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RESEARCH ARTICLE

Risks of morbidity and mortality during the COVID-19 pandemic in Russian regions

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Abstract

The COVID-19 pandemic has covered all Russian regions. As of May 8, 2020, about 190 thousand cases have been identified, more than 1600 people with the corresponding diagnosis have died. The values of the indicators are expected to rise. However, the statistics of confirmed cases and deaths may underestimate their actual extent due to testing peculiarities, lagging reporting and other factors. The article identifies and describes the characteristics of the regions in which the incidence and mortality of COVID-19 is higher. Migration of potential carriers of the virus: summer workers and migrant workers from Moscow and large agglomerations, as well as return of labour migrants to the North increase the risks of the disease spread. The risk of mortality is higher in regions with high proportions of the poor and aged residents, for whom it is difficult to adapt to the pandemic, and lower in regions with greater health infrastructure. Based on the revealed patterns, a typology of regions on possible risks is proposed. Above all the risks in and near the largest agglomerations (the cities of Moscow and Saint Petersburg, Moscow and Leningrad Oblasts), in the northern regions where the share of labour migrants is high (Khanty-Mansi and Yamalo-Nenets Autonomous Okrugs), in southern underdeveloped regions (Ingushetia, Karachay-Cherkess, Kabardino-Balkarian Republics, Dagestan, North Ossetia). For the latter, the consequences may be most significant due to the limited capacity to adapt to the pandemic and self-isolation regime, and additional support measures may be required in these regions.

Keywords

coronavirus, morbidity, mortality, Russian regions, risks, consequences

JEL codes: I10, I15, I18

Introduction

In Russia, according to Rospotrebnadzor (2020), about 190 thousand cases of coronavirus disease (COVID-19) were detected as of May 8, including over 26 thousand people discharged (≈ 12% of confirmed cases), more than 1.6 thousand people have died (≈ 0.88%). Broad scope, high incidence of morbidity and mortality, spread of the disease in all Russian regions (Appendix 1), scale of socio-economic consequences (Zemtsov and Tsareva 2020) determine the relevance of the study. The values of these indicators are expected to increase, as the number of new confirmed cases of the disease has not been steadily decreasing, however, the proportion of discharged patients is increasing and in general the growth rate of new cases is decreasing.

However, the statistics of confirmed cases and deaths may underestimate their real extent due to a number of distortions discussed in the methodological part of the work. Therefore, it is relevant to assess the risks and, accordingly, the future consequences of the pandemic for the population in certain regions. The authors proposed an appropriate methodology based on approaches to assessing the social risks of natural disasters (Welle and Birkmann 2015; Zemtsov et al. 2016).

The purpose of the article is to identify characteristics of Russian regions affecting the incidence of COVID-19 and mortality, and on their basis to assess the risks of the pandemic for the population of the regions at the exponential stage of the coronavirus disease spread.

Methodology, data and their limitations

For analysis, we use the official data of Rospotrebnadzor (2020) on confirmed cases of the new coronavirus infection COVID-2019 in Russia, and on mortality – data of the portal "Coronavirus today" (2020), which aggregates data of Rospotrebnadzor.

The number of officially confirmed cases may be a distorted reflection of the real spread of the coronavirus disease with a certain lag. The fact is that not all patients will contact the doctor (in half of the identified carriers according to Rospotrebnadzor the disease was asymptomatic), there is a lag between the infection entering the human body, the disease and the identification of the virus. Official data may be belatedly available to Rospotrebnadzor. The share of identified cases depends to a large extent on the quality of the tests, the system and method of testing, the coverage of the population with testing, which in turn depends on the level of the health care system development, availability and proximity of laboratories, density of private laboratories, etc. Although according to Rospotrebnadzor, over 4 million tests for coronavirus were carried out, the availability of tests at the regions significantly varied, especially in the first weeks. According to our estimates, the correlation coefficient between the number of tests and the number of confirmed cases as of April 24, 2020 is about 0.3. As the number of tests grows, registered and actual infestations should converge. Therefore, in our opinion, the provision of the population with tests is a significant but not determining factor. Tests for antibodies showing the number of cases of illness have been carried out in other countries and prove that the rates of real morbidity are understated (Nazarov and Sisigina 2020). However, in our view, officially recorded morbidity is proportional to real cases, which enables assessing multifactor regressions where the restrictions mentioned above may be partially eliminated. In doing so, factors and their impact can change as the disease spreads, so we use the latest available data.

Mortality of patients with coronavirus disease can also be significantly underestimated. By far not all those who are ill apply to medical institutions. Many die from exacerbation of concomitant chronic diseases without having an officially confirmed diagnosis of

COVID-19. Some of the deaths during the pandemic will also be attributed to out-of-time care due to overcrowding in medical facilities and the high engagement of emergency medical services. In some cases, deaths from certain socially sensitive diseases, such as HIV (Skochilov et al. 2018), may be underreported due to transfer to other causes of death or provided later. The disease cannot always be correctly established and identified posthumously. Also, there is a lag between real deaths and reporting. In some cases, the time lag between events and statistical registration may reach several months, and final data across the country will be available only at the end of the year. Therefore, in the case of such large-scale events, the excess of total mortality over a given time span (when an event was observed) over total mortality in previous periods is often estimated. For example, it was revealed that the additional mortality from the hot summer of 2010 in Russia amounted to 55.8 thousand people due to cardiovascular pathologies, respiratory problems and other factors (Revich 2011). According to preliminary data in the European Union there is a significant excess of total mortality in April over average values, in some countries by over 50% (EuroMOMO 2020). In Russia, according to the results of April and May, it is also possible to identify additional mortality. According to preliminary data for April, the mortality rate in Moscow increased by 20% compared to previous years, taking into account the decrease in the number of deaths in certain categories, for example from external causes (RBK 2020). In this case, we also believe that the deaths from COVID-19 reflected in the statistics will be proportional to the total additional mortality of the population, giving the basis for the econometric calculations.

Risk assessment models of natural hazards are applied to identify the characteristics of regions affecting population morbidity and mortality (Zemtsov et al. 2016). Traditionally, two components are taken into account: exposure of the population to the danger and its vulnerability. The first case involves the potential number of those who will become ill. This is due to the intensity of the regional community's interaction with other communities and within the community. Vulnerability of the population includes characteristics of the most sensitive part of residents (susceptibility), the ability of the health system to respond quickly to threats (coping capacity), as well as the ability of the population to adapt (adaptive capacity).

The main testing characteristics of the regions and their indicators are presented in Table 1, the data – in Appendix 2. Official Rosstat data is used unless stated otherwise. The values of the indicators are given for the last available year, mainly at the end of 2018, apart from the self-isolation index. We assumed that regional differences in annual indicators are relatively sustainable, so they can be used to identify common characteristics of regions affecting morbidity and mortality from COVID-19 this year.

In our view, regions with a high share of urban residents are most susceptible to the spread of the pandemic, as in cities there is a high intensity of interaction between people in multi-storey buildings, in crowded public transport, and here the proportion of residents who visited foreign countries – foci of the disease (China, Italy) – is also higher. Not far from major cities (with few exceptions) are the largest airports. Roughly half of the flights are via Moscow, Saint Petersburg, Krasnodar, Simferopol and Sochi (Habr 2020), which also increases the likelihood of the disease spread. The increase in the share of urban dwellers is a global contributor to pandemics (other things being equal), especially in developing countries. In the major cities of the third world, not only the intensity of communications is higher, but also the natural and environmental conditions are worse, which has a negative impact on the population health.

Table 1. Potential characteristics of regions affecting morbidity and mortality during the COVID-19 pandemic.

