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Assessing the Influence of Medical, Demographic and Economic Factors on the Dynamics of Infant Mortality in Russia’s Regions

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Abstract. The issues of identifying and assessing the degree of influence of various factors on child mortality become particularly relevant in the light of the reduction in the proportion of children in the population and the decline in the birth rate. The quantitative assessment of the contribution of specific factors to the risk of child mortality is a key prerequisite for the substantiation of management measures aimed at minimizing it. Despite ample evidence of the influence of economic, medical and demographic factors on people’s health, there is a shortage of works devoted to the identification of quantitative correlations of these parameters with infant mortality in the context of Russian regions and the substantiation of approaches to the application of these tools in the practice of improving the child health care system. This study presents the results of assessing the relationship between a number of economic, demographic parameters and indicators of the provision with health care resources and infant mortality. Russia’s regions have been grouped according to the level of health care resources provision (bed fund, doctors, outpatient facilities), the characteristics of the leading regions have been analyzed. The correlation analysis revealed that the greatest correlation with the indicator of infant mortality of the regional population is demonstrated by age-specific birth rates in the youngest reproductive ages (15–19 years and 20–24 years), indicators of the provision of beds for pregnant women and children. Regression analysis of panel data for Russian regions revealed quantitative relationships between the infant mortality rate, age-specific birth rates, the value of

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gross regional product and the health care resources provision. The results of the study may be of interest to specialists in the field of regional child health care.

Key words: child health, infant mortality, child health care development, provision of medical personnel, regional differentiation.

Introduction

Due to the worsening problems of population reproduction in the context of declining birth rates, the preservation of children's health is of particular importance. However, data from representative sociological studies show that Russians are often dissatisfied with the quality and accessibility of medical care and the work of medical organizations (Voskolovich, 2021). These circumstances indicate the need for further improvement of the health care system, including children's health care.

Studies of Russian authors confirm, that the provision of the health care system with resources directly affects the indicators of public health. Accessibility of medical care is one of the primary conditions for population reproduction, reduction of morbidity, disability and mortality rates. It has been found that an increase in the provision of physicians and outpatient facilities is accompanied by a decrease in morbidity and disability among children (Timofeev et al., 2021). At the same time, there are multidirectional trends indicating a decrease in the provision of the health care system with individual resources: in the period 2015–2019 there was a decrease in the number of hospital organizations with a simultaneous increase in the capacity of organizations, a reduction in the number of hospital beds and a decrease in their availability for the population, an increase in the provision of doctors and a parallel decrease in the provision of nursing staff, including midwives (Dolgikh, Ignatov, 2021). The trend of increase in the number of children with disabilities by 6.6 thousand people in the same period looks alarming against this background (Kondakova, Natsun, 2019).

To address the issues of human resources and material and technical provision of health care at the federal level, a range of measures have been taken, including in the course of implementing the national project "Health care", which makes it possible to expect a reversal of negative trends and the formation of favorable conditions for the preservation and strengthening of children's health. In the national project, issues of improving children's health care are regulated within the framework of the federal project "Development of children's health care". The key indicator of this project is "infant mortality rate" (the number of deaths per 1,000 newborns). In addition to reducing infant mortality, the project prioritizes the provision of accessible and quality medical care for children, and also for pregnant women[1]. According to the 2021 report, during the implementation of the national project "Health care", infant mortality rate decreased from 5.1 (in 2018) to 4.6 cases per 1,000 newborns (in 2021)[2]. Undoubtedly, this reflects progress in the development of children's health care, in particular the improvement of the medical care system for pregnant women, women in labor and newborns. At the same time the largest share of deaths in children in the first year of life falls in the

[1] Development of children's health care, including the creation of modern infrastructure of medical care for children. Available at: https://xn--80aapampemcchfmo7a3c9ehj.xn--p1ai/projects/zdravookhranenie/zdorove_detey

[2] On the results of the 2021 national project "Health care" and the federal projects, included in it. Available at: https://static-0.minzdrav.gov.ru/system/attachments/attaches/000/060/073/original/Буклет_итоги_2021_года.pdf?1655456575

perinatal period. The contribution of preventable causes to perinatal mortality remains predominant[3].

According to a methodology developed by the Eurostat expert commission and the OECD[4], the preventable causes of infant mortality include deaths from neonatal tetanus, obstetric tetanus and spina bifida. Treatable causes include neonatal tetanus, obstetric tetanus, and certain conditions, occurring in the perinatal period[5]. Russian statistics do not allow us to trace the dynamics of mortality in the context of the listed causes, with the exception of mortality due to "certain conditions arising in the perinatal period".

At the same time, we can assume that, to a large extent, the causes of infant mortality due to infectious diseases can be classified as preventable. This is indicated by the findings of foreign research works. For example, in a study of potentially preventable causes of death, based on a retrospective analysis of 1,779 pathology reports of deaths in children aged from 7 days to 14 years, it was found that about 8% of them were preventable and occurred in children under 2 years. The most common causes of these deaths were sepsis, pneumonia and meningitis (82% of preventable cases). The authors of the study point out that in most cases the doctors were informed in advance about the symptoms of the disease (1–7 days before the child's death), with approximately 30% of patients seeking medical care repeatedly (Bamber et al., 2015). A study of infant mortality in rural China, using data from 1996–2015, found that infectious diseases accounted for about 20% of infant deaths in the first year of life. Among them, in turn, the leading positions belonged to acute respiratory infections (pneumonia), diarrhea, septicemia, meningitis. At the same time, a territorial differentiation of infant mortality rates due to infectious diseases was observed; the authors linked it to the differences in the level of economic development, the coverage of the rural population with public health infrastructure and services and hygiene education (Wang et al., 2020).

