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The Causality of Deviation from the Optimal Parameters of a Regional Demographic System

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Abstract*: This study is based on the identification of causal relationships that determine the current trends in the demographic system of the regions of the Russian Federation. The achievement of optimal parameters of the demographic system is a factor in the implementation of the principle of sustainable development of territories. Demographic behavior is explained from the perspective of an institutional approach and is defined as a reaction and adaptation to changes in the institutional environment. From the standpoint of determinism, the response of the demographic system can be defined as a consequence and causality as the influence of the institutional environment. An attempt to formalize conclusions about the influence of the institutional environment on the demographic parameters of the territory and the application of mathematical research methods have allowed the authors to conclude that the economic well-being of the population was the dominant factor in the increase of the birth rate.

Keywords*: causal relationships, sustainable development, institutional approach, demographic system, Volga Federal District, statistical research methods.

I. INTRODUCTION

The development indicators of the world community determine the need for a paradigm shift in establishing the development vectors of both the global system and macro- and mesosystems. From January 1, 2016, the actions of all national actors in world society must take into account the 17 goals of sustainable development set out in the "2030 Agenda for Sustainable Development" [1]. The main idea of this document is to create normal non-discriminatory living conditions for all nations of the planet in the present and future. It is assumed that governments should create national mechanisms for implementing the goals of sustainable development [2]. Improvements in any area of human life should be directed towards a common goal, i. e. the optimization of demographic indicators: an increase in life expectancy and fertility, and a reduction of mortality.

The fields of science that study real social and natural processes and phenomena give the fundamental role to the principle of determinism, according to which, these processes and phenomena are determined as a consequence since they arise, exist and are destroyed as a result of the action of causes [3]. For the principle of communication, causality is one of the ways of communication, namely the connection of phenomena and processes, in which the cause under certain conditions gives rise to an effect. Moreover, from the position of the development principle, any change leads to the emergence of a new quality, that is, it has its cause and effect [4]. Causal relationships are characteristic not only of development processes, but of destructive changes (degradation and decay) in case of any changes, be it for a natural reason or an artificial and targeted anthropogenic impact on the world around [5].

The result of the creation of a sustainable type of society is the achievement of optimal parameters of the demographic system, in which the population size makes it possible to effectively use natural resource opportunities while improving socio-economic indicators [6]. The growing threat of depopulation of the country, which arose due to increasing mortality with a decrease in the birth rate and periodically with an outstripping increase in mortality with an increase in the birth rate, actualizes the problem of achieving optimal criteria and conditions for stabilizing demographic indicators [7]. One of the 17 goals of sustainable development, "Ensuring a healthy lifestyle and promoting well-being for all at any age", acts as the most important component of sustainability and involves achieving the most favorable state of the demographic parameters of the territories.

The optimum population can be interpreted as a type of population reproduction, which provides the best possible indicators of the quality of life of the population with the sustainable development of the national socio-ecological and economic system [8]. If we consider the demographic optimum as the correspondence of the quantitative and qualitative characteristics of the population to the development goals of the territories, then the Russian demographic system will be characterized as underpopulation [9].

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A study of the current situation of a negative nature and determination of ways to resolve it must be carried out from the perspective of a causal approach. If underpopulation is a consequence, then what is its causality?

II. METHODS

In the 20th century, the dynamics of demographic processes are interpreted from the perspective of the theory of demographic transition. The essence of the theory of the demographic transition is to change the types of reproduction of the population, from the traditional to the modern way, when the socio-economic formation changes from a traditional to a post-industrial society, from the community to the individual, from a religious to a less religious society. According to the transition theory, the traditional way of life is characterized by high fertility and mortality, as a result of which, there is a rapid change of generations and the transition turns it into a modern society, which is characterized by low birth and death rates [10]. The accumulation of facts that contradict the theory of demographic transition has determined the need for a different, more modern understanding of the dynamics of the demographic parameters of the social system [11].

