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Modeling Health Risk Factors in Russia Using Input-Output and Econometric Approaches

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***Abstract*. The article analyzes particular reasons (risk factors) that cause the deterioration of public health. Much attention is paid to the ecological factor. The maximum permissible concentration of harmful substances in the atmosphere and water reservoirs is exceeded in practically all the cities in Russia. [1]**

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) on the health condition of Russian citizens. With the help of a CAIIN [2] model complex, a forecast for the ecological-economic development of the Russian Federation by the year 2015 has been made. The forecast helped to estimate the influence of the ecological factor on the sickness rate.

***Keywords*: health risk factors, a forecast for the Russian ecological-economic development, regression analysis of morbidity.**

I. The Health and Ecological Situation in Russia

The period of transition from a command economy to a market economy is characterized by a severe health aggravation of Russian citizens. The yearly registered number of people who fell ill with cancer for the first time increased by 86% from 1990 to 2009; the number of those who fell ill with diseases of the digestive system increased by 22%, and the number of those who fell ill with diseases of the circulatory system increased nearly as much as twice. Fig. 1 illustrates the morbidity situation in Russia (all types of sicknesses).[3]

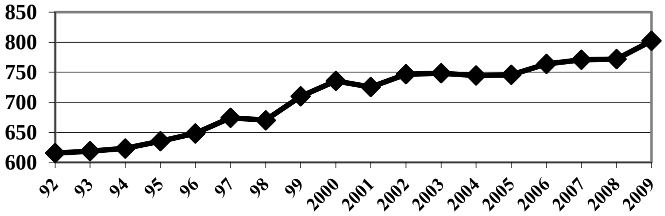

Fig.1. Morbidity in Russia (patients whose disease was diagnosed for the first time, for every thousand people).

The quality of public health determines the dynamics of demography of the Russians to a large extent. The process of depopulation has been going on in Russia since 1992 (Fig. 2). The major factors of depopulation are the decrease of birthrate and the increase of mortality. Yearly the number of births decreased from 2.5 mljn. in 1987 to 2.0 mln. in 1990, and to 1.76 mln. in 2009. The number of the newborns per 1,000 people decreased from 13.4 in 1990 to 12.4 in 2009.

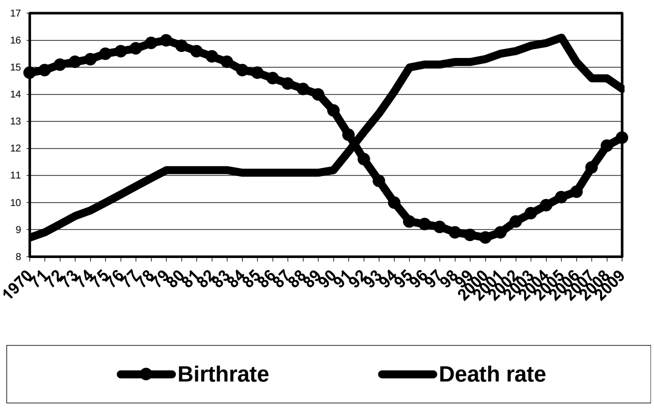

Fig.2. The coefficients of birthrate and mortality (per 1,000 people).

The level and dynamics of birthrate 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. The demographic situation determines the negative dynamics of the expected lifespan which is an important characteristic of public health quality. Life expectancy of the population in Russia was 68.7 years in 2009; men's lifespan was 62.8 years and women's, 74.7. This rate of lifetime decrease is unprecedented during peacetime, especially as the general tendency in the civilized world is lifetime growth.

