from depopulation to the extended demographic reproduction in the country as a whole and its individual territorial entities. Such an approach implies the construction of functional dependencies of the growth rate on the conditions of vital activity using the accumulated statistical data for each territory using, for example, since 2000. In particular, the experience of forming such dependencies shows that the transition to the extended reproduction mode in the country is possible provided that the real income of the population and the size of payments for children under the age of 17 increase by about 30-35% relative to their current level. With a 2-3% annual increase in these indicators, this goal can be achieved by 2030.

Conclusions

The use of objective and reliable estimates of the potential of demographic reproduction in the development of strategies ensuring the transition of the population of Russia and most of its regions from prolonged depopulation to a steady increase in its number is a necessary condition for their effectiveness. In our opinion, the reproductive potential of the population in each time period should be assessed by the characteristics of the intensity of this process, determined by the current age-specific fertility and mortality rates. Unlike the total fertility rates, mortality rates, and natural increase, such characteristics do not depend on the differences in the current age-specific structure of the population (phase of the demographic wave). These include, in particular, the population growth rate and the gross reproduction rate. However, these indicators have certain issues due to the fact that their assessment does not take into account the mortality rate of the female population over 50 years of age and the entire male population, as well as the fertility rate of boys.

At first glance, these problems can be solved quite easily in the growth rate modifications calculated according to the marginal age-specific structure of the population corresponding to its value and according to the age-specific structure determined by the mortality rates in the male and female population of different age groups using the current values of all age-specific mortality and fertility rates.

However, such modifications are also not free from significant flaws. In particular, the marginal age-specific structure in case of population decrease, i.e. with growth rate <1, often does not correspond to the basic laws of generation change. In such a structure, the proportion of people of the older age groups in the population is increasing.

The age structure determined by mortality rates is very sensitive to their estimates. In particular, when these estimates are underrated, the population growth rate increases significantly, which, as shown in the paper, does not correspond to the real situation. Under such conditions, the use of growth rate as an indicator characterizing the reproductive potential of the population in the period under review seems to be quite reasonable, partly due to the fact that when it is estimated, the fertility and mortality rates of only the female population under 50 years are used and these estimates are characterized by fairly high confidence.

Growth rate estimates obtained for 2000-2017 for the population of Russia and its regions indicate the presence of similar patterns in their dynamics, formed under the influence of changing life conditions in this period. In such a situation, such patterns can be described by functional dependencies linking growth

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rate values with factors reflecting these conditions. On their basis, it is possible to determine the most effective and efficient directions of socio-economic policy ensuring Russia's access to the expanded demographic reproduction mode. In particular, the work substantiates that such a regime can be achieved by 2030, subject to an increase in the real income of the population and payments to low-income families for the maintenance of children under 17 years of age by 30-35% compared with their current levels.

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