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RUSSIA'S BIRTH RATE DYNAMICS FORECASTING[1]

This article covers contemporary issues of Russia's population reproduction, their causes and the state policy aimed to overcome the same. The urgency to fulfill the task related to assessment of the most probable future dynamics of Russia's population birth rate in the context of a low child-woman ratio, and subject to an impact of pronatalist policies implemented by the state, is justified. In order to fulfill the task based on the crude birth rate behavior probability distribution function, a probabilistic assessment of future dynamics of Russia's population reproduction has been carried out. Based on a modernized method suggested by Hurst, the following two forecasting paths of the crude birth rate dynamics have been built: the first path conforms to the scenario where a value of the crude birth rate is to tend to values between 8–10.5 births/1,000 people (probability is 0.182), in particular, through a negative external impact, the second path is to tend to values between 13–16.5 births/1,000 people (probability — 0.618), in particular, through a positive external impact. Notwithstanding that these scenarios significantly differ from each other, the paths of the crude birth rate dynamics for 2015–2041, corresponding to the reliable prediction time, forecasted according to the abovementioned scenarios, are virtually identical. The analysis of the findings allowed for the conclusion that the state demographic policy is not capable of having a significant impact on the future dynamics of the birth rate, substantially determined by the current situation and conjuncture shifts. These conclusions confirm the view prevailing in academic circles and suggesting that the state regulation of Russia's demographic situation should be primarily focused on the improvement in health and a rise in the life expectancy of the population.

Keywords: birth rate, state management, demographic waves, probability function, Hurst`s modernized method, forecasting, reliable prediction time

Contemporary Russia is enduring a protracted depopulation process that is a systematic decrease in the population of the state due to narrow population reproduction conditions, when the succeeding generation is numerically less than the preceding one. Having fallen below the population replacement level (2.1 births per woman) in the 1970s, an extremely low value of the aggregate birth rate to date remains unchanged (in 2013, it stood at 1.707 births per woman[2]).

According to some demographers, in particular A. I. Antonov [1, 2], an underlying cause of this decline in this country's birth rate is in lessening the need for children. This stems from the dying-out of the economical function of a family (for the implementation of which a great number of children in the family is needed), the dissemination of non-family values and individualism values. Thus, in contemporary Russian society, the need for 1–2 children prevails, which leads to a change in the social crude birth rate and a reduction in the number of children in a family. In other words, the birth rate reduction, to a large extent, is caused by social rather than economic reasons. At the same time, Russia's state demographic policy is mainly focused on financial incentives of fertility, including maternity capital payments.

Consequently, there is a need to assess the most probable future dynamics of Russia's population birth rate in the context of a low child-woman ratio, and subject to an impact of pronatalist policies implemented by the state.

In order to fulfill the task based on crude birth rate behavior probability distribution function, a probabilistic assessment of the future dynamics of Russia's population reproduction has been carried out. As part of the study, the forecasting paths of the crude birth rate dynamics based on a modernized method suggested by Hurst, distinguishing the reliable prediction time, have been built [3].

[2] Demographic Yearbook of Russia. 2014: statistical book / Rosstat. M., 2014. [Web resource]. URL: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/doc_1137674209312 (date of access: April 13, 2014)

Methods

Probabilistic method. Where there are small fluctuations, a nonlinear system is described by probability distribution function g (probability density), to be calculated based on initial time series, connected with F system's potential function by the Fokker — Planck equation as follows:

$$\frac{\partial g}{\partial t} = \nabla(g\nabla F) + \nabla^2(Dg), \tag{1}$$

where *g* is the probability density; *F* is the potential function of the nonlinear system in question, characterizing the number of stable and unstable equilibrium points corresponding to extrema of the function.

The right side of the equation consists of the following two members: drift $\nabla(g\nabla F)$ and diffusion $\nabla^2(Dg)$. The drift makes the demographic system's subject (a man), in case of small deviations (due to order parameter fluctuations), from an equilibrium position, move towards the nearest local minimum. The diffusion's role is twofold: it describes the range of the distribution function that is to be hinged on a local minimum, and probability with which the fluctuation may transform such demographic system from a metastable (local) minimum into a global minimum. If there is no fluctuation, then the diffusion of the system from local to global is impossible.