Region Characteristics	Designation	Indicator description
Exposure of the population to the pandemics caused by high intensity of interactions within the regional community	Urb	Share of urban residents in total population, %
	Isol	Yandex self-isolation index, a reverse indicator to highway congestion in major cities. According to the data on 27.04.2020.
Exposure of the population to the pandemics caused by proximity to major cities as potential sources of infection and the intensity of external relations of the regional community	Demo	Demo-geographical potential of the region (calculation: population of other regions divided by distance to them squared), person per 1 km^2
	TrudMigrIn	Number of employed population entering the region for work, % of the employed population of the region
	TrudMigrOut	Number of employed population leaving for work from the region, % of the employed population of the region
	TrudMigrAll	Number of employed population entering the region for work and leaving the region, % of the employed population of the region
	Tourism	Number of residents on tours to China, Italy, France and Germany, per 1 million population
	Airport	Passenger traffic of the region's main airports, millions per capita (according to Avia Adv (2020) data)
Susceptibility of the population to the consequences of the pandemics	Life	Life expectancy at birth, years
	Age	Average age of the population of the region, years
	Old	Share of people over working age, %
	Des	Average annual total morbidity rate, per thousand people
	Mort	Average annual total mortality rate, per 1 thousand population
Health care system's capacity to respond quickly to the disease spread	Beds	Number of beds, per capita
	Doctor	Number of doctors, per 10 thousand population
	Medpers	Number of middle-level medical personnel, per 1 thousand people
	Medexp	Budget expenditure on health care per capita, thousand rubles
Capacity of the population to adapt to the consequences of the pandemics	Income	Average per capita income of the population considering the interregional price index, thousand rubles
	Poverty	Poverty rate (share of population with monetary income below regional subsistence level in total population), %

Source: Compiled by the authors.

Another important spatial factor of the disease spread is the proximity of other major cities, which can have a negative impact through temporary or other types of migration, transit streams, etc. (Ponomarev and Radchenko 2020). We calculated the demo-geographical potential of regions using the gravitational model, i.e. estimated how many people live in other Russian regions considering the distance to them. The regions near the largest agglomerations have the greatest potential: Moscow Oblast, Tver, Kaluga, Ryazan, Oryol, Vladimir, Tula Oblasts near Moscow, as well as Leningrad and Novgorod Oblasts near Saint Petersburg.

The Yandex self-isolation index, calculated as the inverse of traffic density in the regional center directly estimates the population mobility and, accordingly, the potential of the infection. But here, in our opinion, there is a reverse dependence – the number of cars decreases as the number of diseased increases together with the spread of information about it in the media and the actions of the authorities (the presence of positive the relationship was confirmed by the results of econometric calculations).

To assess the intensity of foreign relations, we used various indicators of foreign and intra-Russian tourism and temporary labour migration. Intra-Russian migrants (Florinskaya et al. 2015) often maintain links with their place of origin, they have higher mobility, and consequently, their larger numbers both in the region of arrival and in the donor region can influence the rate and the scale of morbidity. Temporary migrant workers, for example, may have contributed to the coronavirus disease spread by returning from Moscow to the regions of Central Russia or to the North. The increase in global population mobility (tourism, labour mobility) has become a factor of the rapid spread of infection to almost all countries.

To describe the health care system's capabilities to withstand threats, we used population health assessments (regional health capital) as well as health infrastructure development. In the first case, general morbidity rates, the proportion of older people, average age and life expectancy calculated on the basis of age mortality rates, in the second the costs of health care and the provision of doctors and beds. Population ageing is another global factor that increases the likelihood of pandemics, as a set of chronic diseases accumulate with age that can escalate during pandemics, the risk of death rises. This particularly affects death rates from COVID-19. Healthcare costs are rising worldwide but are mainly aimed at serving senior citizens and buying high-priced medications from major pharmaceutical giants. At the same time, the accessibility of medicine from the point of view of availability of doctors and beds in hospitals in Russia decreased due to the optimization. Costs are higher in those regions where the incidence is higher, but they are better at recording cases, for example, private companies place their laboratories closer to potential customers.

The ability of the community to adapt to the pandemic also depends, in our view, on living standards. In particular, wealthier communities on average have greater resources to purchase the necessary equipment, medicines, for self-isolation: dacha, use of delivery services, remote work, etc.

To identify the most significant characteristics of regions, we have consistently tested all variables based on their correlation. Figure 1 shows the coefficients of pair correlation for identified significant variables (the designation of symbols is given in Table 1).

The combination of identified characteristics of regions was expected to help indirectly assess the risks to morbidity and mortality. The limitations of the approach are related to the fact that significant variables associated with the spread of the pandemic are identified to the current date, while it is necessary to predict the final situation. Therefore, we did not use the revealed coefficients in regressions to construct finite risk indices but rather defined weights for selected region characteristics using the main component method. We assumed that the combination of significant factors in the main component would be an estimate of the initial risks of morbidity and mortality. The production of two indices we interpreted as an assessment of the integral risk index from the COVID-19 pandemic.

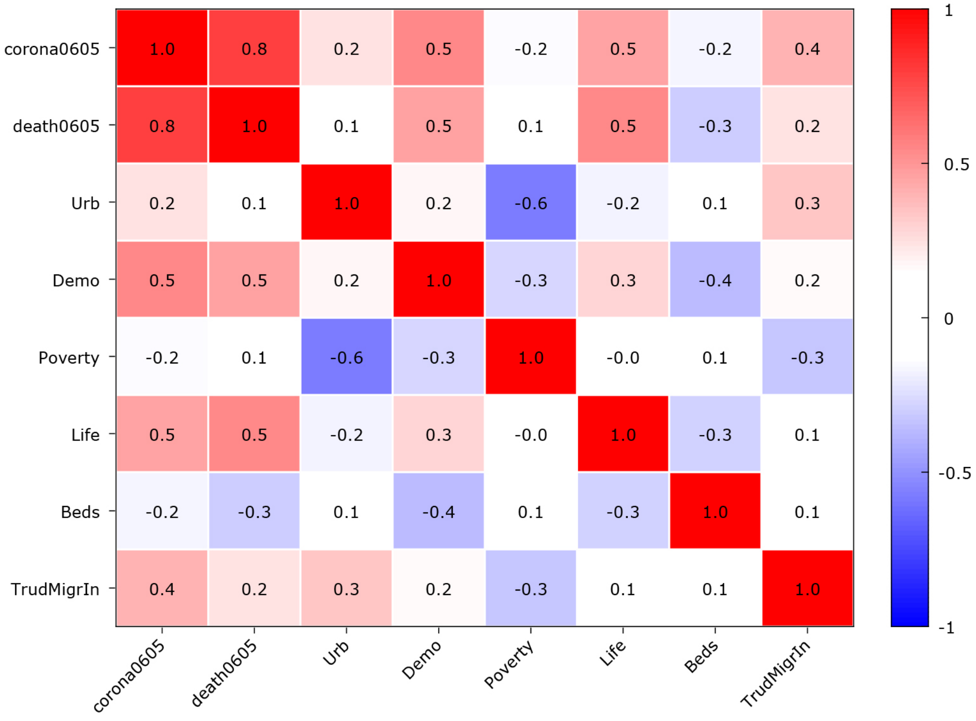

Figure 1. Pair correlation coefficients for identified significant factors determining morbidity and mortality from COVID-19 in Russian regions. **Source:** Calculations of the authors.

The use of econometric methods in non-stationary processes, the nature of which is not fully studied, is always fraught with significant errors, especially when changing the time horizon. Factors identified for different observational periods can vary dramatically, and at the early stages the role of random events is high. Therefore, we are rather talking about risk assessments for the stage of exponential growth of the disease. But it is at this stage that occupancy of medical facilities is maximized due to the high spread rate of infection in the community, and consequently, additional mortality may increase. Moreover, when using the least-squares method, we cannot talk about identifying factors or causalities, but only about different characteristics of regions, in which incidence and mortality of COVID-19 are higher or lower.