On average, men's lifespan is 10 – 15 years less than that in the developed countries; women's lifespan is 6 – 8 years less. Russia takes the 107th place in the world in terms of life expectancy. To overcome the present situation, it is necessary to turn back the negative tendencies of the birth rate and mortality, to considerably lessen the level of falling ill and to

[1] The investigation is fulfilled in the network of project IX.84.1.3 (Institute Economics IE SB RAS)

[2] CAIIN – Comprehensive Analysis of Intersectoral INformation, created in the Intersectoral Research Department of the Institute of Economics and Industrial Engineering SB RAS (Novosibirsk, Russia)

[3] Statistical data, which is analyzed in this article, is taken from statistical handbooks [1-5].

decrease the influence of reasons that worsen health of the Russians. According to preliminary information, the so-called "demographic cross over Russia" will seize its existence in the nearest future when the birth rate will be higher than mortality. This will influence an unimportant growth of life interval. Public health is formed and supported by a combination of living conditions. The particular reasons that cause aggravation of health are called risk factors. Risk factor parameters and the intensity of their influence on the population's health changed during the period of Russia's economic reforms. Specialists single out the following risk factors that have had a negative influence on the health of Russians in the last 15 years: 1) economic (the low level of salary and retirement payment, worsening of conditions of life and of labor, worse structure and quality of food etc.); 2) psychological (excessive stress situations caused by the socio-economic instability of the society and its high level of criminalization); 3) cultural (the fall of the general level of culture, including sanitary and hygienic culture, which contributes to bad habits and an unhealthy way of life); 4) medico-infrastructural (quality and quantity of medical service, a low level of medical care and preventive health care); 5) genetic (parents' health); 6) climatic and ecological (worsening of climate and of the environmental situation in the country).

Specialists of the World Health Organization believe that 20% of public health deterioration is due to the bad environmental situation. This is an urgent problem for Russia as its territory, especially industrial cities, ecologically is one of the most unfavorable in the world. According to the survey based on modern Russian medical and ecological research, shared contribution of environmental pollution to worsening the population's health in Russian industrial cities and regions of Russia is from 30 to 50%, while according to some other predictions it is higher than 60%.

Environmental pollution has been decreasing since the early 1990s: spillover of sewage into water bod ies was 27.8 bln. m^3 in 1990 and 15.9 bln. m^3 in 2009. The volume of emission was 34 mln. tons and 19.0 mln. tons respectively during those years (Fig. 3). However, this "improvement of the ecological situation" was going on because of a long-

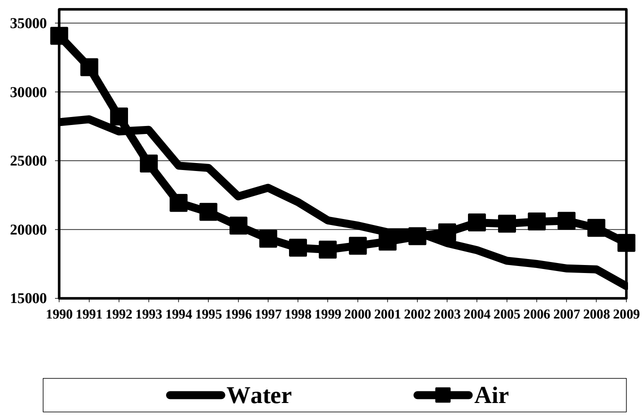

Fig.3. Volumes of waste water disposals (million cubic m) and emissions from stationary resources (thousand tons) in Russia.

term decrease of production volume of the national economy from 1990 to1998, but not because of essential improvement of nature conservation and manufacturing technologies (from the point of view of their influence on environmental quality).

We can see a close correlation between stationary pollution and growth of GDP (see Fig.4), which also illustrates inalterability of production technologies.

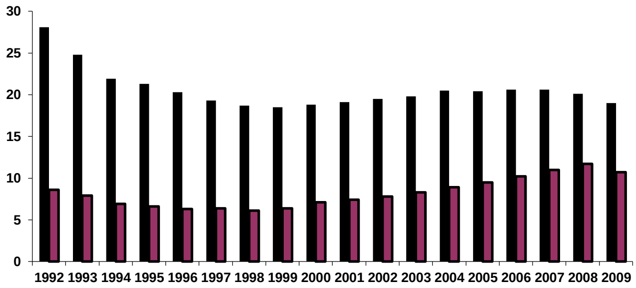

Fig.4. Pollution – mln tons, GDP – bln (before 1998 – trillion, price of 2000).