The theory of demographic transition says that the result of going through all stages of transformation should be demographic stabilization, which eradicates the issues of deviations from the demographic optimum as underpopulation and overpopulation. Since real data cast doubt on the theory of transition, changes in the demographic system have other reasons. One of the approaches that explain demographic behavior is institutionalism (institutional approach). Institutionalism is based on the determinism of various institutions: their interaction with each other and the external environment, replete with synergistic effects and feedback loops [11].

Institutionalism interprets demographic behavior as a reaction and adaptation to changes in the institutional environment. We can make the following conclusion from the position of the institutional approach and the principle of causal relationships: the reaction of the demographic system is a consequence, causality is the influence of the institutional environment. The demographic crisis of the 20th century in Russia is due to a decrease in the efficiency of the health care system, social insurance, law and order, high unemployment and due to an increase in the number of crimes, etc. The beginning of the 21st century was marked by constructive transformations in the Russian socio-economic system through institutional changes. An analysis of the dynamics of general socio-economic indicators confirms this position. Consequently, the destructive institutionalization of the end of the 20th century leads to a narrowed type of economic and demographic reproduction. At the beginning of this century, the bifurcation of demographic development is a situation where its divergent character changes to convergent [12].

The institutional approach to the study of demographic processes is based on analysis, which makes it possible to describe causal relationships that determine the destructive and constructive phenomena of demographic development. The institutional environment affects the functioning indicators of the socio-ecological-economic system, including the state and dynamics of demographic indicators, many of which are formalized [13]. It can also be argued that institutional changes, as a result, are evaluated according to a number of formalized socio-economic indicators (GDP, economic growth rate, unemployment rate, incomes and expenses of the population, investments, number of offenses, capacity of outpatient organizations, investments in fixed assets, etc.) [14]. Formalization of the results of the functioning and influence of institutions makes it possible to evaluate (confirm and refute) the theory of institutionalization of demographic development. We will try to formalize the theory of the institutional approach through statistical analysis and prove that in this century, the bifurcations of demographic development represent a situation when its divergent character changes to convergent due to institutional transformations.

III. RESULTS

Table 1 shows a sample of socio-economic indicators for the Volga Federal District (VFD) [15] that characterize the birth rate in the country and the result of the influence of the institutional environment on the socio-economic condition of the region.

Table 1: Initial data for calculations and analysis (VFD)

Year/rate	Total fertility rate (number of births per 1,000 population)	Per capita cash income (per month, rubles)	Investments in fixed assets per capita, rubles	Unemployment rate, %	Number of recorded crimes (per 100,000 population)
2002	9.1	2,998	9,436	7.7	1,565
2003	10.0	3,915	11,309	7.6	1,773
2004	10.2	4,783	15,065	7.8	1,951
2005	9.8	6,156	19,940	7.4	2,654
2006	10.1	7,989	25,753	6.5	2,967
2007	11.1	9,929	37,909	6.1	2,619
2008	11.8	12,351	49,184	6.3	2,298
2009	12.1	13,867	42,449	8.6	2,118
2010	12.4	15,697	48,017	7.6	1,850

2011	12.4	17,282	57,044	6.6	1,643
2012	13.3	19,597	67,565	5.3	1,567
2013	13.3	21,864	77,340	4.9	1,403
2014	13.3	24,020	80,208	4.5	1,352
2015	13.3	26,300	82,956	4.8	1,519
2016	12.8	25,737	81,909	4.8	1,367
Statistical value calculation					
Median value	12.1	13,867	48,017	6.5	1,773
Less than the median value					
More than the median value					
Skewness	-0.387	0.126	-0.001	-0.077	0.839
Kurtosis	-1.424	-1.386	-1.467	-1.365	-0.430
Arithmetic mean	11.7	14,165.7	47,072.3	6.4	1,909.7
Dispersion	2.2	65,752,202.2	718,290,595.9	1.8	265,387.8
Mean square deviation	1.5	8,108.8	26,800.9	1.3	515.2
Variation coefficient, % (not more than 33%)	12.8	57.2	56.9	20.6	27.0

