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Estimation of the opportunity of the environmental load's decrease at the transition to the innovational way of development*

The article offers an approach for constituting various types of functions that tie economic and ecological indicators. The models based on such patterns should enable investigation of potential development scenarios in strategic planning and their comparative analysis. Calculation results based on Karelia data are presented for major types of functions offered.

Model, environment, investments, pollution function

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Economic development is connected with influencing the environment as the creation of new productions and the expansion of the existing ones lead to positive socio-economic results, but also have negative features, for instance, worsening of ecological conditions. In 1990s the recession in economy was accompanied by the reduction of influence on the environment.

In 1999 the economic growth, which began in the majority of regions, caused significant deterioration of the ecological situation. The high degree of the basic equipment's and environmental funds' deterioration was considered as a principal cause of the predicted negative influence' increase. In reality the growth of pollution appeared not to be so significant, and according to some parameters

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the economic growth was accompanied by the reduction of the environmental load [1, 2]. The analysis of the Russian Federation's and separate regions' data has shown, that the construction of models which will allow predicting ecological parameters' changes depending on the scenarios of the regional economic development is possible.

Within the framework of this research the environmental economic models are constructed on the basis of various functions' types connecting economic and ecological parameters of the territories' development, their features, the key parameters' characteristic, the conditions of aggregation and interrelation of the equations' parameters of different levels are considered. The mentioned models allow taking into account the environmental restrictions of the economic territories' development and can be used at developing various strategic documents.

The research's precondition is the developed situation with the regulation of the economy's negative influence on the environment which is based on the pollution valuation on the basis of the maximum permissible concentration, emissions and dumps, and also by means of realizing the principle "the polluter pays". In conditions when the economic growth operates as the basic priority, the valuation measures are a very weak tool of regulation of the pollution level.

In the Russian reality it works as follows: if the environmental contamination from the part of an enterprise meets the pollution valuation, it is considered, that the level of pollution does not exceed the opportunity of the assimilation potential of a territory and thus the ecological factor is taken into account. And if an enterprise doesn't follow the pollution valuation, another parameter (temporarily coordinated dumps and emissions) is used. Temporarily coordinated standards, as a rule, are close to the limits of pollution. They are operating for a long time and do not stimulate an enterprise to reduce pollution.

The existing principle of pollution valuation has also lost its urgency because it does not meet the requirements of the modern ecological ideology demanding the pollution prevention, instead of its consequences' liquidation. The modern approach to the environmental load regulation is based on the strategy of conformity to the parameters of the best existing accessible technologies [12]. This approach allows establishing unified technical standards and maximum permissible pollution levels, achievable at the use of some concrete technology.

A very important problem at the present stage is also the necessity of the ecological factor's account at forecasting the socio-economic development of a territory. According to a new edition of the Town-Planning Code, the basic ecological substantiations of economic activities should be carried out at the stage of planning of territories' development [3].

The strategic documents being developed now, as a rule, only formally take into account ecological restrictions of economic growth. It is caused by the absence of the necessary toolkit for the preliminary operative estimation of the negative influence of economic development on the environment. The majority of approaches realized both in our country and abroad is focused on complex models and demands big files of qualitative data that causes certain difficulties for their use [7, 8, 9, 11, 13]. In this connection the development of more simple models which do not demand big files of information is actual, that allows operative estimating the influence of certain authorities' and business' steps on ecological parameters.

Considering the economy's influence on the environment in Karelia Republic, it is possible to note, that it is determined by considerable volumes of emissions into atmosphere, of water consumption for the industrial purposes, wastewater discharge and so on *(tab. 1)*. The condition of the surrounding environment as a whole in the republic is characterized by a very weak intensity.