Results and discussion

The first cases of the disease in Russia were reported in early March among Chinese workers in the Zabaykalsky Krai, and among Russian citizens – in Moscow among arrived tourists from Italy. Already by the end of March, the number of confirmed cases was growing exponentially. From that point on, the spread of the disease throughout the country began

(Fig. 3), Moscow's share of new cases steadily decreased from 81% on April 5 to 38% on April 29. And only two weeks after the introduction of the self-isolation regime (March 29, 2020), there was a deviation from this trend (Fig. 2) towards lower growth rates.

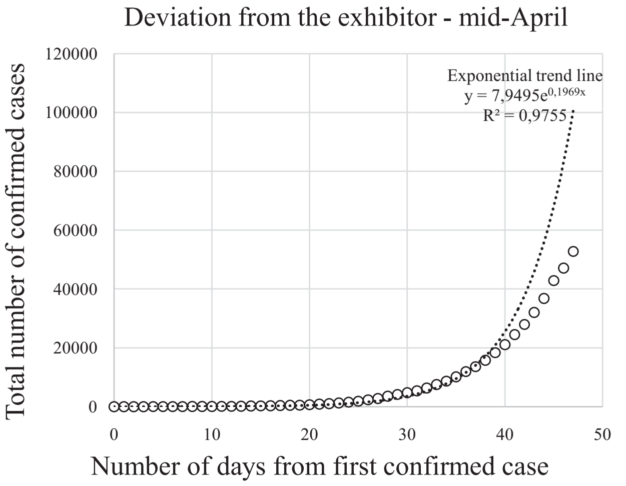

Figure 2. The cumulative number of confirmed cases of COVID-19 in Russia depending on the number of days from the beginning of the first recorded case. **Source:** Calculated by the authors according to Rospotrebnadzor data.

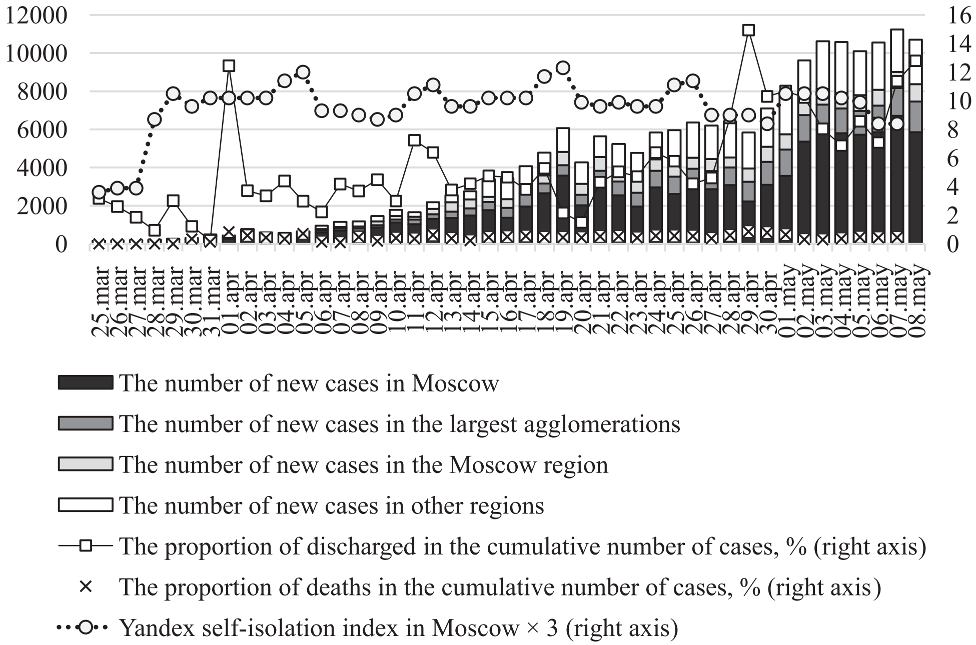

Figure 3. Dynamics of the number of confirmed cases of COVID-19 in Russian regions (percentages are given on the right axis). **Source:** Calculated by the authors according to Rospotrebnadzor and Yandex data.

Daily growth in new cases generally fell until the last week of April (Fig. 4). But in the first days of May, the number of cases in Moscow again rose to 60% of the total for Russia, which may be due to the second wave of the pandemic, the launch of tests in many private laboratories or the consequence of uncoordinated actions by the authorities during the introduction of digital passes in mid-April, which caused queues in the metro. With the introduction of digital passes, the travel intensity of the population increased slightly, and the Yandex self-isolation index on working days fell accordingly from 3.4 to 3.2 (Fig. 3; index values multiplied by 3 for visibility and dimensionality of the right axis of the graph).

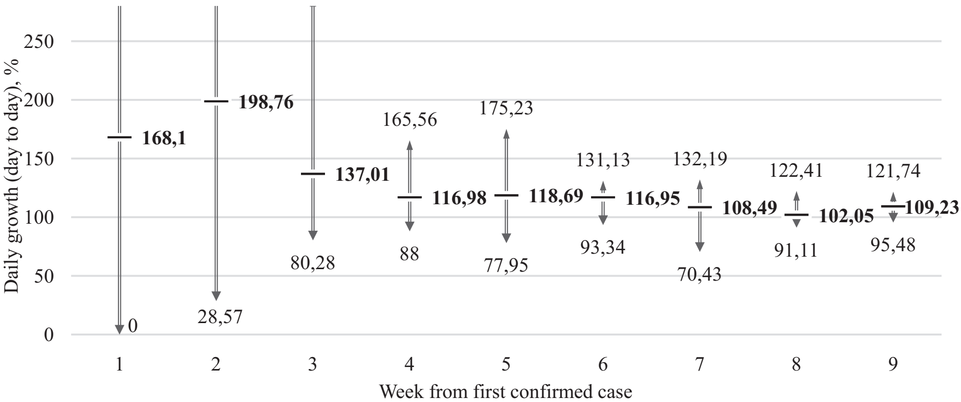

Figure 4. Change of daily growth in the number of new cases in Russia by week: maximum, average (in bold) and minimum value, %. **Source**: Calculated by the authors according to Rospotrebnadzor data.

Fixed dynamics of the disease spread in Russian regions vary significantly (Figs 5, 6). The highest speed and maximum value are in the city of Moscow and neighbouring regions (Moscow and Kaluga Oblasts), as well as in the north (Murmansk, Yamalo-Nenets Autonomous Okrug) and in the North Caucasus regions. The lowest values are in the farthest and sparsely populated Tuva, Chukotka Autonomous Okrug, Sakhalin and Altai.

As of May 6, 2020, the confirmed incidence of COVID-19 according to econometric calculations (Table 2) is higher in regions near large centers as potential sources of infection (Demo). Figure 6 shows a belt with increased morbidity around the capital and on the axis of the most intensive communications: Saint Petersburg – Moscow – Nizhny Novgorod. Many temporary migrant workers and dacha owners returned from Moscow to neighbouring regions – Ryazan, Kaluga, Bryansk, Kursk and Oryol Oblasts. After the introduction of the self-isolation regime, labour migrants began to actively leave the capital, carrying the disease across the European part of the country.

At the stage of exponential growth, the coronavirus infection spread from the largest agglomerations to the regions of the North Caucasus, Yamalo-Nenets and Khanty-Mansi Autonomous Okrugs with high life expectancy. Note that the incidence of the COVID-19 population is higher in a number of regions with high life expectancy (Life) and a high proportion of older people, for example in the cities of Moscow and Saint Petersburg, Moscow, Voronezh, Rostov, Tambov Oblasts, Mordovia, Mari El. As we see it, higher life expectancy, and correspondingly a low mortality of older residents and people with chronic diseases in the previous period may have led to increased incidence of COVID-19 this year, given that when the diagnosis is confirmed there is a certain shift towards the most severe cases. In Tyva or Chukotka, where life expectancy was low and deaths from all causes were higher than the average Russian in previous years, the incidence of COVID-19 is lower, as the proportion of vulnerable members of the community is lower.

