THE MODELING OF THE ECOLOGICAL AND HEALTH SITUATION IN RUSSIA WITH USING INPUT-OUTPUT MODEL[1]

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Key words: the health situation in the Russia; risk factors; sickness rate regression analysis; forecasting the economic development with using a dynamic Input-Output Model of Russia

1. The health and demographic indicators in the Russia

The period of transition from command economy to market economy is characterized by serious enough health aggravation of the Russian citizens. The number of yearly registered people who fell ill with cancer for the first time increased by 75% during 1990 - 2007, the number of those who fell ill with diseases of the digestive apparatus increased by 22% and the number of those who fell ill with diseases of the circulatory system increased nearly as much as twice. The Figure 1 illustrates the common morbidity.

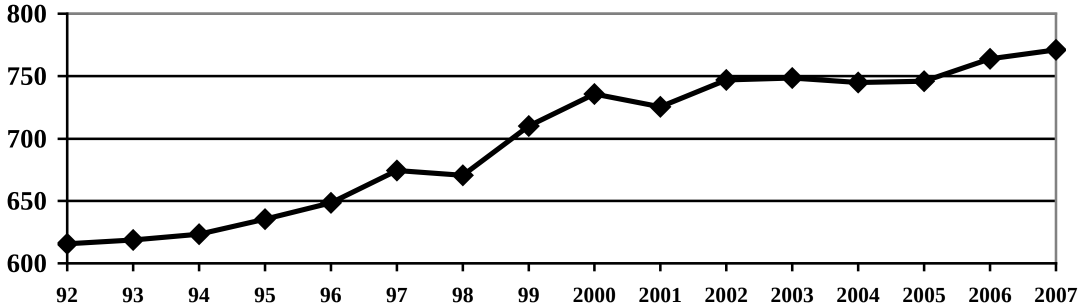

Fig.1. Morbidity in Russia (registered patients with the first diagnosed disease for every thousand people)

Quality of public health determines the dynamics of demographics of the Russians very much. The process of depopulation has been going in Russia since 1992. The major factors of the depopulation process are the decrease of the birth rate and the increase of mortality. Yearly birth rate decreased from 2,5 mln in 1987 to 2,0 mln in 1990, and to 1,61 mln in 2007. The number of the newly-born per 1000 people decreased from 13,4 in 1990 to to 11,3 in 2007. The level and dynamics of birth rate in Russia are relatively close to those in Europe, but the Russian model of mortality does not have any analogs in Europe, as the overall coefficient of mortality is constantly increasing: from 11,1 (in 1987) to 14,6 (in 2007) deaths per 1000 people.

Demographics define the negative dynamics of the expected life interval, which is an important characteristic of quality of public health. Life interval of the population of Russia was 67,5 years in 2007; men's life interval was 61,4 years and women's – 73,9. Men's life interval is on average 10 – 15 years less than that in the developed countries; women's life interval is 6 – 8 years less. Because of the differences of the mortality level the difference of life interval of men and women is 13 years, while in developed countries it is 7 years. Russia takes the 107th place in terms of the given rate. To overcome the present situation, it is necessary to turn back the negative tendencies of the birth rate and mortality,

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to lessen considerably the level of falling ill and to decrease influence of reasons that worsen health of the Russians.

2. The influence of various factors on the health condition of Russian citizens

Public health is formed and supported by a combination of living conditions. Concrete reasons causing aggravation of health are called risk factors. Risk factors parameters and intensity of their influence on the population's health were changed during the period of Russia's economic reforms.
Specialists single out the following risk factors that have had a negative influence on health of the Russians during recent 15 years: 1) economic (a low level of the salary and retired pay, worsening of conditions of life, labor, cure and recreation, change for the worse of structure and quality of feeding etc.); 2) psychological (excessive stress situations caused by socio-economic instability of the society and its high level of criminalization); 3) lowering of the general level of culture, including sanitary and hygienic culture, which provides spreading of bad habits and unhealthy way of life; 4) a low level of medical care and preventive health care; 5) worsening of environmental situation in the country.
Let us see in detail the last risk factor. Specialists of the World Health Organization believe that 20% of losing public health is connected with environment. This is an urgent problem for Russia, as its territory, especially industrial cities, is one of the most unfavorable in the world if state of environment is considered. According to the survey of modern Russian medical and ecological research shared contribution of environmental pollution to worsening the population's health in industrial cities and regions of Russia is from 30 – 50%, but according to some predictions it will be higher than 60%.
Environmental pollution has been decreasing since the early 1990's (Fig.2). However, this "improvement of the ecological situation" was going on because of a long term decrease of production volume of the national economy during 1990-1998, but not because of essential improvement of nature conservation and manufacturing technologies from the point of view of their influence on environmental quality. Though there is some decrease in yearly pollution (for example, decrease in water resources pollution), nature does not have time to neutralize pollution accumulated before and as a result there is increase of their general level.