The impact of the quality and accessibility of health care on children's health goes hand in hand with the influence of socio-demographic factors. The problem of providing the population with quality health care services is itself addressed by social and economic policy instruments and is relevant to the tasks of reducing non-monetary inequalities. At the same time, according to expert estimates, the health care system's influence on health is limited to only 10% contribution against 50% contribution of conditions and lifestyle factors (Karpov, Mahnev, 2017). At the same time, countries with higher incomes per capita have an advantage in health financing opportunities and in achieving better health indicators for children. At the same time, a significant share of the poor and a lack of health care financing are associated with high rates of infant and neonatal mortality and slow progress in reducing them.

The problem of neonatal mortality deserves special attention due to the fact that it is this age period, that remains the most difficult in terms of selecting effective health care strategies, even in developed countries. Observations on groups of

[3] Meeting with top officials of the constituent entities of the Russian Federation of the Volga Federal District on the implementation of the national project "Health care" and the federal projects, included in it. Available at: https://www.mrckb.ru/files/proekta-zdravooxranenie.pdf (Slide 9).

[4] Avoidable mortality: OECD/Eurostat lists of preventable and treatable causes of death (January 2022 version). Available at: https://www.oecd.org/health/health-systems/Avoidable-mortality-2019-Joint-OECD-Eurostat-List-preventable-treatable-causes-of-death.pdf

[5] Preventable mortality: Causes of death that can be mainly avoided through effective public health and primary prevention interventions (i.e. before the onset of diseases/injuries, to reduce incidence Treatable (or amenable) mortality: Causes of death that can be mainly avoided through timely and effective health care interventions, including secondary prevention and treatment (i.e. after the onset of diseases, to reduce case-fatality). Available at: https://www.oecd.org/health/health-systems/Avoidable-mortality-2019-Joint-OECD-Eurostat-List-preventable-treatable-causes-of-death.pdf).

countries with different levels of income show, that the higher the GDP per capita, the lower the burden of child mortality losses, but the higher the share of neonatal mortality in its structure. Consequently, with the growth of people's incomes and the financing of health care, a noticeable reduction in child mortality can be achieved primarily by overcoming infectious diseases in older age groups of children (prevention, immunization) and an overall improvement in their living conditions (sanitary and hygienic conditions, quality of nutrition). A significant reduction in neonatal mortality requires improvements in obstetric and gynecological services, better access to emergency obstetric care and intensive care for newborns (Li et al., 2021). At the same time, there is evidence that the risk of neonatal mortality is higher for children born to poor mothers with low education level and in rural areas (Yaya et al., 2020). This demonstrates the need to reduce intracountry disparities in the population's access to quality health services, and also the importance of educating the population about the prevention of health problems and early childhood development.

Finding the most effective approaches to the reduction of infant and neonatal mortality remains relevant for the Russian Federation as well. In the post-Soviet period, it was possible to achieve a significant reduction in these losses. However, in contrast to the EU countries, a long-term trend (from 1990 to 2012) in Russia was a decrease in the neonatal mortality rate, while the post-neonatal mortality rate increased, which experts attributed to the under-reporting of early neonatal deaths (Baranov et al., 2015). In 2012, new criteria for registering live births came into force, which should help to solve this problem[6]. In general, when solving the tasks of reducing infant and neonatal mortality, it is necessary to take into account the interregional differentiation of factors that influence these parameters, and also possible imperfections in the statistical accounting of mortality cases (Baranov et al., 2020). The regions, in particular, are characterized by significant differences in the provision of health resources (financial, human and material) (Kalashnikov, 2015). The construction of regression models can increase the reliability of the risk factor analysis that affects the health (Gurvich et al., 2008).

Materials and methods of research

The information base of the study was the statistical data characterizing the provision of health care resources in the regions of the Russian Federation for the period from 2010 to 2020. Data for 2021–2022 are not available in the analysis, because at the time of preparing the article, they were only available in the public domain for selected indicators. Infant mortality rate, early neonatal mortality and mortality rate of the child population aged 0–17 years (per 100,000 people of the corresponding age) were chosen as key indicators of the health of the child population.

The aim of the study was to assess the impact of demographic and economic parameters, and also indicators of provision with health care resources on the mortality of the child population in Russia's regions.

Objectives of the study:

1) to compare the dynamics of infant mortality with the dynamics of indicators characterizing the provision of health care resources for the period 2010–2021 in Russia as a whole;

2) to group the regions according to the level of indicators of provision of health care resources to the population;

3) to conduct a correlation and regression analysis of the influence of economic, medical, and demographic factors on infant mortality;

[6] On medical criteria for birth, the form of the birth certificate and the procedure for its issuance: Order 1687n of the RF Ministry of Health and Social Development, dated December 27, 2011. Available at: https://base.garant.ru/70113066/

4) to formulate proposals, aimed at minimizing the risks of infant mortality due to the considered factors.

The methods of mathematical data processing include hierarchical cluster analysis to identify and characterize quantitative and qualitative assessments of regional differentiation of the provision of health care resources, correlation and regression analysis to identify economic, medical and demographic factors that have the most pronounced correlation with the mortality rate of the child population. Among the methods of regression analysis, we chose the method of multiple linear regression on panel data, which provides an opportunity to quantitatively assess the relationship between infant mortality and indicators of economic and demographic development of regions and the provision of health care resources. At the first stage of the analysis we calculated pairwise correlation coefficients for the formed set of variables. At the second stage, multiple linear regression models with random and fixed effects were built for those variables that had maximum correlation coefficients with the dependent variables using Stata software.