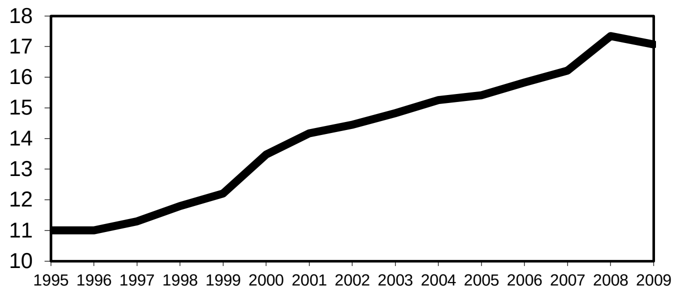

Fig.5. Motor vehicle emission of polluting substances into atmosphere (mln tons)

Though there is some decrease in yearly pollution (for example, decrease in water resources pollution), nature does not have time to neutralize the pollution accumulated before and as a result there is an increase of its total level. Pollution concentration is higher than the maximum permitted pollution concentration in 210 cities (46 % of Russian population). 20% of urban population lives in ecologically harmful conditions. A considerable source of contamination of the air is motor vehicle (Fig.5). There is also considerable contamination of water resources: the clean water requirement in Russia is satisfied only by 50%.

Children's health is affected by the changes of environmental quality most strongly. According to numerous data, a high children's sickness rate is registered in ecologically unfavorable areas; infants' and children's mortality rates are extremely high (25% higher than in safe areas); more frequent miscarriages take place. There are quite many signs of ecological "pathology", such as the growing number of rare diseases that children can contract or atypical clinical course of common diseases. Moreover, young people and even children start coming down with stomach ulcer, pancreatic diabetes, hypertension, heart disease and even cerebral hemorrhage.

Though many researchers believe that the most important factors causing health aggravation are social, we think that the main risk factor causing sickness rate growth is the ecological factor, for it may influence all other factors. There is a great deal of toxic waste in the air, water and soil, which has a negative effect on a human body. There are about 200 of chemical compounds (carcinogenic hydrocarbon, carbon dioxide, poisonous yellow lead etc.) in automobile exhaust fumes – the main air pollutants in cities. Radioactive substances are accumulated in troposphere as a result of nuclear weapon tests, nuclear reactor accidents and nuclear industry waste. Heavy metals such as mercury, lead, cadmium and others, which pollute water and soil, not only cause diseases but also influence the chromosomal bond as well as educational abilities and memory. Since these pollutants are able to penetrate into all tissues and organs of a living organism and human brain, they cause violent disorders of the central nervous system, which lead to the growing number of mental diseases and suicides. Even if a person has a sound central nervous system, the organism has to mobilize its adaptive mechanisms when unfavorable ecological factors have been in action for a long time. The reserves of adaptive mechanisms gradually become exhausted, they overstrain themselves and collapse prematurely. As a result, diseases and unhealthy conditions develop.

There is a growing amount of showing dependence of schizophrenia, different mental diseases, mental retardation, and social apathy on unfavorable environmental factors. These phenomena cause inability to adapt to dynamic economic conditions, to find a respectable place in the economic life of the society; as a result, this leads to a low standard of life of the population. Ecological factors turn out to give rise to psychological and economic risk factors.

Some researchers also prove interdependence of ecological and cultural factors. For example, neuropsychic disorders, climatic conditions and unfavorable ecological factors cause a decrease of the population's resistance to alcohol which causes alcoholism greater than per capita consumption of alcohol.

II. Regression Analysis of Morbidity

In order to study the dynamics of the sickness rate of the Russian population, we carried out a multi-factor analysis of indices that characterize health problems of the Russian population depending on climatic, infrastructural, social, economic, and ecological factors. For this purpose, an information base for the years 2005-2008 was constructed. It included 80 subjects of the Russian Federation (oblasts, regions, and republics).