We investigate several indicators as a statistical aggregate [16]. The median value of the birth rate characterizes that until 2009 in the VFD (from the given sample), there were less than 12.1 births per 1,000 population. Since 2010, the birth rate has been increasing and, according to this totality until 2016, the value is higher than 12.1 births, with a maximum value of 13.3 in the period between 2012 and 2015. The skewness and kurtosis coefficients characterize the population as having a normal distribution with slight skewness. The set is homogeneous, as evidenced by the indicators of variation. Therefore, correlation-regression analysis can be applied to this series of dynamics.

From the sample of per capita incomes, a large range of variation was determined, ranging from 2,998 to 26,300 rubles. The coefficient of variation was 57.2%, which determines the heterogeneity of the aggregate. At its core, the heterogeneity is due to the annual increase in average incomes, which determines the increase in the material well-being of the nation. The value of the median income indicates that until 2009, there had been a gradual increase in their values to 13,867 rubles per month. In subsequent years, the dynamics were positive, reaching their maximum value in 2016. The conclusions about the normal distribution in this series (with slight skewness) determine the possibility of further study of the trait using the method of correlation and regression analysis [17].

Investments in fixed assets indicate an increase in the production potential of the territory, which determines the expansion and modernization of production capacities and the possibility of increasing the welfare of the population. Over 15 years, per capita investment has increased from 9,436 to 81,909 rubles with a significant acceleration of growth in the period between 2006 and 2013, but with a slowdown in growth since 2014. The normal distribution of the value makes it possible to use statistical methods of multivariate research.

From 2002 to 2008, the unemployment rate had been reduced from 7.7% to 6.3%. However, in 2009, there was an increase in adverse events in the labor market, which was ensured by a sharp deterioration in the macroeconomic situation in the region. By 2016, about 4.8% of the economically active population had become unemployed. The studied series is characterized by homogeneity and normal distribution with slight skewness.

A statistical assessment of registered crimes as a sample indicates an annual decrease in the degree of criminalization in the society in the VFD: an increase in the number of violations of the law had been observed until 2006; from 2007 to 2016, the number of registered crimes dropped by two times.

We take the following studied values as the results of the impact of the institutional environment: the average per capita cash income, the investment in fixed assets per capita, the unemployment rate, the number of recorded crimes. Over the analyzed period (especially since 2010), a positive trend has been outlined in all areas of the regional system of the VFD: a growth in income and fertility, an increase in capital investment in fixed assets, a reduction in unemployment and crime. The essence of this study is to answer the question of whether fertility growth is a response to the constructive evolution of the institutional environment in this century. For this, it is necessary to conduct further statistical analysis, which consists in applying the method of correlation analysis. We take the birth rate (as a criterion for assessing the development of the demographic environment) as the effective feature (dependent variable) and the following will be the intervening variables: the average per capita cash income, the investment in fixed assets, the unemployment rate, the number of recorded crimes.

The correlation coefficient determines the strength and direction of the linear relationship in a pair of indicators, but the coefficient itself does not give a concrete answer about the presence of a linear relationship between the studied values. Therefore, it is necessary to determine two alternative hypotheses and test the hypothesis of the presence of a linear relationship and the statistical significance of the correlation coefficient [18].

We establish two opposite hypotheses:

1) the main hypothesis (H0), which claims the absence of a linear relationship in a pair of indicators and denies the statistical significance of the correlation coefficient;

2) an alternative hypothesis (H1), which states the presence of a linear relationship and the statistical significance of the correlation coefficient [19].