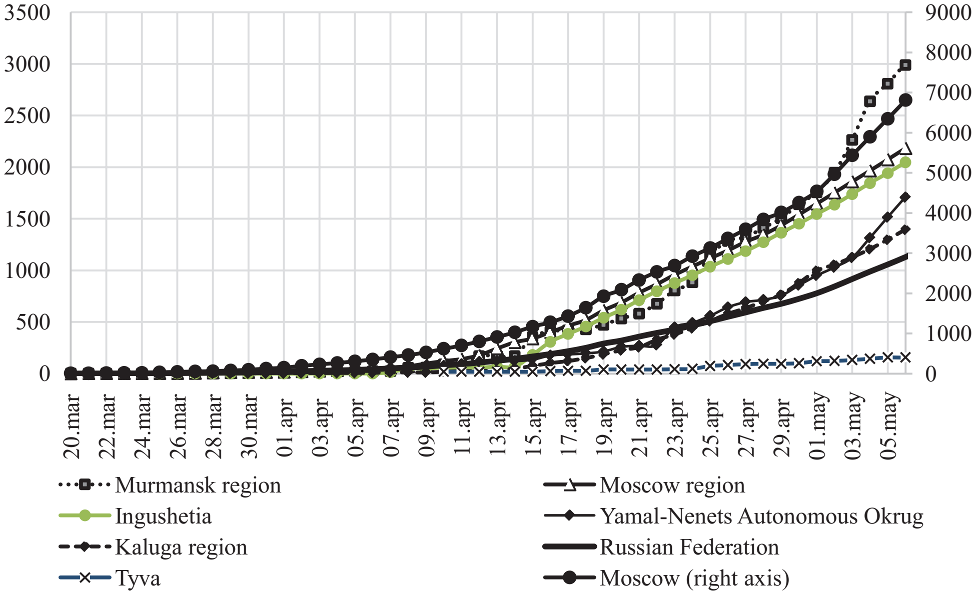

Figure 5. Cumulative number of confirmed cases of COVID-19 per 1 million population in Russian regions. **Source:** Calculated by the authors according to Rospotrebnadzor data.

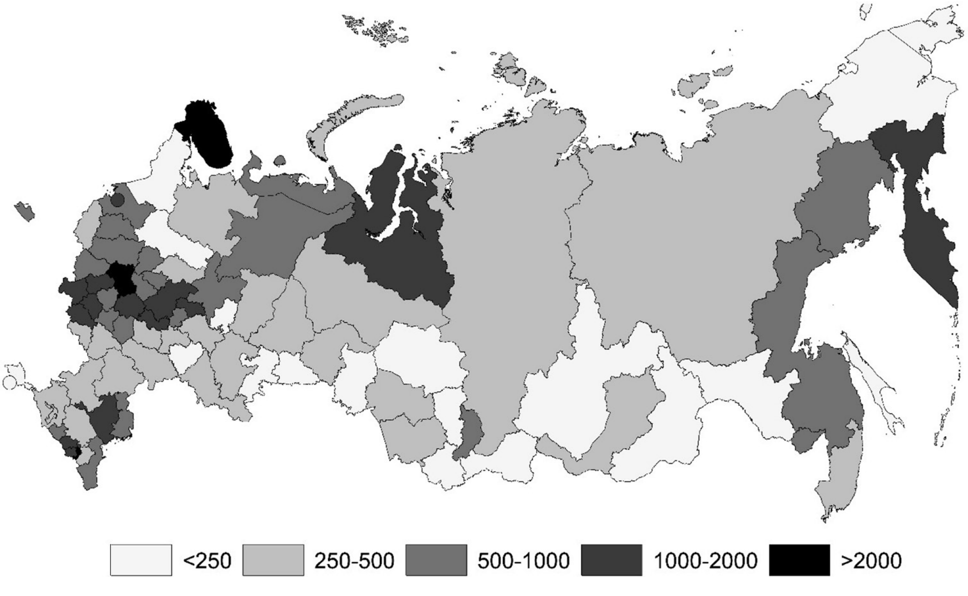

Figure 6. Number of confirmed cases of COVID-19 per 1 million population as of 06.05.2020. **Source:** Calculated by the authors.

Table 2. The results of COVID-19 incidence factors estimation.

	Coefficient	Standard error	t-ratio	p-value	
Const	−8144.5	2479.1	−3.28	0.0015	***
Demo	0.46	0.2	2.06	0.0423	**
Life	118.8	33.8	3.51	0.0007	***
TrudMigrIn	47.6	25.9	1.84	0.0695	*
R^2	0.48	R^2 adjusted		0.46	

Note: Dependent variable is the number of confirmed cases of COVID-19 per 1 million population as of 06.05.2020. The method of least squares is used for 85 regions. Standard errors are robust. The model with significant variables is presented. **Source:** Calculated by the authors.

Also, the incidence is higher in regions where the proportion of migrant workers from other regions is high (TrudMigIn) as an estimate of the disease transmission between regions, especially from the city of Moscow on a shift to the northern regions (Mikhailova 2020). This share is highest in Yamalo-Nenets and Khanty-Mansi Autonomous Okrugs, the cities of Moscow and Saint Petersburg, Magadan Oblast, Kamchatka Krai.

The COVID-19 death rate in Russian regions strongly correlates with morbidity, the correlation coefficient is 0.78 (Fig. 1). Therefore, one of the most significant characteristics of the regions with higher COVID-19 mortality (Table 3) was a high proportion of citizens (Urb) as an indicator of intensity of internal links, and consequently, indirectly, the share of the media. This proportion is higher in the cities of Moscow and Saint Petersburg, Magadan and Murmansk Oblasts, Yamalo-Nenets Autonomous Okrug, which recorded above-average mortality (Fig. 7). In cities, infection rates are higher due to the intensity of contacts and higher incidence, and consequently overcrowding of medical facilities. There is reason to believe that in cities there is higher incidence of the disease and mortality due to high density of laboratories, stricter reporting, qualification of medics, etc.

Among more aged population, deaths from COVID-19 are on average higher (Chen et al. 2020). In some regions with high life expectancy (Life) and average age above the Russian average, such as the cities of Moscow and Saint Petersburg, Mordovia, Penza and Moscow Oblasts, Chuvashia, the death rate from COVID-19 is indeed higher. In our view, the high life expectancy, and the consequently reduced mortality of aged residents and populations with chronic diseases in previous years, could have led to their increased deaths from COVID-19 this year.

Mortality is also higher in regions where the proportion of the population with income below the subsistence level (Poverty) is higher, such as the republics of Ingushetia, Kabardino-Balkaria, Kalmykia, Karachay-Cherkessia, Mari El. The ability of poor, socially vulnerable populations to adapt to the pandemic is limited, as they often work in the informal sector based on personal contacts and cannot afford remote work or work breaks.

The provision of beds in hospitals is an indirect indicator of the health care system development, of its ability to meet the challenges and to connect the largest proportion of seriously ill patients to ventilators, so the higher the availability in the region, the lower the mortality rate (Beds). For example, the lowest indicator values are in Chechnya, Ingushetia, Moscow Oblast, Leningrad and Kaluga Oblasts where deaths from COVID-19 are higher than the national average.

Table 3. The results of COVID-19 incidence factors estimation.

	Odds	Standard Error	t-ratio	p-value	
Const	−181.7	64.2	−2.80	0.0059	***
Urb	0.28	0.14	2.02	0.0446	**
Poverty	0.59	0.25	2.39	0.0191	**
Life	2.31	0.78	2.96	0.0040	***
Beds	−1.44	0.67	−2.15	0.0344	**
R^2	0.42	R^2 adjusted		0.39	

Note: Dependent variable is the number of confirmed deaths of COVID-19 per 1 million population as of 06.05.2020. The least squares method is used for 85 regions. Standard errors are robust. The model with significant variables is presented. **Source:** Calculated by the authors.