Here is the list of sickness rate explanatory factors:

- *Climatic:* difference between average temperatures in July and January (degrees C), average monthly precipitation in July and January (mm);
- *Medico-infrastructural*: an average number of hospital beds per 1000 people (by the year's end), number of doctors per 1,000 people (by the year's end), capacities of polyclinics (sick people' attendance at a polyclinic per shift), the state's expenditure on healthcare in the budget (%), expenditure on healthcare per capita (rubles in 2005);
- *Social:* a expenditure on alcoholic drinks in consumers' expenditure (%), level of criminalization (number of registered crimes per 10,000);
- *Economic:* GDP per capita (rubles), a health care expenditure in consumer expenditure (%), the ratio of an average per capita income to the subsistence level (%), ratio of health care expenditure to the subsistence level (%), a share (%) of poor population (people, whose income is less than the subsistence level) in the total amount of population;
- *Ecological:* average per capita disposal of contaminated waste waters (cubic meters per person), average per capita atmospheric emissions (kg per person), average per capita emission of greenhouse gases (kg per person).

To characterize the health of the population the following indices have been taken into account: death rate (including infant mortality rate) and birthrate, life expectancy, general sickness rate, and morbidity per type of disease (the number of the sick whose diagnosis was registered for the first time, per 1,000 people). The following kinds of diseases were studied: new growths, endocrines, immunity and nutrition disorders, metabolic disturbances; infectious and parasitic diseases; diseases of blood circulatory system; diseases of the respiratory and digestive system; skin and hypodermic tissue diseases; diseases of bone, muscular and connective tissues; and diseases of the central nervous system. All the data has been taken from statistical reports of the Federal Statistical Service of the Russian Federation.

The panel regressions have been constructed. The characteristics of equation, which describes sickness rate of the whole population of the Russian Federation, is presented in Table I.

TABLE I

EQUATION OF SICKNESS RATE OF THE WHOLE POPULATION OF THE RUSSIAN FEDERATION THE NUMBER OF REGISTERED CASES PER 1,000 PEOPLE)

N.	Variable	Measure-ment unit	Coeffi-cient	Stan-dard 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%					

As shown in Table1, in the course of regression analysis we managed to receive a statistically meaningful regression equation that satisfies all the premises of regression analysis and explains of the 28.5% difference in sickness rate between regions. A relatively low value of determination coefficient is due to 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.

Nevertheless, the analysis made it possible to identify the major factors that have a statistically important influence on the sickness rate of the population as a whole 4. The sickness rate of the population as a whole increases in case the average per capita atmospheric emissions grow as well as when the average air temperature in July falls and the unemployment rate decreases. Thus it is possible to speak about a statistically significant negative influence of environmental pollution on health.

Interestingly enough, the sickness rate of the Russian population demonstrates a statistically significant decrease in the case of growth of average summer air temperature and growth of unemployment rate. The first fact is explained rather easily – the warmer the weather, the more sunny days, the less the difference between summer and winter temperatures, the more fruit and vegetables and the healthier the people. As far as unemployment is concerned, under its high rate the number of people who come to medical establishments decreases since the unemployed don't need a sick-leave certificate; usually the working people who are sick prefer self-treatment without going to a doctor because they are afraid to lose their job.

III. Forecasting the Ecologo-economic Development of the Russian Federation till the Year 2015

The next stage of our research was concerned with constructing a forecast of ecological-economic development of the Russian Federation for 2011 - 2015. To do this the CAIIN (Comprehensive Analysis of Intersectoral Information) System with an environmental unit was used. The CAIIN was developed by an Interindustry research department at the Institute of Economics and Industrial Engineering of the Siberian Branch of the Russian Academy of Sciences under the guidance of Professor V. N. Pavlov. Figure 6 presents a brief diagram of a variant of the CAIIN system, functioning with an environmental protection block (EP block).