Results of the study

Providing the child population with high-quality and accessible medical care is one of the priorities in the implementation of long-term programs and projects in the field of health care. The implementation of measures of the federal project "Development of children's health care" within the framework of the national project "Health care" for 2019–2021 was financed from the budget in the amount of 60.21 billion rubles. Measures have been taken to strengthen the human resources potential of children's health care: more than 31,000 specialists have improved their qualifications in perinatology, neonatology and pediatrics[7].

The indicators of child mortality in the period under consideration showed different dynamics. If with regard to infant mortality and mortality in children aged 0–17 years the positive trends of its reduction were stable, the values of early neonatal mortality fluctuated. At the same time at the end of the period the value decreased by 42% *(Tab. 1)*.

Despite the fact that considerable attention is paid to the development of health care, the results of the period 2010–2020 show a decrease in the provision of doctors specializing in working with pregnant women and children: pediatricians (by 86%), neonatologists (by 85%) and obstetricians-gynecologists (by 47%). The number of beds for children, pregnant women, women in labor and new mothers, gynecological beds for the same period decreased by 88%, 84% and 72% respectively. At the same time the provision of outpatient and

Table 1. Mortality rates of the child population of the Russian Federation in 2010–2020

Indicator	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Increase / decrease, %
Infant mortality, per 1,000 of newborns	7.51	7.30	8.60	8.19	7.40	6.50	6	5.60	5.09	4.90	4.50	-40
Early neonatal mortality, per 1,000 live births	2.75	2.67	3.64	3.25	2.81	2.43	2.18	1.94	1.72	1.67	1.59	-42
Mortality of children aged 0–17 years, per 100,000 people of the same age	92.2	88.7	98.7	91.7	86.0	75.2	68.4	59.8	54.1	48.6	44.6	-52
Source: Statistical data showcase. Federal State Statistics Service. Available at: showdata.gks.ru												

[7] Passports of the regions of the Russian Federation: Indicators, results. Results of 2021. On the results of the national project "Health care" and the federal projects that are a part of it by the results of 2021. Department of Project Activities of the Ministry of Health Care of the Russian Federation. 2021. P. 9.

Table 2. Provision of health care resources for the population of the Russian Federation, per 10,000 people, at the end of the year

Provision of	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Increase / decrease %
Outpatient and polyclinic institutions	257.90	260.60	263.70	264.50	263.80	263.50	266.60	270.09	272.39	277.50	283.70	10
Doctors of all specialties	50.10	51.20	49.10	48.90	48.50	45.90	46.40	47.50	47.90	48.70	50.40	1
Therapists	no data	6.10	6	5.80	5.40	5.20	5.20	5.20	5.20	5.30	5.60	-8
Neonatologists	no data	2.70	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	-85
Obstetricians and gynecologists	5.70	5.80	3.10	5.70	5.50	5.40	5.50	5.60	3	3	3	-47
Pediatricians	31.60	31.10	4.80	24.80	23.10	22.50	19.70	20	4.09	4.20	4.30	-86
Gynecological beds	9	8.69	8.40	7.90	6.80	3.60	6.50	6.20	3.30	3.20	2.50	-72
Beds for Children	82.20	80.40	66.09	63.50	56.30	11.20	53.60	52.80	10.70	10.60	9.50	-88
Beds for pregnant women, women in labor and new mothers per 1,000 women of childbearing age	21.60	21.70	21.50	21	19.60	4.70	19.10	18.39	4.20	4	3.50	-84
Source: Statistical data showcase. Federal State Statistics Service. Available at: showdata.gks.ru												

polyclinic institutions increased by 10%, doctors of all specialties – by 1%, but the number of therapists decreased by 8%. This indicates that the negative trends affected children's health care *(Tab. 2)*.

At the same time, as of 2020, there was a noticeable differentiation of the country's regions by the provision of the listed health resources. This is illustrated by the results of the conducted hierarchical cluster analysis. We identified the regions with low indicators of the provision of health care in 2020 with outpatient clinics, personnel and beds, and the regions that were leaders by these criteria *(Tab. 3)*. Most regions (77 out of 82 considered) were included in the

Table 3. Values of the health care resources provision in the regions of the selected clusters, at the end of 2020, per 10,000 people

Provision indicator of	Cluster 1			Cluster 2			Cluster 3
	Average	Min	Max	Average	Min	Max	Value
Outpatient and polyclinic institutions	280.0	181.2	361.6	411.5	396.3	440.8	487.6
Physicians: Obstetricians-gynecologists	2.9	1.7	4.7	3.0	1.9	4.2	4.4
Pediatricians	4.1	2.4	6.5	4.3	3.1	5.09	5.7
Neonatologists	0.4	0.2	0.7	0.5	0.3	0.6	1
All physicians	47.8	28.9	89.3	52.7	42.5	62.4	73.7
Hospital beds: For pregnant women, women in labor and new mothers	3.7	2	7.8	3.6	1.9	5.09	8.1
For children	9.9	6.1	24.6	11.6	8	14.9	22
Gynecological	2.5	0.9	5	2.6	2.4	3.2	5.9
Number of regions in the cluster	*77*			*4*			*1*
Source: own calculations in the SPSS Statistics program based on statistical data.							

first cluster. The second cluster recorded higher average rates of provision by all selected indicators, except for beds for pregnant women, women in labor and new mothers, compared to the regions of the first cluster. The second cluster was formed by the Komi Republic, the Arkhangelsk Oblast, the Novgorod Oblast and the Magadan Oblast. An independent cluster (no. 3) was formed by Chukotka Autonomous Okrug, where all indicators of the provision with health care resources were significantly higher than the average for the first and second clusters.