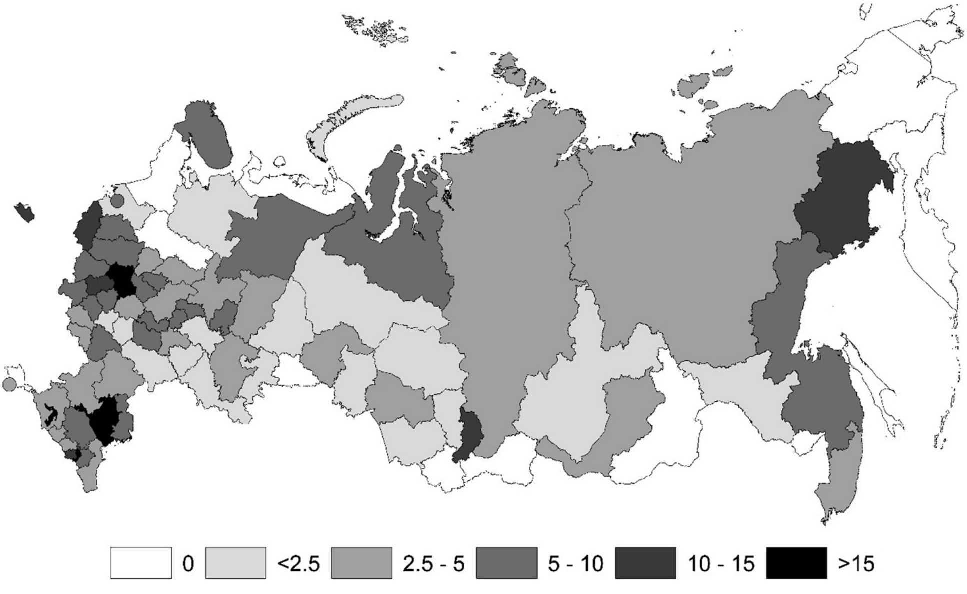

Figure 7. Number of confirmed deaths from COVID-19 per 1 million population as of 06.05.2020. **Source:** Calculated by the authors.

In the next step, using the principal component method, we obtained estimates of the weights of each significant variable for the development of the relevant integral indices (Table 4).

Detailed data on the index values for each region are presented in Appendix 3. The obtained estimates of indices by region are close to the initial parameters of morbidity and mortality from COVID-19 as of May 6, 2020. But since we did not use the weights of the regressions obtained at a particular moment in time, we can say that indices in some approximation estimate the overall risks of regions for the period of the pandemic, at least for its exponential stage. In order to assess the COVID-19 integrated population risk index, we multiplied the two indices received, as we needed to take into account their joint impact.

Table 4. Structure of integral indices.

Variable	Weight in the final index	Correlation with dependent variable
Demo	0.4	0.54
Life	0.35	0.45
TrudMigrIn	0.25	0.4
COVID-19 Incidence Index	1	0.69
Urb	0.3	0.09
Poverty	0.25	0.05
Life	0.6	0.54
Beds	−0.15	−0.31
COVID-19 mortality index	1	0.65

Source: Calculated by the authors.

Figure 8 shows the types of Russian regions by the level of risk and, respectively, the consequences of the exponential spread of the pandemic. According to our calculations, the greatest risks are borne by the population in the largest agglomerations and regions near them (the cities of Moscow and Saint Petersburg, Moscow, Leningrad and Kaluga Oblasts, Tatarstan, etc.), as the population density is higher there, as well as the intensity of interaction, including at the expense of migrant workers. Risks are high in the underdeveloped regions of the North Caucasus (Ingushetia, Dagestan, Karachay-Cherkessia, North Ossetia, etc.) due to high population density, poor development of the health care system, a substantial number of elderly and poor citizens, as well as traditions of large gatherings (weddings, commemorations, celebrations). Risks are higher in the northern regions, where the propor-

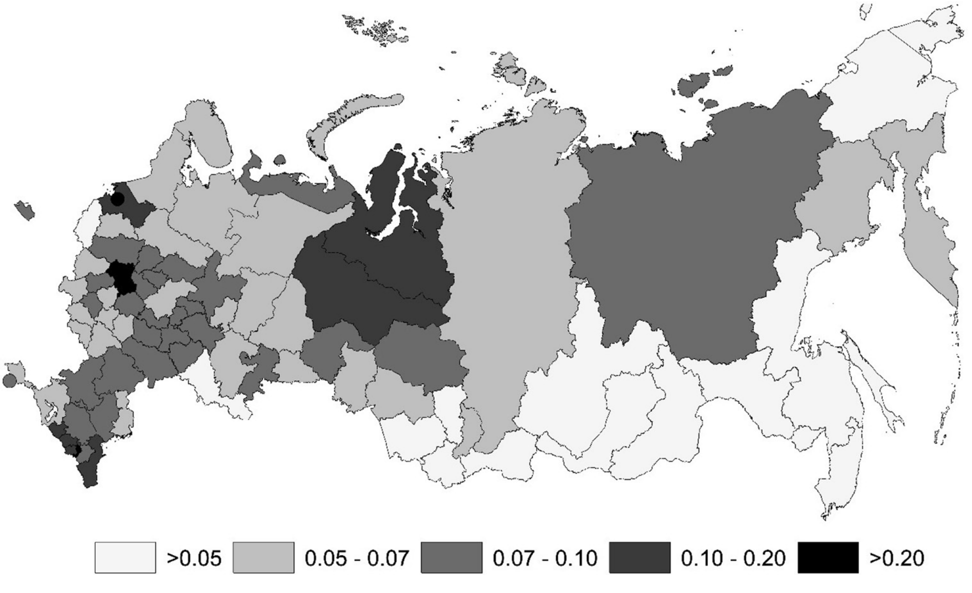

Figure 8. COVID-19 pandemic integral risk indexes **Source:** Calculated by the authors.

tion of migrant workers is higher and the density of interaction in cities and especially in the urban areas with a single ventilation system is higher.

The risks are least in poorly populated and remote regions where social distancing is naturally held: Tyva, Chukotka Autonomous Okrug, Jewish Autonomous Oblast, Irkutsk, Sakhalin Oblasts. Despite its relative proximity to China as one of the hot spots of the disease in the regions of the Far East, the risks are assessed as lower due to low population density and relatively young age structure. Of course, risks vary significantly within regions at the level of individual municipalities.

Conclusion

The maximum recorded proportion of patients with COVID-19 as of May 6, 2020, is higher in regions with large agglomerations (foci of the disease) and in their vicinity, with an ageing population and high share of labour migrants. Confirmed mortality from COVID-19 during the same period was higher in regions with high life expectancy, high poverty and insufficient health care infrastructure development. Therefore, the generalized population risks are higher in the largest agglomerations and regions near them, in the underdeveloped regions of the North Caucasus and the northern mining centers.

Risk assessment by indices is necessary in the face of deficiencies in available statistics which are late and may underestimate the scale and impact of the pandemic. Exceeding the real number of illnesses and additional deaths over confirmed cases is expected. In the Russian regions with high risks, removal of restrictions may be delayed compared to other regions.

Risk assessments strongly depend on the observation period, and the combination of factors will change as the disease spreads, so periodic monitoring of the calculated coefficients and the analysis of their behaviour over time is appropriate. The error of the approach used and the sensitivity of the obtained results to the change of the observation period, and accordingly the composition of the indicators are high. It is also important to consider that several regions have insufficient source data. Calculations performed for the earlier period confirm the described limitations of the approach, therefore the obtained calculations are primarily applicable for estimating the risks of the exponential morbidity growth stage. However, this stage is of greatest interest to politicians and scientists due to the high rate of the disease spread, rapid occupancy of medical facilities and potentially most negative consequences for mortality due to the inability to provide assistance in time, social exclusion of the most vulnerable groups, etc.