In addition to *n* traditional sectors of the economy, *l* elements, which represent natural resources, are allocated here, and one-to-one correspondence is expected between each of these elements and the areas of environmental protection (air protection, water conservation, etc.). At this stage, one natural resource is studied — atmospheric air – is studied. For the environmental activity, the reproduction processes of the main environmental funds and the formation of environmental costs are modeled into the DIOM (Dynamic Input-Output Model). The EP block describes the tangible indicators of ecological processes. Depending on the volume of manufactured goods in the traditional sectors of economy (*Xj*), the volume of pollutants generated during the production process is determined. Thus, this model system allows us to forecast the level of pollution formation in the industrial production depending on the economic development of Russia, with the help of coefficients of formation of atmosphere polluting substances per unit of gross production output. The estimates of the expenditures for reducing water and air pollution help to determine volumes of pollution trapping. The difference between formation and pollution trapping gives us volumes of Fig.6. A brief diagram of the CAIIN system with an EP block.

This is a description of the EP block: emissions.

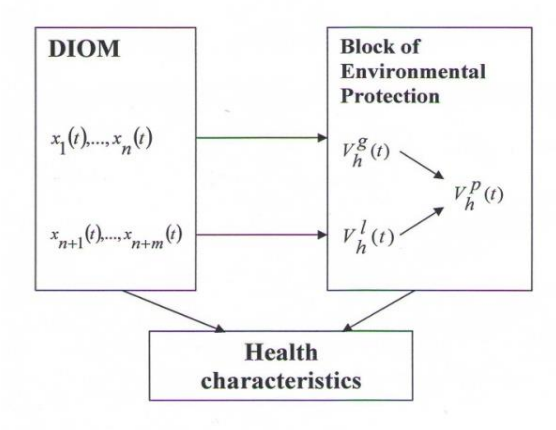

Fig.6. A brief diagram of the CAIIN system with an EP block

This is a description of the EP block:

$x(t) = (x_1(t),..., x_n(t), x_{n+1}(t),..., x_{n+m}(t))$ – vector of gross outputs, where

$x_i(t), i = 1,..., n$ - gross output of industry i in year t,

$x_{n+h}(t)$, $h = 1, ..., m$ - current environmental protection cost for natural resource h;

$$V_h^g(t) = \sum_{i=1}^{n} w_{ih}(t) x_i(t) + D_h(t)$$

- volume of pollutants generated in the production process,

where w_{ih} – coefficient of pollutant h generation (volume of polluted natural resource h, referring to manufacturing of a unit of production of industry i);

$D_h(t)$ - output of pollutant h (volume of pollution or destruction of a natural resource) in a household;

$$x_{n+h}(t) = \sum_{i=1}^{n} v_{ih}(t) V_{ih}^l(t)$$

where $v_{ih}(t)$ – current cost to recover a unit of natural resource h (to destroy or to trap a unit of pollutant h) in industry i;

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

$V_h^l(t)$ - volume of a recovered natural resource (liquidated or trapped pollutant) of type *h;*

$$V_h^l(t) = \sum_{i=1}^{n} V_{ih}^l(t),$$

$$V_h^p(t) = V_h^g(t) - V_h^l(t)$$

- volume of pollutant *h* (a polluted natural resource), which gets into the natural environment without purification (or by volume of destroyed but not reproduced natural resource).

A more detailed description of economic and ecological units of the model complex and of the method initial information is formed appears in [6, 7]. Tables II-IV show indexes of two scenarios of Russian development in 2011-2015, which were worked out for forecast calculations: one is pessimistic and the other, optimistic. In both scenarios we assume that the government support of national economy will not be reduced, and the economic policy will be mild till elections in several large countries (USA, Russian Federation, France, etc.). Key factors which will influence Russian domestic markets are the Presidential election in 2012, Russia's possible joining the WTO in 2011, and Olympic Games in Sochi in 2014. In both scenarios we assume that the Russian government will adopt an active anti-inflationary policy, using administrative and anti-trust measures till the elections.