The presence of a normal distribution in the ranks of the studied indicators makes it possible to test the hypothesis and apply the Student t-test [20]. Test conditions: 95% confidence interval, two-sided verification, boundary points ± 2.16. The results of evaluating the strength of communication and testing the hypothesis in VFD are shown in Table 2.

Table 2: Matrix of correlation coefficients, t-statistic values, hypothesis test results (VFD)

Dependent variable Y_i		Intervening variable X_i			
Total birth rate		Per capita cash income	Investments in fixed assets	Unemployment rate	Number of reported crimes
Correlation coefficient	value	0.947	0.956	-0.689	-0.563
	significance of the linear relationship	significant direct relationship	significant direct relationship	notable reverse relationship	notable reverse relationship
T-statistics value		$t_{fact}>t_{crit}$ 10.66 > 2.16	$t_{fact}>t_{crit}$ 11.73 > 2.16	$t_{fact}>t_{crit}$ 3.42 > 2.16	$t_{fact}>t_{crit}$ 2.46 > 2.16
The accepted hypothesis		H_1: there is a linear relationship between the variables, the correlation coefficient is statistically significant			

IV. DISCUSSION

The performed calculations prove that there is a linear relationship between the dynamics of fertility and the change in factors taken as intervening variables. The closest direct relationship between the demographic trait and the factors that directly and potentially determine the welfare of the population: the average per capita income and investment in fixed assets. This conclusion states that the influence of material factors has a significant impact. This statement is reinforced by the assessment of the impact of unemployment in the region, as its growth leads to a decrease in the birth rate. The criminal situation and the work of law enforcement agencies have less impact, but a linear relationship is proved: a decrease in the number of offenses in society leads to an increase in fertility. We can make the following conclusion: there is a linear relationship between the studied indicators, which means that the dynamics of one indicator (cause) provokes a change in the other (consequence), thereby proving a causal relationship using mathematical methods. Thus, one can argue about the causality of changes in the institutional environment for the demographic parameters of territories.

Regions of the VFD in certain areas have a differentiated development. Therefore, it seems necessary to identify how changes in the institutional environment of the regions can be defined as the causality of the dynamics of demographic indicators of these territories.

We will calculate the correlation coefficients, t-statistics, test the hypothesis of linearity of communication according to the Federal State Statistics Service of the Russian Federation [15]. The calculations are presented in Table 3.

Table 3: Values of correlation coefficients, t-statistics, hypothesis test results(by VFD regions)

VFD region	Indicator	Dependent variable Y_i — total fertility rate			
		Intervening variable X_i			
		Per capita cash income	Investments in fixed assets	Unemployment rate	Number of reported crimes
Republic of Bashkortostan	correlation coefficient	0.915	0.838	-0.330	-0.291
	t-statistics	8.177	5.547	1.262	1.096
	accepted hypothesis	H_1	H_1	H_0	H_0
	significance of the linear relationship	significant direct relationship	strong direct relationship	-	-
Republic of Mari El	correlation coefficient	0.951	0.958	-0.831	-0.677
	t-statistics	11.104	11.992	5.391	3.321
	accepted hypothesis	H_1	H_1	H_1	H_1
	significance of the linear relationship	significant direct relationship	significant direct relationship	strong reverse relationship	notable reverse relationship
Republic of Mordovia	correlation coefficient	0.863	0.918	-0765	-0.708
	t-statistics	6.173	8.362	4.282	3.620