Additional socio-economic support measures may be required in high-risk regions. The self-isolation regime and other imposed restrictions can have a devastating impact on small and medium-sized businesses in Russia and the regional economies with maximum risks. As part of the pessimistic scenario, up to 80% of enterprises from particularly affected industries may close: hotels and restaurants, domestic services, entertainment (Zemtsov and Tsareva 2020). The multiplier may affect the sectors of trade, construction, real estate and transportation, so in this case, up to 3 million entrepreneurs can cease their activities. According to calculations (Zemtsov and Smelov 2018), if the number of small firms in the region is 1% lower, then the gross regional product (GRP) in it is lower by 0.06–0.17%. Then the closure and bankruptcy of 50–60% of firms are fraught with a fall in the region's GRP by 3–10%. The most affected industries are concentrated in many high-risk regions:

the cities of Moscow and Saint Petersburg, Yaroslavl, Kaliningrad, Kaluga, Moscow Oblasts, Stavropol Krai, Kabardino-Balkaria, Chuvashia et al. At the same time, large agglomerations have better opportunities for digital adaptation: remote work, orders via the Internet, online business, etc.; population income is higher in large cities and, accordingly, demand for the products and services of small businesses. Therefore, the most serious social consequences can be expected in the North Caucasus and Crimea, where more than half of the employed are workers in the business sector: tourism, trade, repair, agriculture, etc.

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Appendix

Appendix 1. Main characteristics of pandemic spread in regions of Russia on May 6, 2020.

Region	Number of confirmed cases, persons	Cases per 1,000 residents	Number of confirmed cases, persons	Death toll, persons	Death toll per 1 million inhabitants	Percentage of deaths of total infected,%	Total discharged, persons	Percentage of the total infected,%
Altai Krai	588	252.1	33	3	1.29	0.51	109	18.5
Amur Oblast	117	147.5	8	1	1.26	0.85	14	12
Arkhangelsk Oblast	329	299	24	1	0.91	0.3	112	34
Astrakhan Oblast	570	562.1	29	6	5.92	1.05	108	18.9
Belgorod Oblast	531	343.2	16	5	3.23	0.94	71	13.4
Bryansk Oblast	1367	1139	80	12	10	0.88	313	22.9
Vladimir Oblast	1001	732.9	57	12	8.79	1.2	43	4.3
Volgograd Oblast	647	258	69	12	4.79	1.85	109	16.8
Vologda Oblast	236	202.1	6	0	0	0	77	32.6
Voronezh Oblast	697	299.4	30	12	5.16	1.72	140	20.1
City of Moscow	85975	6815.1	5858	816	64.68	0.95	7870	9.2
City of Saint Petersburg	5884	1092.9	312	37	6.87	0.63	1468	24.9
City of Sevastopol	104	234.7	6	2	4.51	1.92	15	14.4
Jewish Autonomous Oblast	153	956.8	5	0	0	0	15	9.8
Zabaykalsky Krai	238	223.3	23	0	0	0	78	32.8
Ivanovo Oblast	537	534.8	20	6	5.97	1.12	99	18.4
Irkutsk Oblast	231	96.3	31	4	1.67	1.73	65	28.1
Kabardino-Balkarian Republic	925	1067.9	105	3	3.46	0.32	136	14.7
Kaliningrad Oblast	583	581.7	17	11	10.98	1.89	123	21.1
Kaluga Oblast	1407	1393.9	98	12	11.89	0.85	161	11.4
Kamchatka Krai	348	1105.8	1	0	0	0	40	11.5

Region	Number of confirmed cases, persons	Cases per 1,000 residents	Number of confirmed cases, persons	Death toll, persons	Death toll per 1 million inhabitants	Percentage of deaths of total infected,%	Total discharged, persons	Percentage of the total infected,%
Karachay-Cherkess Republic	457	981.5	4	2	4.3	0.44	36	7.9
Kemerovo Oblast	180	67.3	14	4	1.5	2.22	25	13.9
Kirov Oblast	661	519.6	17	4	3.14	0.61	90	13.6
Kostroma Oblast	292	458.3	15	3	4.71	1.03	64	21.9
Krasnodar Krai	1534	271.6	97	21	3.72	1.37	443	28.9
Krasnoyarsk Krai	910	316.6	42	12	4.18	1.32	162	17.8
Kurgan Oblast	56	67.1	1	0	0	0	19	33.9
Kursk Oblast	1129	1019.9	67	4	3.61	0.35	134	11.9
Leningrad Oblast	1200	649.4	51	3	1.62	0.25	258	21.5
Lipetsk Oblast	629	549.8	46	2	1.75	0.32	112	17.8
Magadan Oblast	136	963.2	5	2	14.16	1.47	56	41.2
Moscow Oblast	16588	2182.7	829	127	16.71	0.77	576	3.5
Murmansk Oblast	2237	2990.2	136	4	5.35	0.18	154	6.9
Nenets Autonomous Okrug	33	753.4	0	0	0	0	1	3
Nizhny Novgorod Oblast	3298	1025.9	272	16	4.98	0.49	398	12.1
Novgorod Oblast	417	694.7	18	4	6.66	0.96	43	10.3
Novosibirsk Oblast	809	289.6	63	9	3.22	1.11	179	22.1
Omsk Oblast	197	101.3	6	3	1.54	1.52	39	19.8
Orenburg Oblast	767	390.7	39	4	2.04	0.52	217	28.3
Oryol Oblast	813	1099.4	57	7	9.47	0.86	135	16.6
Penza Oblast	601	456	32	8	6.07	1.33	193	32.1
Perm Krai	673	257.8	25	9	3.45	1.34	218	32.4
Primorsky Krai	684	359.5	49	7	3.68	1.02	105	15.4

Region	Number of confirmed cases, persons	Cases per 1,000 residents	Number of confirmed cases, persons	Death toll, persons	Death toll per 1 million inhabitants	Percentage of deaths of total infected,%	Total discharged, persons	Percentage of the total infected,%
Pskov Oblast	226	358.9	12	8	12.7	3.54	24	10.6
Republic of Adygea	202	444.2	12	7	15.39	3.47	107	53
Altai Republic	37	169	1	0	0	0	2	5.4
Republic of Bashkortostan	1160	286.3	24	14	3.46	1.21	255	22
Republic of Buryatia	450	457.6	43	4	4.07	0.89	125	27.8
Republic of Dagestan	2267	734.6	181	14	4.54	0.62	325	14.3
Republic of Ingushetia	1018	2046.6	52	26	52.27	2.55	190	18.7
Republic of Kalmykia	351	1287.6	29	5	18.34	1.42	53	15.1
Republic of Karelia	103	166.7	12	0	0	0	17	16.5
Komi Republic	726	874.5	28	7	8.43	0.96	129	17.8
Republic of Crimea	125	65.4	17	0	0	0	39	31.2
Mari El Republic	783	1150.8	33	4	5.88	0.51	444	56.7
Republic of Mordovia	977	1228.2	54	5	6.29	0.51	121	12.4
Republic of Sakha (Yakutia)	348	359.9	17	4	4.14	1.15	44	12.6
Republic of North Ossetia - Alania	1253	1791.8	93	7	10.01	0.56	158	12.6
Republic of Tatarstan	1313	336.8	102	3	0.77	0.23	149	11.3
Republic of Tyva	51	157.2	0	0	0	0	29	56.9
Republic of Khakassia	340	634.1	22	8	14.92	2.35	32	9.4
Rostov Oblast	1434	341.2	81	11	2.62	0.77	147	10.3
Ryazan Oblast	1310	1175.8	84	5	4.49	0.38	89	6.8
Samara Oblast	675	212.1	81	6	1.89	0.89	64	9.5
Saratov Oblast	835	342.1	98	3	1.23	0.36	106	12.7