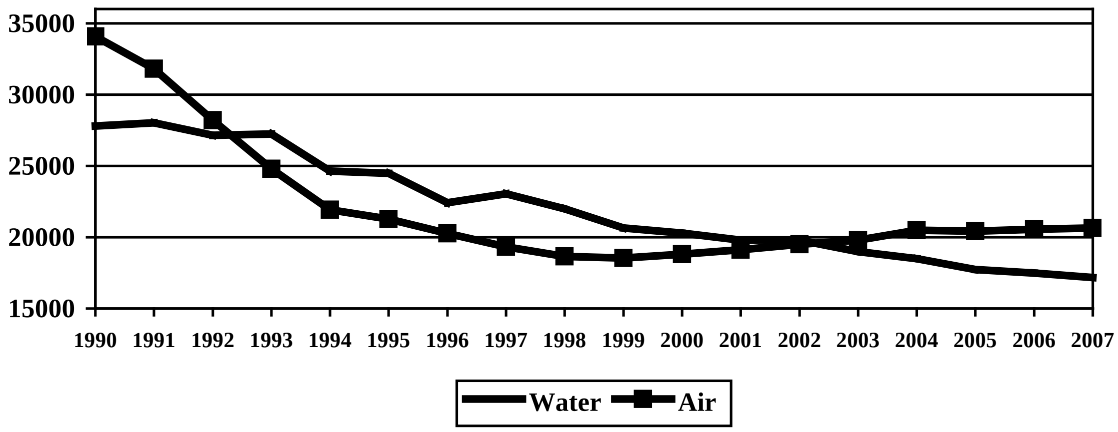

Fig.2. Volumes of waste water disposals (million cubic m) and emissions (thou tons) in Russia

Maximum concentration level of harmful substances are 5-10 times higher and more in the atmosphere of 125 Russian cities. According to the Russian State Committee on Statistics, only 15% of urban population live on the territories where air pollution does not exceed hygienic regulations. 1/5 of urban population live in ecologically harmful conditions; the cities where health control of environment is organized are spoken about here. A very hard situation with water supply of population emerges as a result of river and underground water pollution: clean water requirement in Russia covers only 50%. Slowdown of growth rate of air and water pollutant concentration in connection with decrease of the volume of polluted waste disposal and atmospheric emission is an absolutely positive fact. Considerable sources of contamination of the air is motor transport (11 mln tons in 1995 and 16,2 mln tons in 2007).

Children health rates have the most sensitive response to changes of environmental quality. Numerous data prove that a high children's sickness rate is registered in ecologically unfavorable areas, infant and children's mortality rate are higher (25% higher in comparison with safe areas), a more frequent non carrying of pregnancy is observed.

The level of unusual diseases, atypical clinical course of well-known diseases among children and "rejuvenation" of some diseases (ulcer diseases, pancreatic diabetes, essential hyportension, coronary heart disease, myocardial infarction and even cerebral stroke among children) also define ecological pathology.