Table 1. Dynamics of the parameters of economic activities' negative influence on the environment in Karelia Republic from 1990 to 2009*

Parameters	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Emissions of harmful substances into atmosphere, it total, thousand t	301	191	150	139	138	132	136	129	126	122	122.3	105.8
Index by 1990, %	*100*	*63.5*	*49.8*	*45.8*	*45.8*	*43.9*	*45.2*	*42.9*	*41.9*	*40.5*	*40.6*	*35.2*
Including firm substances	87	34	33.4	30.3	27.6	27.5	29.9	27.7	26.5	27.7	28.2	20.7
Gaseous substances	214	157	116.7	111.2	107.8	105.3	106.7	101.5	100.1	94.2	94.0	85.2
Water intake, in total, million m^3	356.0	241.2	212.5	225.7	220.6	229	233	241	243	238	230	221
Index by 1990, %	*100*	*67.8*	*59.7*	*63.4*	*62.0*	*64.3*	*65.4*	*67.7*	*68.8*	*66.9*	*64.6*	*62.1*
Used water, in total, million m^3	336.4	226.9	198.8	218.3	214.4	222.0	225.5	236.6	235.6	226.3	220.7	213.5
Index by 1990, %	*100*	*67.5*	*59.1*	*64.9*	*63.7*	*66.0*	*67.0*	*70.3*	*70.0*	*67.3*	*65.6*	*63.5*
Including for the industrial needs	237.0	144.2	128.0	153.4	137.6	149.6	155.1	164.7	155.0	135.0	130.0	127.5
For household needs	77.7	70.3	56.8	53.9	55.8	52.8	52.7	53.0	52.2	48.3	47.0	45.1
Dump of sewage, in total, million m^3	273.3	234.3	215.0	226.0	220.4	224.4	242.4	240	243	241	233	223.6
Index by 1990, %	*100*	*85.7*	*78.7*	*82.7*	*80.6*	*82.1*	*88.7*	*87.8*	*88.6*	*88.2*	*85.3*	*81.8*
Including non-cleared		40.4	20.0	20.7	21.8	20.1	21.2	16.7	13.1	12.4	11.5	9.4
Insufficiently cleared		182.2	185.0	180.2	176.5	174.2	187.9	188.7	194.0	191.6	185.5	180.3
Normative cleared		11.7	9.8	25.2	22.1	30.1	33.3	35.1	35.2	34.7	34.4	34.0
Waste products, in total, million t	**	**	**	**	68.4	67.0	70.0	101.5	101.7	106.4	95.6	72.7
Index by 2002					*100*	*98.0*	*102.3*	*148.4*	*148.8*	*155.6*	*139.8*	*106.3*
Including 1st class of danger, thousand tons					0.03	0.04	0.07	0.04	0.05	0.04	0.08	0.36
2nd class of danger, thousand tons					5.09	0.28	0.24	0.18	0.13	0.09	0.06	0.04
3d class of danger, thousand tons					13.05	63.39	39.49	28.91	25.18	19.1	22.7	26.9
4th class of danger, million tons					0.25	0.547	0.554	0.573	2.014	0.694	0.671	0.560
5th class of danger, million tons					68.2	66.4	69.4	100.9	99.7	105.7	94.9	72.1

*Absolute parameters of pollution are resulted according to the state reports on the environmental condition in Karelia Republic in corresponding years.
** In connection with the change of classification the data are not comparable.

However in the areas where the enterprises of pulp and paper industry and metallurgy work, more intense ecological conditions can be found, as large enterprises' influence on reservoirs', atmospheric, grounds' condition is considerable. First of all, it is typical for industrial centers, such as Petrozavodsk, Segezha, Kostomuksha, Kondopoga, Pitkyaranta, etc.

Among the largest polluters of the environment we can name Public Corporations "Karelian Pellet", "Kondopoga", "Segezha Pulp and Paper Mill", "Pulp and Paper Plant "Pitkyaranta"", "Bumex", Closed Joint Stock Company "Petrozavodskmash", the branch of "NAZ-SUAL". The ecological enhancement at these enterprises basically passes under the economic scenario and is the consequence of the general enhancement. So, at the Public Corporations "Karelian Pellet" the roasting machines' enhancement has allowed to lower the total amount of emissions of nitrogen and sulfur, and the emissions of sulphur dioxide were reduced twice in comparison to the level of 1990.