The average value of infant mortality in the first cluster of regions was 4.7 per 1,000 live births in 2020, in the second cluster – 3.2 per 1,000 live births, and in Chukotka Autonomous Okrug – 14.7 per 1,000 live births. In this region, the early neonatal mortality rate (12.82 per 1,000 live births) was also significantly higher than the average values in the first and second clusters (1.64 and 0.89 per 1,000 live births, respectively)[8].

A for the regions of the second cluster, except for the Novgorod Oblast, we can say that these are territories with low population density[9], and for all of them the funding level of territorial programs of state guarantees per inhabitant is higher than the average value for the first cluster. The Magadan Oblast is close to Chukotka Autonomous Okrug both in terms of the funding level for these programs and in terms of the share of the population with incomes below the subsistence level, which indicates the similarity of economic and demographic conditions in these regions *(Tab. 4)*. The difference between the Novgorod Oblast and other regions of the second cluster in terms of economic and demographic parameters indicates, that high rates of health care resources are achieved here due to other factors. For example, according to the report on the implementation of the national project objectives “Health care” in 2021, the Novgorod Oblast shows higher rates of staffing of outpatient clinics (82%) than Chukotka Autonomous Okrug (70.2%)[10].

The data demonstrate that higher health care expenditures and a good supply of material resources and personnel in general accompany lower registered infant and early neonatal mortality in the regions. An exception to this rule is Chukotka

Table 4. Selected economic parameters of regions by health care resource provision

Indicator	Cluster 1	Komi Republic	Arkhangelsk Oblast	Novgorod Oblast	Magadan Oblast	Chukotka AO
	Average					
Expenses for territorial programs of state guarantees, rubles per inhabitant/insured	20088.3	30429.15	26977.03	15908.51	59271.77	77698.46
Share of population with monetary income below the subsistence level, %	14.27	15.3	12.8	13.7	8.7	8.0
Sources: Social situation and living standards in Russia 2021. Federal State Statistics Service. Available at: https://rosstat.gov.ru/folder/210/document/13212; Health care in Russia 2021. Federal State Statistics Service. Available at: https://rosstat.gov.ru/folder/210/document/13218						

[8] Number of children deaths in the first year of life per 1,000 births per year. Statistical data showcase. Federal State Statistics Service. Available at: https://showdata.gks.ru/report/297720/

[9] According to the data for 2023, population density was 0.07 people/km2 in Chukotka AO, 1.74 people/km^2 in the Komi Republic, 1.7 people/km^2 in the Arkhangelsk Oblast, in the Magadan Oblast – 0.29 people/km^2, in the Novgorod Oblast – 10.57 people/km^2.

[10] Passports of the regions of the Russian Federation: Indicators, results. Results of 2021. On the results of the national project “Health care” and the federal projects that are a part of it by the results of 2021. Department of Project Activities of the Ministry of Health of the Russian Federation. 2021. Pp. 128, 220.

Autonomous Okrug, where, with favorable economic parameters, there are high levels of infant and neonatal mortality. This discrepancy in the general pattern is probably due to the suboptimal layout of medical organizations in the region under conditions of low population density and insufficient transport connectivity of the territory (Polikarpov et al., 2022) and the associated problems of ensuring the provision of quality medical care to the population.

Assessing the impact of demographic and health factors on child mortality: construction of a spatial regression model using one-year data

To build a spatial regression model, only the infant mortality rate was left as a dependent variable, because the values of the early neonatal mortality rate and the mortality rate of children aged 0–17 years old show a strong positive correlation with its values (Spearman's ρ values 0.657 and 0.837 respectively at $p = 0.01$). In addition, it is the infant mortality rate that is the most frequently used target indicator in the practice of implementing state health care programs. We assessed the impact of demographic indicators and indicators of the health care resources provision[11] on the mortality rate of the child population in two stages. At the first stage, a pairwise correlation analysis (Spearman's ρ criterion was calculated) between infant mortality and all selected indicators[12] was carried out using data for 82 regions of Russia[13] *(Tab. 5)*.

Table 5. Infant mortality rate correlation coefficients with indicators characterizing birth and provision of regional health care resources

Variable	Spearman's ρ	Significance level of p
Age-specific birth rates, 15–19 years old, per 10,000 women of that age, 2020	0.418	0.01
Age-specific birth rates, 20–24 years old, per 10,000 women of that age, 2020	0.416	0.01
Provision of hospital beds per 10,000 people (at the end of 2019), beds for pregnant women, women in labor and new mothers	0.321	0.01
Provision of hospital beds per 10,000 people (by the end of 2019), beds for children	0.269	0.05
Provision of doctors per 10,000 people (by the end of 2019), neonatologists	0.216	Parameters were not calculated because correlations are not significant
Age-specific birth rates, 25–29 years old, per 10,000 women of that age, 2020	0.163	
Age-specific birth rates, 30–34 years, per 10,000 women of that age, 2020	0.157	
Age-specific birth rates, 45–49 years old, per 10,000 women of that age, 2020	0.083	
Provision of hospital beds per 10,000 people (by the end of 2019), gynecological beds	0.077	
Age-specific birth rates, 35–39 years old, per 10,000 women of that age, 2020	0.076	
Age-specific birth rates, 40–44 years, per 10,000 women of that age, 2020	0.06	
Provision of doctors per 10,000 people (at the end of 2019), pediatricians	0.003	
Provision of outpatient and polyclinic facilities per 10,000 population (end of 2019)	-0.123	
Provision of doctors per 10,000 people (at the end of 2019), obstetricians and gynecologists	-0.125	
Provision of doctors per 10,000 people (at the end of 2019), all doctors	-0.179	
Source: own calculations in SPSS Statistics.		