Though it is accepted to believe in literature that the most important factors influencing health aggravation are social, we think that ecological factor is the main one among other risk factors influencing increase of sickness rate as it may influence all other factors. There is a great deal of toxic waste having a negative effect on the human body in the air, water and soil. There are about 200 of chemical compounds (carcinogenic multiring hydrocarbon, carbon dioxide, poison yellow lead etc.) in car exhaust fumes – the main air pollutants in cities. Radioactive substances are accumulated in troposphere because of testing nuclear weapon, nuclear reactor accidents and nuclear industry waste. Heavy metals, for example, mercury, lead, cadmium etc., polluting water and soil, not only cause diseases but influence chromosomal bond and educational abilities and memory. The following pollutants having ability to penetrate into all tissues and organs of a living organism and a human brain, cause the deepest nervous system disorders which lead to increase of mental diseases and suicides. Even if a person has a sound nervous system the organism has to mobilize its adaptive mechanisms when unfavorable ecological factors influence the nervous system for a long time. The reserves of adaptive mechanisms gradually become exhausted and adaptive mechanisms overstrain themselves and collapse prematurely. As a result, diseases and unhealthy conditions develop.

Data pointing at dependence of schizophrenia on different mental diseases, mental retardation, and dependence of social apathy on unfavorable environmental factors have considerably increased. These phenomena cause inability to adapt to dynamic economic conditions, to find a respectable place in economic life of the society and as a result it leads to a low standard of life of the population. It turns out that ecological factors influence psychological and economic risk factors of developing diseases.

There are also researches that prove dependence of ecological and cultural factors. For example, neuropsychic diseases, climatic conditions and unfavorable ecological factors cause decrease of the population's resistance to alcohol which influences falling ill with alcoholism more than per capita consumption of alcoholic drinks.

3. Sickness rate regression analysis

In order to explain the dynamics of sickness rate of the Russian population we carried out a multi-factor analysis of indices that characterize the health condition of the Russian population depending on climatic, infrastructural, social, economic, and ecological factors (Table 1). For this purpose, an information base for 2007, for which statistical information was available at the time of research (the year nearest to the forecasting period (2007 – 2012) was taken), was constructed. It included 80 subjects of the Russian Federation (oblasts, regions, and republics).

The following indices characterizing the health condition of the population were chosen: death rate (including infantile) and birth rate (the number of dead and sick per one thousand people), life expectancy, general sickness rate, and morbidity per type of diseases (the number of the sick with the diagnosis registered for the first time per one thousand people). The following kinds of diseases were studied: new growths, endocrinous, immunity and nutrition disorders, metabolic disturbances; infectious and parasitic diseases; diseases of blood circulation and hematopoietic organs; diseases of respiratory and digestive organs; skin and hypodermic tissue diseases; diseases of bone, muscular and connective tissues; and diseases of the nervous system.

As it can be seen in Table 2, in the course of regression analysis we managed to receive a statistically meaningful regression equation that satisfies all the premises of regression analysis and gives an explanation of the 28.5% difference in sickness rate between regions. The relatively low value of determination coefficient can be explained by the fact that the index "sickness rate of total population" takes into account the registered cases of diseases in the whole spectrum of illnesses, each of them having their own specificity and causes.

Table 1

List of sickness rate explanatory factors

Group of factors	Factor
Climatic	Average air temperature in July, degrees C Average air temperature in January, degrees C Difference between average temperatures in July and January Average temperature in July and January Average precipitation in July, mm Average precipitation in January, mm Average monthly precipitation in July and January, mm
Infrastructural	Average number of hospital beds per 1000 people (by year end) Number of doctors per 1,000 people (by year end, number of persons)
Social	The share of expenditures on alcoholic drinks in consumers' expenditure The ratio of expenditures on alcoholic drinks to subsistence level, % Voluntary infliction of hard health harm, number of registered crimes per 10,000 Crimes connected with illegal drug circulation, number of registered crimes per 10,000 Unemployment rate Share of urban population
Economic	Share of health care expenditures in consumer expenditures, per cent[2] The ratio of average per capita incomes to subsistence level, per cent Ratio of health care expenditures to subsistence level, per cent Average per capita income
Ecological	Average per capita disposal of contaminated waste waters, cubic meters per person Average per capita atmospheric emissions (with account of motor transport), kg per person Average per capita emission of greenhouse gases (with account of motor transport), kg per person

Nevertheless, due to the analysis it was possible to identify the strongest factors that have a statistically important influence on the sickness rate of the population as a whole[3]. The sickness rate of the population as a whole increases in case average per capita atmospheric emissions grow. Thus it is possible to speak about a statistically significant negative influence of environmental pollution on

[2] Strictly speaking, there are both direct and reverse connections between the sickness rate of the population and the share of health care expenditures in total consumer expenditures. However, for the purpose of analysis we consider it justifiable to use the index of the share of health care expenditures in total consumer spendings as an explanatory variable because the growth of health care expenditures to a greater extent leads to an increase in revealing latent diseases due to the fact that there are more cases of turning for medical help, greater availability of medical equipment, and supply of medical personnel in health centers.