	accepted hypothesis	H_1	H_1	H_1	H_1
	significance of the linear relationship	strong direct relationship	significant direct relationship	strong reverse relationship	strong reverse relationship
Republic of Tatarstan	correlation coefficient	0.957	0.958	-0.663	-0.738
	t-statistics	11.981	12.117	3.196	3.945
	accepted hypothesis	H_1	H_1	H_1	H_1
	significance of the linear relationship	significant direct relationship	significant direct relationship	strong reverse relationship	strong reverse relationship
Udmurt Republic	correlation coefficient	0.846	0.858	-0.495	-0.538
	t-statistics	5.720	6.023	2.053	2.321
	accepted hypothesis	H_1	H_1	H_0	H_1
	significance of the linear relationship	strong direct relationship	strong direct relationship	-	notable reverse relationship
Chuvash Republic	correlation coefficient	0.945	0.946	-0.709	-0.669
	t-statistics	10.373	10.512	3.622	3.249
	accepted hypothesis	H_1	H_1	H_1	H_1
	significance of the linear relationship	significant direct relationship	significant direct relationship	strong reverse relationship	strong reverse relationship
Perm region	correlation coefficient	0.930	0.913	-0.271	-0.761
	t-statistics	9.159	8.060	1.017	4.234
	accepted hypothesis	H_1	H_1	H_0	H_1
	significance of the linear relationship	significant direct relationship	significant direct relationship	-	strong reverse relationship
Kirov region	correlation coefficient	0.963	0.962	-0.346	-0.508
	t-statistics	12.800	12.641	1.328	2.129
	accepted hypothesis	H_1	H_1	H_0	H_0
	significance of the linear relationship	significant direct relationship	significant direct relationship	-	-
Nizhny Novgorod region	correlation coefficient	0.957	0.963	-0.532	-0.491
	t-statistics	11.951	12.867	2.263	2.031
	accepted hypothesis	H_1	H_1	H_1	H_0
	significance of the linear relationship	significant direct relationship	significant direct relationship	strong reverse relationship	-
Orenburg region	correlation coefficient	0.898	0.920	-0.810	-0.678
	t-statistics	7.356	8.472	4.987	3.322
	accepted hypothesis	H_1	H_1	H_1	H_1
	significance of the linear relationship	significant direct relationship	significant direct relationship	strong reverse relationship	notable reverse relationship
Penza region	correlation coefficient	0.897	0.948	-0.617	-0.379
	t-statistics	7.308	10.703	2.828	1.476
	accepted hypothesis	H_1	H_1	H_1	H_0
	significance of the linear relationship	significant direct relationship	significant direct relationship	strong reverse relationship	-
Samara region	correlation coefficient	0.979	0.944	-0.563	-0.450
	t-statistics	17.130	10.287	2.458	1.816
	accepted hypothesis	H_1	H_1	H_1	H_0
	significance of the linear relationship	significant direct relationship	significant direct relationship	notable reverse relationship	-
Saratov region	correlation coefficient	0.915	0.912	-0.807	-0.642
	t-statistics	8.175	8.030	4.933	3.016
	accepted hypothesis	H_1	H_1	H_1	H_1
	significance of the linear relationship	significant direct relationship	significant direct relationship	strong reverse relationship	strong reverse relationship
Ulyanovsk region	correlation coefficient	0.965	0.978	-0.479	-0.666
	t-statistics	13.271	16.881	1.967	3.129
	accepted hypothesis	H_1	H_1	H_0	

	significance of the linear relationship	significant direct relationship	significant direct relationship	-	notable reverse relationship

V. CONCLUSION

An assessment of the dependence of fertility on average per capita incomes and the potential for increasing the welfare of the population of the regions of the VFD leads to conclusions about the presence of a strong linear relationship. Consequently, an increase in the well-being of the population directly contributes to an increase in the birth rate. In most regions, demographic characteristics are interconnected with the state of the labor market: the reduction in unemployment strengthens the economic situation of the population of the regions. In 9 out of 14 regions, the criminal situation and the work of law enforcement agencies are the factors that lead to solving the problem of demographic imbalances in the territories. In general, it can be argued that the trends in demographic development are formed under the influence of institutional transformations, primarily those that form the material base of the population, and subsequently, taking into account the differentiated approach, other factors of the institutional environment. Consequently, the favorable trend in addressing the underpopulation of Russian regions at the beginning of this century is due to the constructive institutionalization of the national community of the Russian Federation.

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