TABLE II
KEY FACTORS OF NATIONAL ECONOMY IN RUSSIA IN 2011-2015

Factors	2011	2012	2013	2014	2015
Pessimistic scenario					
Real interest rate (in %)	+2	+4	+5	+6	+7
Change in real wages (in %)	+5	+6	+2	+1	0
Change in real exchange rate RBL/USD (in %)	+15	+12	-10	-5	0
Urals price (in USD per barrel)	110	100	80	70	60
Change in GDP (in %)	+3,4	+3,4	+3,4	+2,4	+1,4
Change in gross output (in %)	+2,4	+2,4	+2,4	+1,1	+0,2
Optimistic scenario					
Real interest rate (in %)	-2	-3	4	4	4
Change in real wages (in %)	+9	+12	+7	+7	+8
Change in real exchange rate RBL/USD (in %)	+15	+12	+8	+5	+2
Urals price (in USD per barrel)	110	125	130	140	150
Change in GDP (in %)	+7,9	+9,7	+6,0	+6,2	+6,7
Change in gross output (in %)	+6,7	+8,3	+4,0	+5,3	+6,0

The pessimistic scenario assumes that the post-crisis recovery in 2010-2011 will not be steady, and growing government debts will lead national government to implementing strict budget economy.

The optimistic scenario assumes that efforts of national administrations to avoid economic stagnation and to solve their debt problems will be effective. High oil prices on the world market will allow the Russian government to increase state productive and social spending.

The dynamics of key indicators that will affect Russian economy in 2011-2015 are shown in Table II. More detailed hypotheses of scenarios are described in [8].

TABLE III
INDUSTRY OUTPUTS IN 2011-2015
ACCORDING TO THE PESSIMISTIC SCENARIO (GROWTH RATE, %)

Industry	2011	2012	2013	2014	2015
Power engineering	98,9	98,6	101,3	100,2	99,2
Fuel industry	101,8	101,8	101,3	101,2	101,0
Ferrous metallurgy	95,6	95,7	102,8	100,6	98,4
Non- ferrous metallurgy	100,5	100,1	100,7	99,3	97,9
Chemical and petrochemical industry	93,6	93,6	103,9	101,6	99,2
Machine-building and metal-working industry	106,8	106,7	109,2	105,6	101,9
Logging, wood-working, pulp and paper industry	94,5	94,5	99,0	95,7	92,5
Building materials industry	96,5	97,0	98,0	94,4	90,9
Light industry	100,4	101,0	103,7	101,4	99,1
Food industry	99,6	100,2	100,7	99,7	98,7
Other industries	94,0	93,9	98,4	95,5	92,7
Construction	105,4	104,8	100,3	98,8	97,4
Agriculture	98,4	98,2	99,3	98,8	98,3
Transport	99,2	99,0	100,6	100,0	99,4
Trade	109,4	109,1	105,2	104,9	104,5
Other branches of material production	101,6	100,8	99,4	98,6	97,8
Non-material service	106,2	105,6	102,7	102,3	101,9

TABLE IV
INDUSTRY OUTPUTS IN 2011-2015 ACCORDING TO THE OPTIMISTIC SCENARIO (GROWTH RATE, %)

	2011	2012	2013	2014	2015
Power engineering	100,8	99,9	98,0	98,4	98,8
Fuel industry	102,1	102,8	101,9	101,9	102,0
Ferrous metallurgy	96,9	98,0	96,2	97,2	98,2
Non- ferrous metallurgy	100,6	102,1	97,5	97,9	98,5
Chemical and petrochemical industry	98,4	99,1	98,7	100,0	101,0
Machine-building and metal-working industry	113,1	116,3	106,4	107,4	109,3
Logging, wood-working, pulp and paper industry	101,3	105,0	97,8	98,9	100,6
Building materials industry	103,5	108,4	98,9	99,8	101,9
Light industry	102,4	105,4	101,0	101,7	103,1
Food industry	105,9	106,8	105,1	105,4	106,1
Other industries	100,1	103,0	97,1	98,1	99,5
Construction	114,9	118,6	109,3	109,4	110,2
Agriculture	103,6	103,6	102,5	102,7	102,9
Transport	103,0	103,6	102,4	102,7	102,9
Trade	115,9	119,3	115,2	115,0	115,2
Other branches of material production	107,0	108,4	103,7	103,7	104,0
Non-material service	112,4	113,0	109,0	108,8	108,9

Forecast estimates make it possible to assess the amount of emission of polluting substances into the atmosphere (see

Fig. 7). The ecological block estimates are based on the hypothesis that pollutant generation coefficients as well as environmental protection expenditures will stay at the level of 2009. It means that there is no radical replacement of production technologies from the point of view of their influence on the environmental quality.