[3] Here and later the level of reliability of statistical significance is considered to be 90%.

health condition. It is interesting to note that the sickness rate of the Russian population demonstrates a statistically significant decrease under the growth of average summer air temperature and the growth of unemployment rate. The first fact is explained rather easily – the warmer the climate, the more there are fruit and vegetables and the more there are sunny days in a year and the less the difference between summer and winter temperatures. The second one can be explained by the fact that under a high unemployment rate, the number of cases of people turning to medical establishments decreases as there is no need in getting medical certificates and the sick prefer self-treatment at home. Moreover, the analysis of particular illnesses as well as such factors as life expectancy and mortality rate of the population proves the positive influence of unemployment on the health of the population. Consequently, this fact cannot be explained only by the frequency of medical aid appealability. Apparently, with the growth of unemployment people spend less time in places of mass gatherings of people and take more rest, but there is another very important explanation. Unlike many other countries, less expensive food is, as a rule, healthier (food grown in small private holdings, local products without various additives, etc.). That is why unemployed people who lose their incomes have to eat cheaper and, as a result, healthier food. The latter also confirms the fact that in the course of investigation on a wide range of diseases there has not been identified any statistically significant effect of the population income level on sickness rate.

Table 2

Equation of sickness rate of the whole population of the Russian Federation (the number of registered cases per 1,000 people)

No	Variable	Measurement unit	Coefficient	Standard error	Validity level
1	Constant		1052.4	97.9	99.9
2	Average per capita atmospheric emissions	Kg/person	0.153	0.07	96.8%
3	Average air temperature in July	C	-14.68	4.95	99.6
4	Unemployment rate	%	-4.41	1.89	97.8%
R^2 = 28.5%, reliability level 99.9%. Normality of residual distribution 99.9%					

The most widespread type of diseases in Russia is the diseases of respiratory organs (39.9% of the total number of registered illnesses in 2007). Meanwhile it is considered that it is primarily the respiratory organs that are negatively affected by the emission of greenhouse gases, which is supported by the results of the conducted analysis (see Table 3).

In table 3 it can be seen that the sickness rate of the population of Russia suffering from respiratory diseases shows statistically meaningful growth with the increase of average per capita emission of greenhouse gases, the growth of the number of hospital beds, and the size of urban population and decreases with the increase of unemployment level (the determination coefficient of the equation is equal to 46.9%). Therefore, the increase of greenhouse gases emission negatively affects the population health increasing the number of respiratory organs diseases. The influence of unemployment rate was studied above; as regards the dependence of the growth in respiratory diseases on the increase on the number of hospital beds and the share of urban population, it can be explained by the ease of transmitting this kind of diseases from person to person, which takes place with the increase of the number of people gathering in one place.

Table 3

Equation of respiratory organs sickness rate of the population of the Russian Federation in 2007 (number of registered cases per 1,000 people)

No	Variable	Measurement unit	Coefficient	Standard error	Validity level
1	Constant		92.6	51.3	92.5%
2	Average per capita emission of greenhouse gases	Kg/person	0,097	0,052	93,2%
3	Average number of hospital beds by year end	beds per 1000 people	8.568	2.367	99.9%
4	Share of urban population	%	1,53	0,541	99,4%
5	Unemployment rate	%	-1,77	0,95	93,4%
R^2 = 46.9%, reliability level 99.9%. Normality of residual distribution 99.9%					