The enhancement begun at the branch of "NAZ-SUAL" in 1994 allowed to reduce the total emissions of harmful substances from 9.6 to 7.2 thousand tons in 2000, of the especially polluting substances from 3.3 to 2.6 thousand tons, and the fluorine contamination of water was within the limits of norm. Since 1994 Public Corporation "Kondopoga" has invested 0.9 billion rubles for the actions on emissions' reduction in the atmosphere and 1.8 billion rubles for the decision of water purification's problems. The share of the repeated water use and recycled water has grown for one third and has made 86 %. Sulfur dioxide's emissions have decreased and have made 36 % in comparison to the level of the year of 1990. Since 1999 biological clearing constructions' enhancement has been carried out. The enhancement at the "Segezha Pulp and Paper Mill" has allowed to reduce the emissions by this Public Corporation into atmosphere and to improve water purification. Public Corporations "Pitkyaranta" carries out the equipment's enhancement which will allow reducing the influence on the environment [6, 12].

Ecological enhancement at the enterprises of Karelia was considerably promoted by such factor as the frontier arrangement of the region that favors to the development of trans-boundary contacts, facilitates the production's export. It can be explained by the fact that the Ministry of Environment of Finland which is interested in ecological conditions' improvement in the frontier region took part in investing to ecological programs of practically all the enterprises.

Investments are the basic economic parameter reflecting the enhancement processes. Therefore it is logical to assume, that for forecasting the economic development's influence on the environment it is necessary to establish the presence of quantitative interrelations of investments into the fixed capital and into environmental protection with ecological parameters (emissions of polluting substances into the atmosphere and effluents). And it is necessary to place investments both into new construction and into the production enhancement at which the influence on the environment can considerably decrease.

In figure 1 the data of Karelia Republic are considered. Two tendencies are evident, each of which can be approximately described by linear dependence. By 1998 at approximately tenfold recession of investments into the region's economy emissions into the atmosphere had decreased for 40 %, and then at fourfold growth of investments into the regional economy the considerable part of which went to the production enhancement and to the transition to more modern technologies, the emissions into the atmosphere decreased for one fifth, to 40 % in comparison to the level of the year of 1990.

Considering similar dependence on the effluent parameter *(fig. 2)*, it is possible to note its sharp decrease in the beginning of the considered period (till 1993) in connection with recession, but the volume of dump was stabilized, despite of the further reduction of investments till 1998 and their growth during the following period. It is possible to speak about the investments' influence on the effluent decrease only since 2005 (due to accrued growth, i.e. cumulative effect).

In spite of the fact that the investments into a fixed capital are connected to simultaneous improvement of general production and ecological factors, target investments on commissioning environment protection objects still keep the urgency. The analysis of the dependence of the levels of pollution from the environment protection investments shows, that fluctuation of the investments' volume into the environment protection in the republic rendered various influence on the change of emissions' volumes into the atmosphere from stationary sources and dumps of sewage into the surface waters. In the beginning of the 1990s the reduction of emissions and effluents occurred at constant investments, but afterwards the sharp falling of investments in the second part of the 1990s did not result in the change of the polluting parameters.

Figure 1. Dynamics of the emission of pollutants into the atmosphere depending on the dynamics of investment into fixed capital of Karelia Republic in 1990 – 2008, in % to 1990