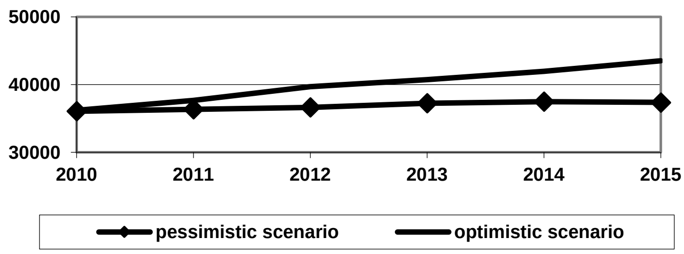

Fig.7. Amount of emissions polluting the atmosphere (thousand tons) according to the forecast estimates.

We can see that the second scenario, which is more optimistic from the viewpoint of economic development, is more pessimistic from the ecological viewpoint because of the growing environmental pressure. According to the first scenario, emissions will increase by 3,5% in 2010-2015; according to the second scenario, by 20 % in the same period.

Having studied the most interesting results of the econometric analysis of sickness rate in Russia and having estimates of the pollution for the period being forecast, let us now evaluate the effect of ecological factors on the health of the population of Russia in 2010-2015. For this purpose we will use the regression that will model the sickness rate of the Russian population (see Table 1) and construct an interval estimate of the part environmental pollution plays in the population sickness rate.

The value of the coefficient under the variable "Average per capita emissions" accounts for 0.153 and its standard error is equal to 0.07. It means that the increase of per capita emissions per kg will lead to the growth of sickness rate from 0.0363 to 0.269 of all the registered cases per one thousand people with the probability of 90%. Taking into account the estimate of emission dynamics for 2011-2015, let us evaluate the change in the population sickness rate during this period, under the influence of ecological factors, assuming that the population size in Russia will not change (see Table V).

Thus, the pessimistic scenario forecasts that between the years 2010 and 2015 the emissions in Russia are expected to reach, on average, 1.8 kilo per capita per year, which might lead to growing numbers of the first-time sick, namely from 47 to 348 thousand people. As the optimistic scenario presupposes a higher economic growth rate in the period discussed and, consequently, a greater pressure on the environment (the increase of average per capita emission would account for 10.3 kilo per person), the ecological "contribution" to the population's sickness rate would be more considerable – from 266 to 2234 thousand people. The other authors' articles are devoted to problems of the influence of various factors, including ecological factor, on the health condition of Russian citizens, for example [9,10].

TABLE V
AVERAGE PER CAPITA EMISSIONS AND THE NUMBER OF FIRST-TIME SICK PEOPLE IN RUSSIA IN 2011-2015

	2011	**2012**	**2013**	**2014**	**2015**
Pessimistic scenario					
Increase of average per capita emissions (kg per person in comparison with the previous year)	+6,5	-22,5	+3,6	+6,0	+8,6
Growth in the number of the first-time sick for the ecological reason (thousand people in comparison with the 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
Optimistic scenario					
Increase of average per capita emissions (kg per person in comparison with the previous year)	+6,5	-7,3	+4	+7,4	+7,2
Growth in the numbers of the first-time sick for the ecological reason (thousand people in comparison with the 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

Attempts to estimate the influence of ecological factor on the health are occurring in articles of other authors, but often these researches are executed at the regional level or use subjective estimations in regression analysis [11-15]. Research results presented here give a numerical estimate of the influence of various factors on the health of the Russian population; they also make a forecast of the effect of ecological factors on the 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 on the number of the first-time sick. The proposed approach combines the application of the advantages of intersectoral modeling methods and econometric methods in order to analyze and forecast ecological-economic processes.

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