4. Forecasting the economic development of the Russian Federation by the year 2012

The next stage of our research was concerned with constructing the forecast of ecological-economic development of the Russian Federation for 2008 -2012. For forecasting KAMIN System was used – a Dynamic Intersectoral Model of Russia with a block of environmental protection, witch has been created in the Intersectoral Research Department (Institute of Economy and Industrial Organization in Novosibirsk). The ecological model's block considers two environmental protection activities: atmospheric air cleaning and sewage treatment. This model apparatus allows to forecast the level of pollution formation in the sphere of production depending on the economical development of Russia using coefficients of atmosphere and water-polluting substances formation per unit of gross production output. With using estimates of the expenditures on the reduction of water and air pollution the model model complex allows to determine volumes of sewage purification and volumes of pollution trapping. The difference between formation and pollution trapping gives us the volumes of waste water disposals and volumes of emissions (for a more detailed description of models see [1]).

Two scenarios of the forecast were based on the following basic assumptions.

1. The dynamics of macroeconomic and sectoral indices in 2008 corresponded to the reporting data of the Federal Statistical Service of the Russian Federation
2. The dynamics of macroeconomic and sectoral indices in 2009 were estimated with the help of reporting information of the Federal Statistical Service of the Russian Federation for four months of 2009. It was assumed that annual dynamics would not differ greatly from growth rates in the first quarter of 2009.
3. Both variants of the forecast proceed from the assumption that after 2009 there will be no explosive industrial .recovery.

The first scenariot of the forecast was constructed on the basis on the following assumptions.

A. In 2010 the economy would start to emerge gradually from the crisis. In these conditions, demand for Russian exported good would grow, which would stimulate economic growth in Russia.

B. Measures taken to stabilize the Russian financial system would give noticeable results in 2010 that would result in increased crediting of business and population, which, in its turn, would lead to a gradual increase of economic growth rates.

Both factors mentioned above would be partly manifest in 2010, which would lead to a slight growth of GDP by 2% and the growth of gross output by approximately 1% (Table 4).

According to our estimates, under this variant, the year 2011 would be a period of transition from the state of crisis to economic growth. Production growth rates in 2011 would be higher than in 2010 but lower than those corresponding to the development path of the Russian economy in 2000 -2007; GDP would account for 5.4% and gross output would reach 4%. Under this variant of the forecast, the Russian economy would enter the path of economic growth similar to the one of 2000-2007 only in 2012 when the increase of gross output would reach 7% and GDP 8.4%.

In accordance with the first scenario, investments into fixed capital in 2010 would stay at the level of 2009 and only in 2011 their growth would be revived (the growth rate would l be 10%). Later, in 2012, investment activity would grow and the growth rate of investments into fixed capital would be equal to approximately 15%. Such dynamics of investments into fixed capital is explained by a very important objective reason: the depreciation of fixed capital in the Russian economy remains high, which inevitably requires renewal of high investment activity.

As regards industrial development, according to the first scenario most industries (13 and 22) would not restore their production by 2012. The crisis would most negatively affect (it was already felt in the end of 2008 – the first half of 2009) ferrous and non-ferrous metallurgy and building materials industry. Under this scenario, the economic recovery, which will start in 2010, would not lead to a recovery of production output by the end of the forecasting period, nor to reaching 3/4th of the production output of 2008.

Table 4

Growth rates of GDP, gross output, and investments[4] in 2008-2012, %

	2008	2009	2010	2011	2012	2012/2007
The first scenario						
GDP	105,6%	93,3%	102,0%	105,4%	108,4%	114,8%
Gross output	104,2%	87,1%	100,7%	104,0%	107,0%	101,7%
Investments	109,1%	85,0%	100,0%	110,0%	115,0%	117,3%
The second scenario						
GDP	105,6%	95,3%	104,3%	108,2%	108,4%	123,2%
Gross output	104,2%	94,1%	103,0%	107,0%	107,0%	115,5%
Investments	109,1%	85,0%	105,4%	115,0%	115,0%	129,3%

The second scenario is based on the assumption that there the slump of production in 2009 would not be so great. Estimates for this variant were based on the following assumptions.

A. Measures taken to stabilize world economy would be starting to bring positive results by the end of 2009 already.

B. Beginning with 2010, there would be economic recovery in the USA, European Union and Japan; there would be greater economic growth in China and other key countries of the world economy. This would lead to an increase of demand for traditionally exported Russian goods and would stimulate a noticeable production recovery in Russia by 2010 already. World economic growth would also encourage the stabilization of the Russian banking system, which would get an opportunity to attract financial resources from abroad.