For the purpose of determining a type of demographic stability, capabilities of nonlinear dynamics methods, as part of which nonequilibrium potential functions may be built, are distinguished. Different minima of the potential function belonging to certain phase path attraction zones of evolution of the indicators used, the so-called "attractors", correspond to different demographic states. Any change in the economic system parameters may lead to a change in the number of states and/or their stability. The task here is to describe the probability of the implementation of a certain equilibrium state. Due to the opportunity to obtain a probability distribution function based on processing statistical data with a large number of indicators, such a task becomes nontrivial.

The calculation of probability density function $g(x)$, where *x* is the value of crude birth rate, is carried out based on the assumption that the indicator has a fluctuating nature that predetermines the occurrence of certain values of the crude birth rate with known probability only, in the future. In the event of ergodic behavior of the indicator, whose probability distribution is under examination, the probability distribution function is deemed a time-invariant (constant) function). In this case, the indicator's probability density function $g(x)$ may be renewed by replacing ensemble averaging with time averaging, by time series of the crude birth rate, whose length tends to infinity or is too great as compared to the forecasting period.

The renewal of potential $F(x)/D$, normalized to a diffusion coefficient, is carried out according to known probability distribution function $g(x)$. The renewal of potential $F(x)$ is carried out by solving the Fokker — Planck equation in a stationary case:

$$0 = \nabla(g\nabla F) + \nabla^2(Dg), \tag{2}$$

based on the deduced probability distribution function $g(x) = N \cdot e^{F(x)/D}$, from which an expression for normalized potential follows

$$F(x)/D = -\ln(g(x)/g_0). \tag{3}$$

Potential is approximated by the polynomial of degree *n*.

Hurst`s modernized method. According to the method suggested by Hurst, in the classical theory, the average value $<\xi(t)>$ on time interval τ, having the same dimension as time *t*, is calculated for the available time series $\xi(t)$:

$$\langle \xi(t) \rangle_\tau = \frac{1}{\tau}\sum_{t=1}^{\tau} \xi(t). \tag{1}$$

Thereafter, accumulated deviation dependence $X(t, \tau)$ on time interval τ, according to which absolute range function *R* is computed, is calculated:

$$X(t,\tau) = \sum_{u=1}^{t}\left\{\xi(u) - \langle \xi(t) \rangle_\tau\right\}, \quad R(\tau) = \max_{1 \le t \le \tau} X(t,\tau) - \min_{1 \le t \le \tau} X(t,\tau). \tag{2}$$

The range depends on the length of interval τ and may go up with its increase. Further, the dependence of dimensionless function *R/S* versus the length of time interval τ is calculated by dividing *R* by standard deviation *S* of series $\xi(t)$:

$$S(\tau)=\sqrt{\frac{1}{\tau}\sum_{t=1}^{\tau}\left\{\xi(t)-\left\langle\xi(t)\right\rangle_{\tau}\right\}^{2}}. \quad (3)$$

Based on the research findings of many natural processes, Hurst found the empirical relation between standardized range *R/S* and the length of interval τ through indicator *H*:

$$R/S\sim\left(\tau/2\right)^{H},\ \ H=\frac{\ln\left(R(\tau)/S(\tau)\right)}{\ln\tau-\ln 2}. \quad (4)$$

Subsequently, Hurst proved himself that H may take values from 0 to 1.

When analyzing the crude birth rate value, a value of indicator H may be treated as follows. In case of a lack of long-term statistical dependence (indicator's random behavior), this relation should asymptotically tend to $\tau^{1/2}$ ($H = 0.5$), if the sample length tends to infinity, as proved by B. Mandelbrot through the example of the Brownian motion. Values $H > 0.5$ characterize persisting trends to an increase or decrease of the indicator both in the past and in the future (persistent behavior — a persisting trend) [4]. $H < 0.5$ means population birth rate's tendency to a constant change in the trend: the increase changes to a decrease and vice versa.

The incorrectness of analysis of the time series of the crude birth rate by Hurst's method in the classical theory lies in the assumption that identical fractal structures of the analyzed time series exist throughout the time scales, i.e. the invariability of demographic system attributes that determine its self-development is contemplated.