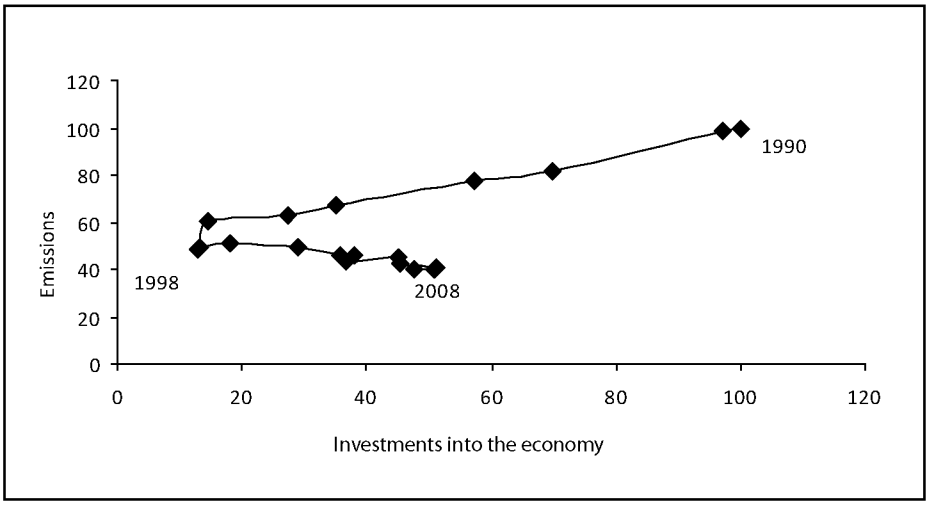
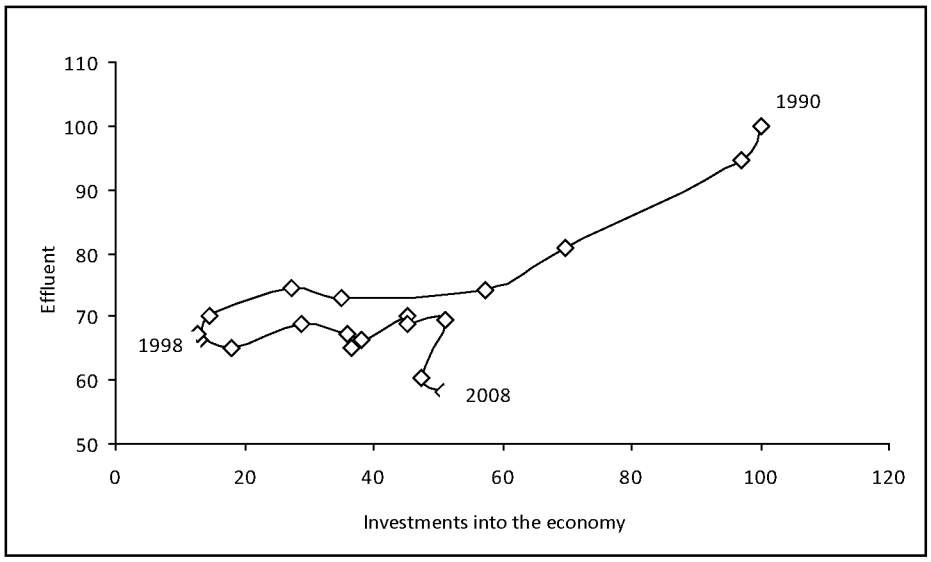


Figure 2. Dynamics of the effluent depending on the dynamics of investment into fixed capital of Karelia Republic in 1990 – 2008, in % to 1990



After the year of 2000 the growth of investments, apparently, promoted reduc-tion of harmful substances' emissions into the atmosphere at rather stable levels of effluents.

The revealed laws testify to the opportunity of construction of two- or three- factorial ecological investment functions (similar to the industrial ones) which should take into account the ambiguity of influence of various scenarios of the economic development on the region's environment depending on the investments' structure. The research is based on the information available in statistical collections of the region [10].

The ecological parameters describing the environment's condition and influence on its economy's development, such as polluting substances' emissions into the atmosphere from stationary sources, effluents into surface waters, water intakes from the natural water sources, waste products' appearance and others are studied.

For estimation of the economy's development the following parameters are chosen: gross regional product (GRP) and its structure, investments and their structure, etc. On the base of the mentioned parameters calculations are carried out for both complex and simple parameters. The branch parameters are used in the equations with simple parameters. Environment protection activity is reflected in the following parameters: investments into the fixed capital, directed on environment protection and the rational use of natural resources, current expenses for environmental protection, etc.