[11] Indicators of health care resources provision are taken for the previous year because they reflect the situation at the end of 2019 and the beginning of 2020, and infant mortality is given for the whole year.

[12] When conducting correlation and regression analysis on one-year data, we did not take into account the values of the indicators for Chukotka Autonomous Okrug, since the parameters of the provision of this region with health resources, and demographic parameters differ sharply from those of other regions.

[13] The number of regions in the analysis is 82, because we considered the autonomous okrugs (Nenets, Khanty-Mansi and Yamalo-Nenets) as part of the oblasts within which they are located (the Arkhangelsk and Tyumen oblasts, respectively).

The strongest positive correlation with the infant mortality rate was demonstrated by age-specific birth rates at the youngest reproductive ages (15–19 years and 20–24 years), provision of beds for pregnant women and beds for children. A weak positive correlation was found between infant mortality and the provision of neonatology physicians, and also between age-specific birth rates in the middle reproductive ages (25–29 years and 30–34 years). Weak negative correlations were established between infant mortality and the provision of obstetrician-gynecologists, all physicians and outpatient and polyclinic institutions.

For those indicators that showed the highest correlation with infant mortality, a pairwise correlation test was performed *(Tab. 6)*. Since this test revealed significantly correlated indicators, the number of variables selected for the next stage of the analysis was reduced.

At the second stage, quantitative parameters of the relationship between infant mortality and the following variables were estimated by using the method of multiple linear regression: age-specific birth rate per 10,000 women aged 15–19, provision of outpatient and polyclinic institutions per 10,000 people, provision of obstetricians-gynecologists per 10,000 people, age-specific birth rate per 10,000 women aged 45–49.

The step-by-step method was used to build the regression model. The value of the parameters of the model by the value of the coefficient of determination, the error, and its semantic interpretation allows us to conclude about its average quality.

Table 6. Correlation coefficients of health care resource provision indicators and demographic indicators

Indicator	Age-specific birth rates, per 10,000 women of a given age, 2020				Provision of outpatient and polyclinic facilities per 10,000 population	Provision of obstetricians and gynecologists per 10,000 population	Provision of gynecological beds per 10,000 population
	20–24	25–29	30–34	45–49			
Age-specific birth rates, 15–19 years old, per 10,000 women of that age, 2020	0.770**	0.331**	0.235*	-0.031	0.044	0.037	0.263*
Availability of hospital beds per 10,000 people (at the end of 2019), beds for pregnant women, women in labor and new mothers	0.405**	0.312**	0.337**	0.178	0.025	0.219*	0.528**
Provision of hospital beds per 10,000 people (at the end of 2019), beds for children	0.449**	0.316**	0.369**	0.006	0.247*	0.102	0.382**
Provision of doctors per 10,000 people (at the end of 2019), neonatologists	0.252*	0.380**	0.399**	0.254*	0.063	0.403**	0.313**
Provision of doctors per 10,000 people (at the end of 2019), all doctors	-0.044	0.155	0.177	0.212	0.186	0.720**	0.299**

Note: * Correlation is significant at the p = 0.05 level (bilateral); ** Correlation is significant at the p = 0.01 level (bilateral).
Source: own calculations in SPSS Statistics.

Table 7. Quality criteria of the obtained regression model

Number of variables	R^2 (determination coefficient)	S (standard estimation error)	Durbin – Watson criterion
4	0.361	0.925	2.155
Source: own calculations in SPSS Statistics.			

The following predictors were included in the final regression model: age-specific birth rates per 10,000 women aged 15–19 and 45–49, and the provision of outpatient polyclinic facilities per 10,000 people and the provision of obstetricians-gynecologists per 10,000 people *(Tab. 7)*.

General view of the regression equation[14]:

$$y = 6.254 + 0.009\,x_1 - 0.006x_2 - 0.591x_3 + 0.085x_4,$$

where y – infant mortality per 1,000 births,

x_1 – age-specific birth rate per 10,000 women aged 15–19,

x_2 – number of outpatient clinics per 10,000 people,

x_3 – number of obstetricians-gynecologists per 10,000 people,

x_4 – age-specific birth rate per 10,000 women aged 45–49.

The results of regression analysis indicate that a single increase in the provision of outpatient clinics and obstetricians-gynecologists in the regions contributes to a slight decrease in infant mortality (by 0.006 and 0.591, respectively), while the increase in the age-specific birth rate in women 15–19 years old contributes to its weak increase. However, the presented regression model does not take into account temporal effects and regional peculiarities, which may make significant adjustments in the estimates of the significance of the contribution of the factors under consideration to the reduction of infant mortality. Identifying such effects and assessing them requires constructing regression models using panel data.

[14] All coefficients for independent variables are significant at the p<0.05 level.