The paper [3] showed that if an assumption that indicator *H* in expression (4) depends on time scale τ is made, and function $H(\tau)$ is determined from derived function *R/S* by τ, then for convenience of numerical differentiation of function *R/S* in the form of a time series, the expression for finding a dependence $H(\tau)$ will be as follows:

$$H^{*}(\tau_k)=\frac{\ln(R(\tau_{k+1})/S(\tau_{k+1}))-\ln(R(\tau_k)/S(\tau_k))-\ln A}{\ln(\tau_{k+1})-\ln(\tau_k)}. \quad (5)$$

The time series may be classified as statistically fractal, random, periodical, based on the behavior of a characteristic function. One more type with global persistence intrinsic to increasing or decreasing functions may also be mentioned. Based on the behavior of this function, the characteristic time for the attainment of a stochastic process may be determined in case of the analysis of the highly nonlinear system with chaotic behavior.

Reliable prediction time. Time τ, when dependence of the Hurst exponent $H(\tau)$ reaches the range of values close to 0.5, is commonly known as the time for attainment of a stochastic process, that, as shown in [7], is close to initial conditions forgetting time tr, when the correlation (relationship) of future values with past ones is lost, a change in the fractal structure occurs, and the precise prediction of the system behavior on time intervals exceeding tr is impossible. The reliable forecasting in respect of time intervals exceeding tr is impossible, so tr may be named a reliable prediction time.

If the demographic system's fractal attributes, among which the reproductive attitudes for population [5, p. 66] may be mentioned as major factors for the birth rate, are considered unchanged, the time series of the crude birth rate may be completed for a certain time interval in future. If the demographic system's fractal attributes remain unchanged for the time of forecasting, the possibility to predict precisely its behavior in such time area emerges. In this case, function *R/S* and the Hurst exponent are considered to be constant for the system with unchanged fractal attributes and not dependent on the length of the time series under examination. Thus, completing the time series for a certain time interval in future is carried out in such a manner as to not change the Hurst function for the time series under examination.

Calculation data

The graphs of distribution function $g(x)$ and renewed potential F(x) with its approximation by a polynomial of degree 6, for a crude birth rate, deduced through the software product [3] developed by the authors, are shown in Figure 1.

Fig. 1b clearly shows the presence of double-well potential, local and global minima corresponding to the two equilibrium positions of the demographic system. In this case, the nonlinear analysis of the long time series of the crude birth rate in the USSR and the Russian Federation showed that the probability of occurrence of this indicator in the region of values 8–10.5 births/1,000 people accounts for 18.2 % in the neighborhood of values 13–16.5 births/1,000 people — 61.8 %. Thus, it is most likely that the value of the crude birth rate will continue to rise in the coming years tending to the values between 13–16.5 births/1,000 people, but in case of an adverse impact on the demographic system, its sharp decrease to values between 8 — 10.5 births/1,000 people is highly probable.

According to the modernized method developed by Hurst and used in this paper, the initial conditions forgetting time in respect of the fertility process are not identified (crossing with 0.5 is connected with scant statistics on large intervals) (Fig. 2). The findings allow the conclusion that the fertility process is persistent, meaning the up trends and the down trends on large intervals are maintained (up to half a length of the time series, in our case, up to 2041).