According to our estimates, for reasons listed above within the framework of the second scenario, in 2010, the recovery of the economy would be more intensive than under the first scenario: gross output would grow by 3%, GDP by 4.3%, and investments into fixed capital would grow by more than 5%.

[4] Note: the estimated growth rates for 2008-2009 took into account reporting data of Federal Statistical Service of RF for 2008 and four months of 2009.

Beginning with the year 2011, the growth rate of investments into fixed capital would increase by 15% annually, which is explained by the need for a more rapid renovation of fixed capital in many branches of the national economy.
Results of the estimates on both scenarios lead us to a conclusion that for a great number of branches of the Russian economy the emergence from the crisis will be rather protracted.
Under the second scenario, five branches would experience negative growth rates of gross output during the whole period: gas industry, ferrous and non-ferrous metallurgy, chemical and petrochemical industries, and the construction materials industry. At the same time, in all probability, high rates of growth could be expected in fund-generating branches (mechanical engineering and construction), trade, and non-material service production.

5. Forecasting ecological development and its influence on the health condition of the Russian population

In the previous section of the article we described the principal hypotheses for the development of different branches of the Russian economy that make it possible to carry out a forecast of gross output volumes in industrial branches and national economy as a whole using KAMIN System. The results of forecasting estimates make it possible to assess the amount of emission of polluting substances into the atmosphere and the amounts of discharge of polluted waste waters into water reservoirs (see Figs. 3 and 4). The ecological block estimates were based on the hypothesis that unit rates of pollution as well as indices of sewage treatment and recovery of main pollutants of the atmosphere will stay at the level of 2007.

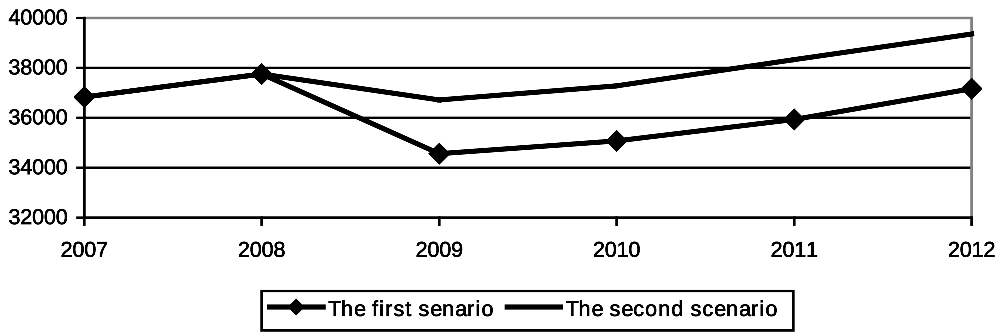

Fig. 3. Amount of emission polluting the atmosphere (thousand tons) according to results of forecasting estimates

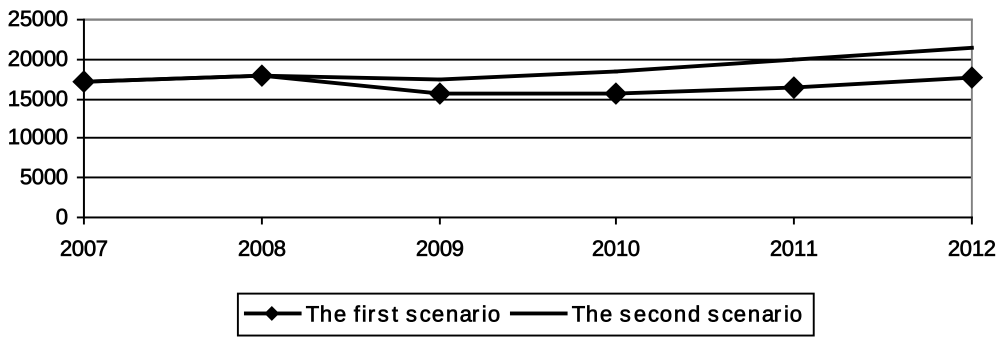

Fig. 4. Amount of waste water discharge (mln. cubic meters) according to results of forecasting estimates

Having studied the most interesting results received during the econometric analysis of sickness rate of the Russian population and having received estimates of the amounts of pollution for the forecasting period, let us now evaluate the effect of the ecological factors on the condition of health of the population of Russia in 2008-2012. For this purpose we will use the regression equation that will model the sickness rate of the Russian population as a whole (Table 2) and construct an interval estimate of the contribution of environmental pollution to the population sickness rate.