Constructing multiple linear regression models based on panel data

It was noted above that there is a strong positive correlation between the infant mortality rate and the provision of beds for pregnant women, women in labor and new mothers, and beds for children. It has not been possible to explain this relationship by constructing a multiple linear regression on one-year data. It can be assumed that it reflects the response of the health care system to the level of infant mortality, which was recorded in the past period. At the same time, in the works of Russian authors there are indications of possible contradictory results of modeling the relationship between the mortality rate and the resource provision of health care (Boitsov, Samorodskaya, 2016; Lakman et al. 2021). Therefore, the contradictions identified in our study deserve a more detailed consideration.

To establish more reliable relationships between the variables describing health care resource provision and infant mortality, a regression model should be built based on panel data. The key advantages of using panel data are the ability to reduce standard estimation errors, and to prevent specification errors due to non-inclusion of significant variables in the model (Rossoshanskii, 2018). Choosing the most appropriate regression model to describe the effects of different factors on the explanatory variable is based on standard procedures for assessing their reliability and comparing the three main types of models: pooled (end-to-end) regression, regression with fixed and random effects. As the results of Russian studies show, for the description of panel data, where the units of observation are the regions of the country, the most suitable are models with fixed effects (Molchanova, Kruchek, 2013; Korolenko, 2019).

The mentioned arguments, and also the analysis of the special literature indicate the expediency of the construction and evaluation of three regression models: the regression "between", the model with fixed effects and the model with random effects.

At the preliminary stage of the analysis, statistics were collected for 82 regions[15], characterizing infant and neonatal mortality, child morbidity from congenital anomalies and malformations, birth rate (by age group of women), provision of health care resources (outpatient clinics, doctors, beds of certain types), financing of territorial state guarantee programs, GRP per capita, living standards (share of population with income below the subsistence wage, GRP per capita). The data were collected for the period from 2014 to 2020. The absence of data for earlier years in the analysis is due to the limitations of the information base (there are no statistical data for certain indicators).

The correlation matrix for the selected statistics was created: the values of Pearson coefficients were calculated. The direction of the relationship between the infant mortality rate and the provision of the population with doctors of certain specialties and hospital beds remained positive *(Tab. 8)*.

Table 8. Mutual correlation coefficients of explanatory variables

Indicator designation	**InfM**	Neon	PrWoB	ArBr15	ArBr45	Malf	ShPoor	ExH	GRPpc	Outp	Doct	Ther	OBGYN	Pedt	GynB	PedB
Neon	.213**	--														
PrWoB	.401**	.108**	--													
ArBr15	.657**	.178**	.465**	--												
ArBr45	.182**	.281**	-.009	-.007	--											
Malf	.152**	.146**	.118**	.158**	-.086*	--										
ShPoor	.304**	.198**	.143**	.363**	.162**	.100*	--									
ExH	-.136**	-.020	-.104*	-.202**	.259**	-.106*	-.306**	--								
GRPpc	-.104*	.325**	-.111**	-.095*	.135**	-.031	-.383**	.410**	--							
Outp	.019	.125**	-.015	.032	-.052	.180**	-.127**	.034	.404**	--						
Doct	-.052	.467**	.019	-.057	.216**	.228**	-.151**	.255**	.491**	.381**	--					
Ther	.119**	.418**	.067	.067	.217**	.141**	.100*	.003	.330**	.263**	.689**	--				
OBGYN	.401**	.301**	.653**	.404**	.068	.146**	.040	.034	.036	-.024	.343**	.282**	--			
Pedt	.291**	.154**	.614**	.362**	-.144**	.156**	-.029	.054	-.090*	-.009	.181**	.077	.835**	--		
GynB	.471**	.188**	.830**	.495**	-.025	.101*	.047	-.130**	.078	.115**	.128**	.156**	.663**	.584**	--	
PedB	.307**	.074	.921**	.379**	-.101*	.127**	.050	-.066	-.073	.072	.084*	.044	.633**	.667**	.814**	--

Note: The most significant correlations are highlighted in color.
** – correlation is significant at the p=0.01 level, * – correlation is significant at the p=0.05 level.
Variable designations: InfM – infant mortality per 1,000 births per year, Neon – provision of neonatologists per 10,000 people, PrWoB – provision of beds for pregnant women, women in labor and new mothers, per 10,000 people, ArBr15 – age-specific birth rate per 10,000 women aged 15–19 years, ArBr45 – age-specific birth rate per 10,000 women aged 45–49 years, Malf – incidence of congenital anomalies (malformations), deformities and chromosomal abnormalities per 1,000 people, ShPoor – share of population with money incomes below the subsistence level (%),ExH – expenses for territorial programs of state guarantees per 1 inhabitant/insured (rubles), GRPpc – Gross Regional Product per capita (rubles), Outp – provision of outpatient clinics per 10,000 people, Doct – provision of doctors of all specialties, Ther – provision of therapists, OBGYN – provision of obstetricians-gynecologists, Pedt – provision of pediatricians, GynB – provision of gynecological beds, PedB – provision of beds for children.
Source: own calculations in SPSS Statistics.

[15] The number of regions in the analysis is 82, because we considered the autonomous okrugs (Nenets, Khanty-Mansi and Yamalo-Nenets) as part of the regions within which they are located (the Arkhangelsk and Tyumen oblasts, respectively).

Significant correlations with the infant mortality coefficient were shown by age-specific birth rates among women aged 15–19 years, the share of the population with incomes below the subsistence level, the provision of beds for pregnant women, women in labor and new mothers, gynecological and pediatric beds, the provision of the population with obstetrician-gynecologists. The connection is less pronounced regarding the provision of pediatricians, neonatologists, the age coefficient of birth rate among women aged 45–49 years, expenditures on territorial programs of state guarantees, the incidence of congenital anomalies, the provision of therapists, doctors of all specialties, outpatient clinics, the value of GRP per capita[16].