Region	Number of confirmed cases, persons	Cases per 1,000 residents	Number of confirmed cases, persons	Death toll, persons	Death toll per 1 million inhabitants	Percentage of deaths of total infected,%	Total discharged, persons	Percentage of the total infected,%
Sakhalin Oblast	29	59.2	0	0	0	0	20	69
Sverdlovsk Oblast	1353	313.5	76	1	0.23	0.07	156	11.5
Smolensk Oblast	535	567.7	1	5	5.31	0.93	87	16.3
Stavropol Krai	864	309.1	40	18	6.44	2.08	188	21.8
Tambov Oblast	971	955.7	62	2	1.97	0.21	125	12.9
Tver Oblast	753	593.1	44	8	6.3	1.06	183	24.3
Tomsk Oblast	160	148.5	13	1	0.93	0.63	29	18.1
Tula Oblast	1446	977.8	77	9	6.09	0.62	157	10.9
Tyumen Oblast	658	433.3	69	4	2.63	0.61	186	28.3
Udmurt Republic	344	228.2	12	10	6.63	2.91	66	19.2
Ulyanovsk Oblast	573	462.7	29	4	3.23	0.7	89	15.5
Khabarovsk Krai	727	550.1	39	7	5.3	0.96	172	23.7
Khanty-Mansi Autonomous Okrug - Yugra	537	322.8	29	4	2.4	0.74	150	27.9
Chelyabinsk Oblast	812	233.6	44	3	0.86	0.37	96	11.8
Chechen Republic	645	442.7	30	8	5.49	1.24	306	47.4
Chuvash Republic	892	729.1	48	8	6.54	0.9	149	16.7
Chukotka Autonomous Okrug	1	20.1	0	0	0	0	2	200
Yamalo-Nenets Autonomous Okrug	925	1708.2	105	3	5.54	0.32	131	14.2
Yaroslavl Oblast	880	698.6	51	5	3.97	0.57	101	11.5

Source: Calculated by the authors according to Rospotrebnadzor data.

Appendix 2. The values of the main indicators used to build risk indexes.

Region	Urb	Demo	Poverty	Life	Beds	TrudMigrIn
Altai Krai	56.7	96.2	17.4	71.1	5.1	0.2
Amur Oblast	67.5	7.6	15.6	69.1	5.6	2.4
Arkhangelsk Oblast	78.5	53.5	12.5	72	5.2	1.01
Astrakhan Oblast	66.8	93.8	15.1	73.4	6.4	0.59
Belgorod Oblast	67.5	201.5	7.5	73.7	4	0.61
Bryansk Oblast	70.4	324.8	13.6	71.3	2.7	0.22
Vladimir Oblast	78.3	615.8	13.1	71.2	4.1	0.62
Volgograd Oblast	77.1	128.1	13.4	73.5	4.6	0.54
Vologda Oblast	72.6	197.8	13.6	71.3	4.2	0.72
Voronezh Oblast	67.8	267.7	8.9	73	4.9	0.84
City of Moscow	98.6	3241	6.8	77.9	2.1	22.85
City of Saint Petersburg	100	1247.3	6.6	75.5	4.3	7.34
City of Sevastopol	93.1	136.7	10.8	73.4	8	3.87
Jewish Autonomous Oblast	68.8	52.9	23.7	68.8	7.8	1.53
Zabaykalsky Krai	68.4	13.1	21.4	69.6	5.4	0.96
Ivanovo Oblast	81.6	510.6	14.7	71.5	3.4	0.27
Irkutsk Oblast	78.7	18.6	17.7	69.2	5.3	1.44
Kabardino-Balkarian Republic	52.1	186.4	24.2	75.8	7.2	0.14
Kaliningrad Oblast	77.7	45.4	13.7	72.6	4.4	0.45
Kaluga Oblast	76	830.6	10.4	71.9	1.9	1.02
Kamchatka Krai	78.4	2	15.8	70.1	6.1	3.95
Karachay-Cherkess Republic	42.8	157.6	22.9	75.9	4	0.25
Kemerovo Oblast	86	80.6	13.9	69.4	3.9	0.25
Kirov Oblast	77.3	123.4	15.2	72.7	4.2	0.56
Kostroma Oblast	72.4	440.8	12.7	71.8	4.1	0.86
Krasnodar Krai	55.2	151.9	10.5	73.4	5.6	2.46
Krasnoyarsk Krai	77.6	30.4	17.1	70.6	3.3	1.96
Kurgan Oblast	62.1	144.7	19.6	70.8	3.1	0.07
Kursk Oblast	68.2	304	9.9	71.7	3.3	0.5
Leningrad Oblast	64.3	3414.9	8.4	72.5	2.3	2.09
Lipetsk Oblast	64.5	364	8.7	72.5	4.3	0.55
Magadan Oblast	96.1	1.8	9.5	69.4	7	6.9
Moscow Oblast	81.5	5234.8	7.3	73.3	3.1	5.1
Murmansk Oblast	92.2	23.6	9.9	71.7	6.4	2.26
Nenets Autonomous Okrug	73.3	17.7	9.7	71.5	5.2	18.21
Nizhny Novgorod Oblast	79.6	251	9.5	71.9	5.3	0.68
Novgorod Oblast	71.3	407.4	13.8	69.7	2.8	0.79

Region	Urb	Demo	Poverty	Life	Beds	TrudMigrIn
Novosibirsk Oblast	79.1	119	14.1	71.6	5.6	0.81
Omsk Oblast	72.8	56.8	13.6	71.5	3	0.3
Orenburg Oblast	60.3	86.7	14.2	70.9	4.3	0.58
Oryol Oblast	66.8	509.7	13.5	71.6	3.3	0.57
Penza Oblast	68.7	242.4	13.5	73.3	3.6	0.24
Perm Krai	75.9	121.3	14.9	70.8	3.9	0.55
Primorsky Krai	77.4	8.2	13.9	70.4	6.9	0.52
Pskov Oblast	71.1	190.7	17	70	3.3	0.38
Republic of Adygea	47.1	156.5	12.8	73.3	5.4	0
Altai Republic	29.2	72.8	24	71.2	4.3	3.84
Republic of Bashkortostan	62.2	98.8	12	71.7	3.3	0.47
Republic of Buryatia	59.1	23.5	19.1	70.7	4.8	0.79
Republic of Dagestan	45.3	132.2	14.7	77.8	4.3	0.14
Republic of Ingushetia	55.5	746.9	30.4	81.6	2.1	0.46
Republic of Kalmykia	45.6	106	23.6	73.5	4.2	0.68
Republic of Karelia	80.7	100.5	15.6	70.7	4.4	0.63
Komi Republic	78.2	47.1	14.9	71.1	4.3	4.33
Republic of Crimea	51	121.5	17.3	72	5	2.01
Mari El Republic	66.6	333.3	20.4	72.2	4	0.66
Republic of Mordovia	63.4	304.4	17.8	73.4	4.8	0.69
Republic of Sakha (Yakutia)	65.9	3.8	18.6	71.7	4.4	6.66
Republic of North Ossetia - Alania	64.3	374.8	14	75.5	5.7	0.39
Republic of Tatarstan	76.9	219.2	7	74.2	2.2	1.76
Republic of Tyva	54.1	19	34.4	66.3	7.2	2.43
Republic of Khakassia	69.7	31.6	18.5	70.2	3.9	2.21
Rostov Oblast	68.1	169.4	13.2	73	4.1	0.48
Ryazan Oblast	72.1	545.2	13	72.7	4.1	0.54
Samara Oblast	79.8	157.5	12.7	71.7	3.7	1.01
Saratov Oblast	75.9	166.2	15.3	72.9	5	0.33
Sakhalin Oblast	82.2	4.3	8.5	70.2	7.1	2.32
Sverdlovsk Oblast	84.9	150.3	9.5	71.2	4	1.07
Smolensk Oblast	71.8	226.7	16.4	71.1	4	0.18
Stavropol Krai	58.6	156.7	13.9	74.2	5.4	0.85
Tambov Oblast	61.1	308.3	9.8	73.2	2.9	0.42
Tver Oblast	76	846.4	12.2	70.5	4	0.72
Tomsk Oblast	72.5	91.6	14.7	72	3.9	2.28
Tula Oblast	74.8	596.9	10	71.2	4.1	0.94
Tyumen Oblast	67.1	111.3	14.9	72.1	3.1	6.81