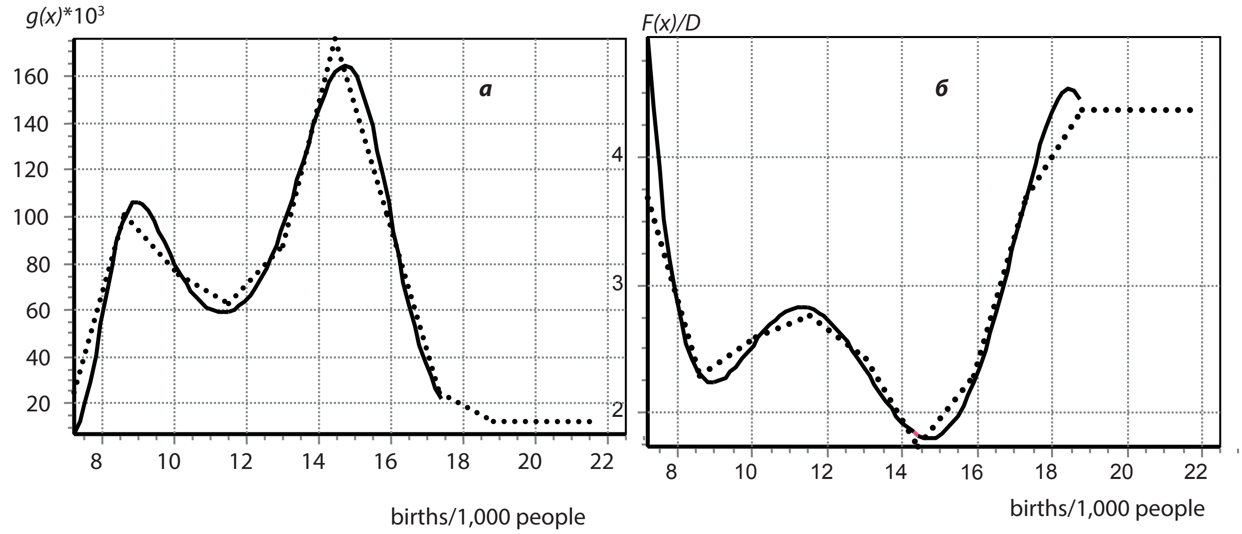

Fig. 1. *Function of probability density (a) and renewed potential F(x) (b) for the USSR and the Russian Federation crude birth rate for 1960–2014. The points correspond to experimental data; the semi-smooth points correspond to approximating curves*

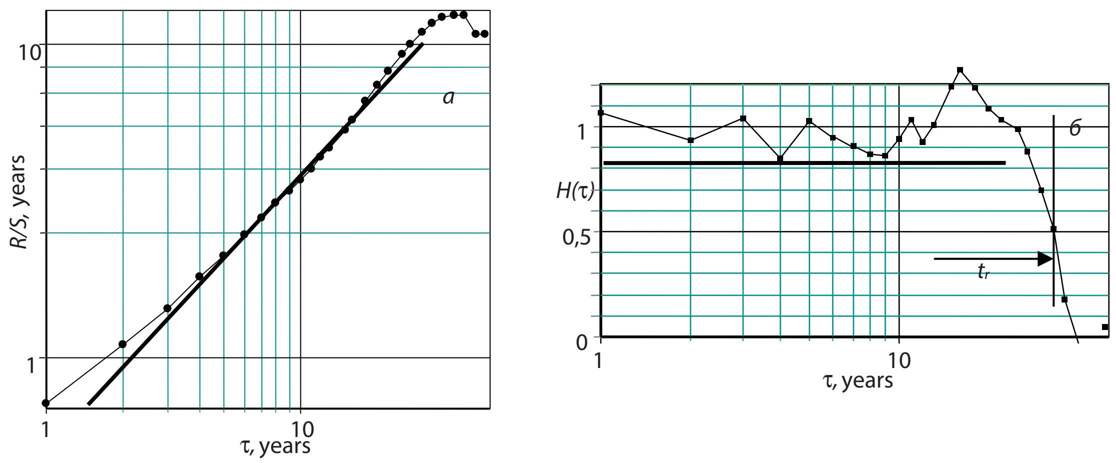

Fig. 2. *Dependence of function R/S on time scale τ (a) and dependence of H on time scale (b) in respect of the crude birth rate in the USSR and the Russian Federation for 1960–2014. Reliable prediction time tr is specified*

[3] See Bystrai, G. P., Lykov, I. A. State Registration Certificate for Computer Program No. 2012615414 "Risk assessment, nonlinear analysis and forecasting in respect of long time series of economic indicators". Rospatent (the Federal Service for Intellectual Property, Patents and Trademarks). Registered on June 15, 2012.