To build the regression model, the variables with the highest correlation coefficients with the explained variable and the least correlated with each other were selected. Age-specific birth coefficients in the groups of 15–19 and 45–49-year-old women are virtually not correlated with each other and have a significant relationship with the explained variable, so both indicators were included in the regression model. Among the indicators characterizing health care resources, the availability of gynecological beds was included in the regression model. It demonstrated a significant positive correlation with the provision of beds for pregnant women, children's beds, pediatricians and obstetricians-gynecologists. Despite the fact that this indicator also correlated with the birth rate in women aged 15–19 years, it was included in the model to test the initial assumption about the effect of the availability of health care resources on infant mortality. Among the indicators reflecting socio-economic conditions in the regions, the level of per capita GRP was included in the regression. In addition to the fact that expenses on territorial programs of state guarantees correlated more significantly with infant mortality, the correlation with age-specific birth rates was also significant for them. The share of the population with incomes below the subsistence level was also more significantly correlated with the infant mortality rate, but was also related to the age-specific birth rate in women aged 15–19.

At the next stage of the analysis, the values of the selected variables were converted to decimal logarithms. Then, based on the obtained modified variables, three regression models were built: regression "between", regression with fixed ("within") and random effects.

The estimate of the "between" regression suggests that the model has average quality, as the R^2 value = 0.4483. The coefficients on the variables, with the exception of the provision of gynecologic beds, are significant *(Fig. 1)*.

The "within" regression (model with fixed effects) gives somewhat more reliable results. The coefficient of determination in it is 0.5044. However, in this way of regression construction the coefficients at demographic indicators (age coefficients of birth rate among women of 15–19 and 45–49 years old) lose significance. The main explanatory variable in this model is GRP per capita, which negatively correlates with the infant mortality rate. The coefficient value for the variable "provision of gynecological beds" is somewhat lower than in the "between" model, but its significance is maintained ($p<0.05$). The reliability of the model estimates is evidenced by the correlation value of the explanatory variables and individual effects corr (u_i, Xb) = -0.6463 *(Fig. 2)*. Since the coefficient of determination of this model is higher than the "between"

[16] Gross regional product by constituent entities of the Russian Federation (gross value added in current basic prices) per capita. Source of data: Appendix of the compilation "Regions of Russia. Socio-economic Indicators", for 2022. Available at: https://rosstat.gov.ru/folder/210/document/13204

Figure 1. Estimation of the “between” regression

```
Between regression (regression on group means)  Number of obs      =       566
Group variable: Region                          Number of groups   =        82

R-sq:  within  = 0.3497                         Obs per group: min =         4
       between = 0.4483                                        avg =       6.9
       overall = 0.3926                                        max =         7

                                                F(4,77)            =     15.64
sd(u_i + avg(e_i.))=  .1846477                  Prob > F           =    0.0000
```

lInfM	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lGynB	.2033547	.1033407	1.97	0.053	-.002423	.4091324
lArBr15	.2894735	.0655253	4.42	0.000	.158996	.4199511
lArBr45	.1970133	.0504054	3.91	0.000	.0966433	.2973834
lGRPpc	-.1098465	.0403063	-2.73	0.008	-.1901067	-.0295863
_cons	2.188044	.5326122	4.11	0.000	1.127478	3.24861

Source: own calculations in Stata (ver 13).

Figure 2. Estimation of the “within” regression

```
Fixed-effects (within) regression               Number of obs      =       566
Group variable: Region                          Number of groups   =        82

R-sq:  within  = 0.5044                         Obs per group: min =         4
       between = 0.0795                                        avg =       6.9
       overall = 0.1846                                        max =         7

                                                F(4,480)           =    122.13
corr(u_i, Xb)  = -0.6463                        Prob > F           =    0.0000
```

lInfM	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lGynB	.0691854	.0243963	2.84	0.005	.0212486	.1171221
lArBr15	.1517188	.0608841	2.49	0.013	.0320865	.2713511
lArBr45	.0035768	.0219967	0.16	0.871	-.0396449	.0467985
lGRPpc	-.582076	.0798921	-7.29	0.000	-.7390574	-.4250946
_cons	8.663649	1.174559	7.38	0.000	6.355736	10.97156
sigma_u	.33822752					
sigma_e	.17414421					
rho	.79045497	(fraction of variance due to u_i)				

```
F test that all u_i=0:     F(81, 480) =     8.27             Prob > F = 0.0000
```

Source: own calculations in Stata (ver 13).

model, we can assume that if individual effects (caused by regional characteristics) are fixed, economic factors come to the fore. This allows us to conclude that regardless of regional specifics, successful economic development of territories and improvement of living standards are of paramount importance for the reduction of infant mortality.

The model with random effects also has a fairly high significance, as evidenced by the value of the Wald statistic (Wald chi2=465.34). The regressors are not correlated with the random residuals of the model. This model restores the significance of the age-specific birth rate for women aged 15–19 years, but loses the significance of the same indicator for women aged 45–49 years *(Fig. 3)*. There remains a positive correlation between the infant mortality and the provision of gynecological beds in the population. This indicates that the regressor in this case can itself change under the influence of the explained variable, which means that the provision of beds increases with a high level of infant mortality, which is generally consistent with the logic of health resource management. Similarly, we can interpret the positive correlations between infant mortality and the provision of other health resources (beds for pregnant women, neonatologists, obstetricians and gynecologists). The positive correlation coefficients of infant mortality and birth rates in the groups of women 15–19 and 45–49 years old are probably due to the fact that pregnancy and childbirth complications are more frequent in these groups of women in labor (Erbaktanova et al., 2014; Kulavskii et al., 2014; Kuleshova et al., 2016; Yavorskaya, Nikolaeva, 2016; Serova et al., 2020).