The estimated value of the coefficient under the variable "Average per capita atmospheric emission" accounts for 0.153 and its standard error is equal to 0.07. It means that the increase of per capita emissions of atmospheric gases per one kg will lead to the growth of sickness rate of the Russian population by 0.0363 to 0.269 of all the registered cases per one thousand people under the confidence probability of 90%. Taking into account the estimate of atmospheric emission dynamics received for 2008-2012, let us evaluate a change in the population sickness rate during this period under the influence of the ecological factors taking the population size of Russia, in the period under review, as unchanged (see Table 5).

Table 5

Dynamics of average per capita atmospheric emission and the number of "freshly" sick in the population of Russia in 2008-2012

	2008	2009	2010	2011	2012
The first variant					
The increase of average per capita atmospheric emission (kg per person in comparison with previous year)	+6,5	-22,5	+3,6	+6,0	+8,6
The growth in the numbers of "freshly" sick by ecological reason (thousand people in comparison with previous year)					
in average	141,0	-488,0	78,1	130,1	186,5
low limit	33,5	-116,0	18,6	30,9	44,3
high limit	248,5	-860,1	137,6	229,4	328,7
The second variant					
The increase of average per capita atmospheric emission (kg per person in comparison with previous year)	+6,5	-7,3	+4	+7,4	+7,2
The growth in the numbers of "freshly" sick by ecological reason (thousand people in comparison with previous year)					
in average	141,0	-158,3	86,8	160,5	156,2
low limit	33,5	-37,6	20,6	38,1	37,1
high limit	248,5	-279,0	152,9	282,9	275,2

Thus, under the first scenario, it is forecast that between the years 2008-2012 the atmospheric emissions in Russia are expected to grow on average to 2.2 kg. per capita, which might lead to the growth in the numbers of "freshly" sick from 11,3 to 84,1 thousand people. As the second scenario presupposes a higher economic growth rate in the forecasting period and, consequently, a greater pressure on the environment (the increase of average per capita atmospheric emission would account for 17,8 kg per person in the forecasting period in general), "the ecological contribution" to the population sickness rate would be more considerable – from 91,7 to 680,5 thousand people.

Research results stated in the article, unlike other investigations in this area, give a numerical estimate of the influence of various factors on the health condition of the Russian population and present a forecast of the effect of ecological factors on total sickness rate. The set of dynamic intersectoral models used in the forecast makes it possible to take into account the influence of structural biases in the Russian economy, which occurred as a result of the world economic crisis, on the ecological situation and the number of "freshly" sick. The proposed approach combines the application of the advantages of intersectoral modeling methods and econometric methods for the purpose of analyzing and forecasting ecological-economic processes.

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Summary.

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The Modeling of the Ecological and Health Situation in Russia with Using Input-Output Model.
In recent years, socio-economic instability and unfavorable ecological situation in Russia have had a marked adverse effect on the health condition of the population. The article analyzes particular reasons, or risk factors, that cause the deterioration of public health. Most attention is paid to the ecological factor. In spite of the reduction of the amount of annual emissions of substances polluting the atmosphere and dumping polluted waste waters, nature cannot neutralize the pollutants accumulated earlier. As a result, it is observed that the maximum permissible concentration of harmful substances in the atmosphere and water reservoirs in practically all the cities of Russia is exceeded.
The present research attempts to give not only analytical but also quantitative assessment of the influence of various factors (with the help of regression analysis), primarily the ecological one, on the health condition of Russian citizens. With the help of a simulating KAMIN System instrument, a forecast for the ecological-economic development of the Russian Federation by the year 2012 was made. Using the results of the forecast the influence of the ecological factor on the sickness rate was estimated.