Region	Urb	Demo	Poverty	Life	Beds	TrudMigrIn
Udmurt Republic	66	143.8	12.2	72.1	4.9	0.39
Ulyanovsk Oblast	75.6	248.2	15.3	72.3	3.7	0.42
Khabarovsk Krai	82	13.7	12.2	69.7	4.8	2.49
Khanty-Mansi Autonomous Okrug - Yugra	92.4	22.8	9	73.9	4.3	22.35
Chelyabinsk Oblast	82.7	151.6	12.8	71.5	3.4	1.06
Chechen Republic	36.7	378.2	20.5	74.8	3.1	0.55
Chuvash Republic	63	212.2	17.8	72.7	3.3	0.26
Chukotka Autonomous Okrug	70.9	1.1	8.8	66.1	6.3	15.2
Yamalo-Nenets Autonomous Okrug	83.9	18.4	5.8	73.5	6.3	34.12
Yaroslavl Oblast	81.6	465.3	10.2	71.9	3.6	1.13

Source: Calculated by the authors according to Rospotrebnadzor data.

Appendix 3. COVID-19 pandemic risk indexes.

Region	Incidence risk index	Rank	Mortality Risk Index	Rank	Total Risk Index	Rank
Altai Krai	0.122	65	0.332	76	0.040	72
Amur Oblast	0.085	81	0.271	83	0.023	82
Arkhangelsk Oblast	0.144	55	0.414	44	0.060	51
Astrakhan Oblast	0.175	29	0.409	50	0.072	36
Belgorod Oblast	0.191	22	0.418	40	0.080	24
Bryansk Oblast	0.143	56	0.423	34	0.061	49
Vladimir Oblast	0.166	41	0.415	43	0.069	40
Volgograd Oblast	0.182	26	0.491	10	0.089	17
Vologda Oblast	0.137	60	0.394	54	0.054	61
Voronezh Oblast	0.183	25	0.386	59	0.071	37
City of Moscow	0.681	1	0.754	2	0.513	1
City of Saint Petersburg	0.360	6	0.610	3	0.220	4
City of Sevastopol	0.203	15	0.446	27	0.091	15
Jewish Autonomous Oblast	0.077	84	0.285	81	0.022	83
Zabaykalsky Krai	0.088	80	0.354	67	0.031	79
Ivanovo Oblast	0.162	44	0.471	17	0.076	33
Irkutsk Oblast	0.082	82	0.349	69	0.029	81
Kabardino-Balkarian Republic	0.235	12	0.503	8	0.118	11
Kaliningrad Oblast	0.154	49	0.466	20	0.072	35
Kaluga Oblast	0.201	16	0.462	21	0.093	14
Kamchatka Krai	0.118	68	0.345	73	0.041	70
Karachay-Cherkess Republic	0.236	11	0.537	5	0.127	9

Region	Incidence risk index	Rank	Mortality Risk Index	Rank	Total Risk Index	Rank
Kemerovo Oblast	0.081	83	0.388	57	0.032	78
Kirov Oblast	0.163	42	0.485	12	0.079	27
Kostroma Oblast	0.169	35	0.410	48	0.069	39
Krasnodar Krai	0.195	18	0.343	74	0.067	42
Krasnoyarsk Krai	0.118	69	0.443	29	0.052	62
Kurgan Oblast	0.118	71	0.412	45	0.048	65
Kursk Oblast	0.154	48	0.386	60	0.060	52
Leningrad Oblast	0.422	3	0.410	47	0.173	6
Lipetsk Oblast	0.175	28	0.362	66	0.064	45
Magadan Oblast	0.125	64	0.316	79	0.039	74
Moscow Oblast	0.601	2	0.486	11	0.292	3
Murmansk Oblast	0.144	54	0.407	51	0.059	53
Nenets Autonomous Okrug	0.257	9	0.349	71	0.090	16
Nizhny Novgorod Oblast	0.155	47	0.386	58	0.060	50
Novgorod Oblast	0.118	70	0.365	65	0.043	69
Novosibirsk Oblast	0.139	58	0.404	53	0.056	56
Omsk Oblast	0.128	63	0.435	33	0.056	57
Orenburg Oblast	0.120	66	0.333	75	0.040	73
Oryol Oblast	0.168	38	0.406	52	0.068	41
Penza Oblast	0.184	24	0.474	14	0.087	19
Perm Krai	0.119	67	0.410	49	0.049	64
Primorsky Krai	0.101	79	0.317	78	0.032	77
Pskov Oblast	0.104	77	0.390	56	0.041	71
Republic of Adygea	0.173	32	0.329	77	0.057	54
Altai Republic	0.148	51	0.294	80	0.043	68
Republic of Bashkortostan	0.138	59	0.377	61	0.052	63
Republic of Buryatia	0.111	75	0.350	68	0.039	75
Republic of Dagestan	0.275	8	0.539	4	0.148	8
Republic of Ingushetia	0.410	5	0.923	1	0.379	2
Republic of Kalmykia	0.181	27	0.456	24	0.083	23
Republic of Karelia	0.115	72	0.420	38	0.048	66
Komi Republic	0.147	52	0.419	39	0.062	48
Republic of Crimea	0.157	46	0.346	72	0.054	60
Mari El Republic	0.169	34	0.472	15	0.080	25
Republic of Mordovia	0.193	20	0.461	23	0.089	18
Republic of Sakha (Yakutia)	0.175	30	0.422	36	0.074	34
Republic of North Ossetia - Alania	0.244	10	0.492	9	0.120	10

Region	Incidence risk index	Rank	Mortality Risk Index	Rank	Total Risk Index	Rank
Republic of Tatarstan	0.213	14	0.518	7	0.110	12
Republic of Tyva	0.024	85	0.231	84	0.005	85
Republic of Khakassia	0.111	73	0.392	55	0.044	67
Rostov Oblast	0.173	33	0.443	28	0.077	31
Ryazan Oblast	0.195	19	0.447	26	0.087	20
Samara Oblast	0.147	53	0.450	25	0.066	43
Saratov Oblast	0.168	36	0.467	19	0.078	29
Sakhalin Oblast	0.110	76	0.279	82	0.031	80
Sverdlovsk Oblast	0.135	61	0.416	41	0.056	55
Smolensk Oblast	0.132	62	0.416	42	0.055	58
Stavropol Krai	0.201	17	0.423	35	0.085	22
Tambov Oblast	0.187	23	0.420	37	0.079	28
Tver Oblast	0.168	37	0.372	63	0.063	46
Tomsk Oblast	0.157	45	0.442	30	0.070	38
Tula Oblast	0.167	40	0.374	62	0.062	47
Tyumen Oblast	0.193	21	0.442	31	0.085	21
Udmurt Republic	0.148	50	0.369	64	0.055	59
Ulyanovsk Oblast	0.163	43	0.478	13	0.078	30
Khabarovsk Krai	0.101	78	0.349	70	0.035	76
Khanty-Mansi Autonomous Okrug - Yugra	0.341	7	0.537	6	0.183	5
Chelyabinsk Oblast	0.142	57	0.462	22	0.066	44
Chechen Republic	0.230	13	0.469	18	0.108	13
Chuvash Republic	0.168	39	0.472	16	0.079	26
Chukotka Autonomous Okrug	0.111	74	0.095	85	0.011	84
Yamalo-Nenets Autonomous Okrug	0.419	4	0.411	46	0.172	7
Yaroslavl Oblast	0.174	31	0.442	32	0.077	32

Source: Calculated by the authors.