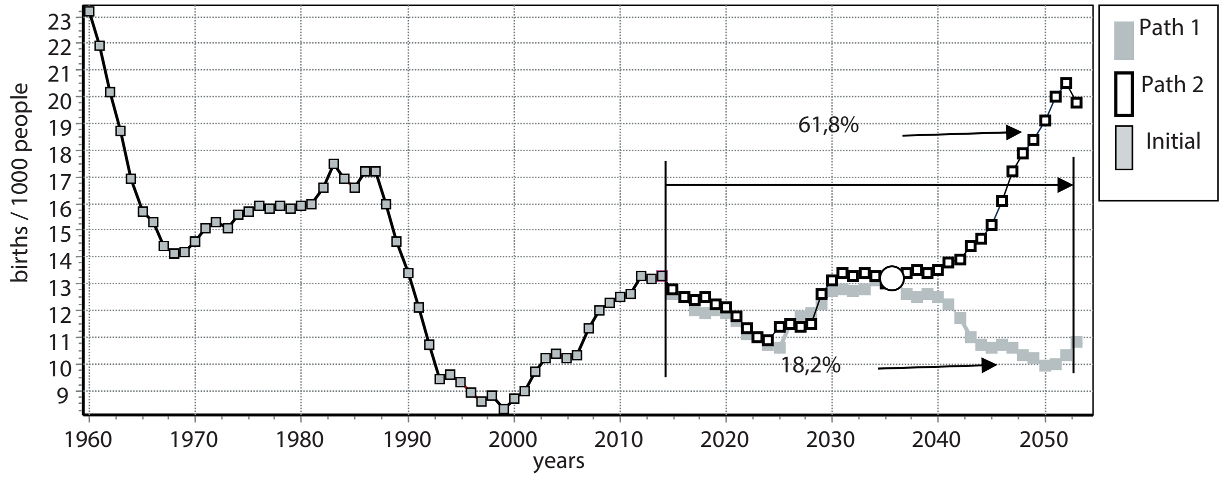

Fig. 3. *Basic time series of the crude birth rate in the USSR and the Russian Federation with forecasted paths, renewed according to the change rate. A bifurcation point of further development of the demographic situation is specified. Figures show the probabilities of implemetation of a certain forecasted path*

The forecasting of a change rate in the crude birth rate was built in such a way that each subsequent point of each path, to be determined by a minimax estimator function of the standard deviation of function R/S, that made it possible to minimize the deviation of the Hurst function for the time series under examinations (1960–2014) from the Hurst function for the time series with a completed forecasting point. An error of function *R/S* (Fig. 2a) corresponds to the two minima of the potential function (Fig. 1b), that leads to two probable outcomes of demographic development. Approximation $H = 0.832+/-0.036$ on the time interval from 0 to 30 years for the best possible calculation of an error of function R/S in future was carried out according to the Hurst exponent (Fig. 2b). Predictive paths of their change were renewed according to the completed time series of the change rate of the crude birth rate (Fig. 3).

Figure 4 shows that the first path conforms to the scenario, where a value of the crude birth rate is to tend to values between 8–10.5 births/1,000 people (probability is 0.182), in particular, through a negative external impact; the second path is to tend to values between 13–16.5 births/1,000 people (probability — 0.618), in particular, through a positive external impact. These two outcomes conform to the two maxima of the probability function (Fig. 1a). Notwithstanding that these scenarios significantly differ from each other, the paths of the crude birth rate dynamics for 2015–2041, corresponding to the reliable prediction time, forecasted according to the abovementioned scenarios, are virtually identical. From 2015 to 2025, according to the first variant, and up to 2024, according to the second variant, a decline in the birth rate is expected; then, up to 2031, according to both scenarios, a growth is forecast, starting from 2032 and, till the end of the reliable prediction time, a stagnation of population reproduction is to be observed.

The forecasted dynamic of the crude birth rate involves quite logical developments substantially caused by demographic waves created during a retrospective period. In particular, a decrease of the crude birth rate in 2015–2025 results from a decline in the number of potential mothers in this period due to reaching the age of 27, corresponding to the contemporary average mother age when bearing a child, by women born in 1988–1999, when the negative dynamic of the indicators was observed. Similarly, a growth of the crude birth rate in 2025–2031 is explained. The forecasted stagnation of the population reproduction in 2031–2041 with insignificant fluctuations of the values of the crude birth rate at a level of 13–14 births per 1,000 people, results from the attenuation of demographic waves.

Conclusion

The findings allow for the preliminary conclusion that the current Russian state demographic policy is not capable of having a significant impact on the future dynamics of the birth rate, substantially determined by the current situation and conjuncture shifts. These conclusions confirm the view prevailing in academic circles that state regulation of Russia's demographic situation should be primarily focused on the improvement in health and a rise in the life expectancy of the population.

At the same time, the existing differences in the social and economic development of the Russian regions [6–11] determine the need not only for implementation of overall federal measures, but also the development of own regional programs in this area. And the Russian constituent entities that face the highest degree of crisis associated with population reproduction cannot go without the optimization of immigration flows [12].

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