Figure 3. Estimation of regression with random effects

```
Random-effects GLS regression                   Number of obs      =       566
Group variable: Region                          Number of groups   =        82

R-sq:  within  = 0.4776                         Obs per group: min =         4
       between = 0.3116                                        avg =       6.9
       overall = 0.3837                                        max =         7

                                                Wald chi2(4)       =    465.34
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
       lInfM |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lGynB |   .1094253   .0234824     4.66   0.000     .0634007      .15545
     lArBr15 |   .3521556   .0378681     9.30   0.000     .2779356    .4263757
     lArBr45 |   .0234711   .0207209     1.13   0.257    -.0171412    .0640833
      lGRPpc |  -.1975338   .0341469    -5.78   0.000    -.2644605   -.1306071
       _cons |   3.099838   .4956586     6.25   0.000     2.128365    4.071311
-------------+----------------------------------------------------------------
     sigma_u |  .17225491
     sigma_e |  .17414421
         rho |  .49454604   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Source: own calculations in Stata (ver 13).

The Hausman test indicates the preferred use of a model with fixed rather than random effects *(Fig. 4)*. This corresponds to the logic of the indicators used, since data on Russian regions, which are known to have specific features of socio-economic and demographic development, were used in the construction of regression models.

The results of regression analysis indicate that when regional differences are fixed, the successful economic development of the regions and the accompanying increase in the standard of living contribute most to the reduction of infant mortality. The second most important factor is improving the provision of health care resources (in the model built – the provision of gynecological beds), and the third factor is the reduction of birth rates among juveniles, who are taken into account in the category of those aged 15–19.

The analysis conducted allows us to formulate proposals aimed at reducing the level of infant mortality. It has been shown that one of the main factors influencing infant mortality is the level of GRP per capita. Its value, in turn, correlates positively with expenditures on territorial programs of state guarantees and negatively with the share of the population with incomes below the subsistence level. Thus, the basic condition for a successful policy to reduce infant mortality is the implementation of measures aimed at improving the social and economic well-being of the Russian regions. This once again confirms the need for a comprehensive approach when setting and implementing economic, social and demographic policy objectives, including at the regional level.

Since the provision of health care resources in the regions has a significant impact on infant mortality, it is necessary to further strengthen the material base of health care institutions, provide timely medical care to pregnant and women in labor, including those living in inaccessible areas

Figure 4. Results of the Hausman test (comparison of models with fixed and random effects)

```
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed          .          Difference          S.E.
-------------+----------------------------------------------------------------
       lGynB |    .0691854     .1094253        -.04024         .0094959
     lArBr15 |    .1517188     .3521556      -.2004368         .0506158
     lArBr45 |    .0035768     .0234711      -.0198943         .0096037
      lGRPpc |    -.582076    -.1975338      -.3845421         .0755942
------------------------------------------------------------------------------
                          b = consistent under Ho and Ha; obtained from xtreg
           B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       44.93
                Prob>chi2 =      0.0000
```

Source: own calculations in Stata (ver 13).

(Burtseva et al., 2020), improve routing algorithms and increase the quality of patient treatment with high risk of pregnancy and childbirth complications (Shuvalova et al., 2017).

A long-term trend in Russia is the decrease in the average age of sexual debut. A related phenomenon is teenage pregnancies, which most often end in medical abortions and much less often in childbirth (Laryusheva et al., 2014). Against this background, the correlation-regression analysis confirmed the relationship between infant mortality and birth rate in women aged 15–19 years necessitates the prevention of unwanted pregnancies among teens, early detection and registration of pregnant juveniles, improving early diagnosis of the risks of pregnancy complications and childbirth in this age group, and also improving the quality of medical support for young mothers. Teenage pregnancy is a phenomenon indicative of social disadvantage. Its prevention is a priority both in terms of the country's demographic security and preservation of the reproductive potential of the younger generation and in terms of minimizing the burden of social and economic losses associated with the risks of maternal and perinatal mortality (Guseva et al., 2008). Today, a number of regions have accumulated positive experience in the functioning of reproductive health care systems for children and juveniles, which can be replicated in order to effectively address these problems (Simakhodskii, Ippolitova, 2016).

Conclusion

The regression analysis performed allowed us to confirm the importance of economic, social and demographic factors in solving the problem of reducing infant mortality in Russian regions. Among the three regression models built, the best quality is the model with fixed effects, in which the greatest influence on reducing infant mortality has an increase in the key indicator of regional economic development – GRP. The model could be improved by including regional data on the number of births with complications, maternal illnesses during pregnancy and the share of babies born prematurely and with low birth weight. More reliable estimates are also possible when taking into account the level of medical organizations where cases of infant mortality are registered.

The favorable economic conditions of regional development and the related economic well-being are a basic condition for reducing infant mortality. Of high importance are also factors such as regional provision of health care resources, the availability of an effective system of three-level organization of medical care for women during pregnancy, labor and delivery and the postpartum period. To prevent infant mortality at the regional level, measures aimed at reducing social disadvantage, including the prevention of teenage pregnancies, are highly important.

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