The basic advantage of the mentioned functions connecting both economic and ecological parameters, will be, that they allow considering the dynamics of ecological investments' efficiency, analyzing the influence of the dynamics of investments' economic structure and taking into account the opportunity of indemnification of one factor by another. They can be two- or three- factorial, be under construction on individual or complex ecological parameters:

$$Z(t) = F(U_1(t), U_2(t), U_3(t), t), \qquad (1)$$

where: $Z(t)$ is the researched environmental parameter;

$U_1(t)$ is the factor reflecting the economy's development and, as a rule, negatively influencing the environment (investments into economy, investments into new construction, etc.);

$U_2(t)$ is the factor reflecting environmental protection activity and positively influencing the environment (investments into the environment protection, etc.);

$U_3(t)$ is the factor reflecting the dynamics of production and, as a rule, positively influencing the environment (investments into production enhancement, etc.);

t is a year.

Similarly to the production functions the concept of the factorial flexibility, showed by logarithmic derivatives of function, under the factors is entered. The parameters ε_1, ε_2 and ε_3 are possible to define as pollution flexibility under the factor, determining its efficiency.

They characterize the degree of factors' influence: investments' increase into new construction causes a 1% growth of the considered ecological parameter for ε_1%, at investments' increase for the environment protection (or other nature protection parameter) for 1% the change is for ε_2%, or to be more precise, decreases, as flexibility ε_2 is negative, and at increasing the investments for enhancement for 1% the change is for ε_3%.

Also the concept of neutral ecological progress which is connected to the change of the pollution level, depending on time or other factors, is entered. The basic influence on the neutral ecological progress is rendered with the structural shifts [4].

During the first stage of the researches [6] which were carried out in three northern regions, the elementary functions were used:

$$Z(t) = A(t) \times U_1^{\mu}(t) \times U_2^{-\eta}(t) \times U_3^{\nu}(t), \qquad (2)$$

where μ, η and ν are constants.

The given function is very convenient for calculations while logarithm it becomes linear, has simple ecological sense, $\mu \geq 0$, $\eta \geq 0$. The parameters $\varepsilon_1 = \mu$, $\varepsilon_2 = -\eta$ and $\varepsilon_3 = \nu$ are flexibility factors.

Calculations carried out in Karelia Republic and other regions showed that the use of only the industrial functions is not absolutely justified. Environmental and economic processes are characterized by their peculiarities and it is necessary to build special functions. On the basis of the carried out calculations it is possible to assume, that the factorial flexibility should gradually vary, to decrease.

More and more modern technologies are led-in and their influence is less, than the influence of the existing ones, the replacement of clearing systems for more perfect gives smaller effect, than their first installation, the restrictions on influence on the environment become more and more rigid, but changes become less. Some kinds of functions with varying factorial flexibilities described in details are offered [4, 5, 6].

Thus, the submitted approach to the influence estimation of the economy's development on the environment included some stages. Originally for the approached estimation of interrelation of indexes and the key functions' parameters - factorial flexibilities and the rate of neutral ecological progress, the data analysis and the construction of various schedules of ecological and economic parameters and their ratio were carried out. In the result the periods with potentially different behavior of the basic characteristics of the researched process were allocated, assumptions of the functions' type were constructed, probable restrictions on their parameters were determined. Then the calculations were carried out, the analysis of the calculations results was carried out, and in view of the received statistical characteristics the functions, which more adequately described the analyzed process, were selected.

Calculations for Karelia were carried out for the whole period of reforms, for both sub-periods and sometimes excluding the beginning of 1990s. The data on polluting substances' emissions into the atmosphere from stationary sources, GRP, investments into the fixed capital and the investments into the fixed capital, directed on environment protection, were used. The peculiarity of the regional data is that the investments strongly change. In different years the investment into the environment protection d in 4 or 5 times or fall in 2 or 3 times, and in 2008 they exceeded the level of the year of 1990 in 352 times.

Also calculations were carried out according to the represented above even more complex functions [5, 6]. When GRP was taken as the first parameter, the corresponding parameter till 1999 made a bit less one unit, and the parameter reflecting the investments' influence into the environment protection, was close to zero. Since 1999 the situation has varied: the first parameter was close to zero, and the second varied from 0.3 to 0.2. It means that till 1998 the economy's influence on the environment was determined by falling GRP, and the investments did not practically influence the environment protection. After 1998 with the beginning of economic growth the change of GRP began poorly influence the ecological parameter, but the influence of the environment protection investments amplified.

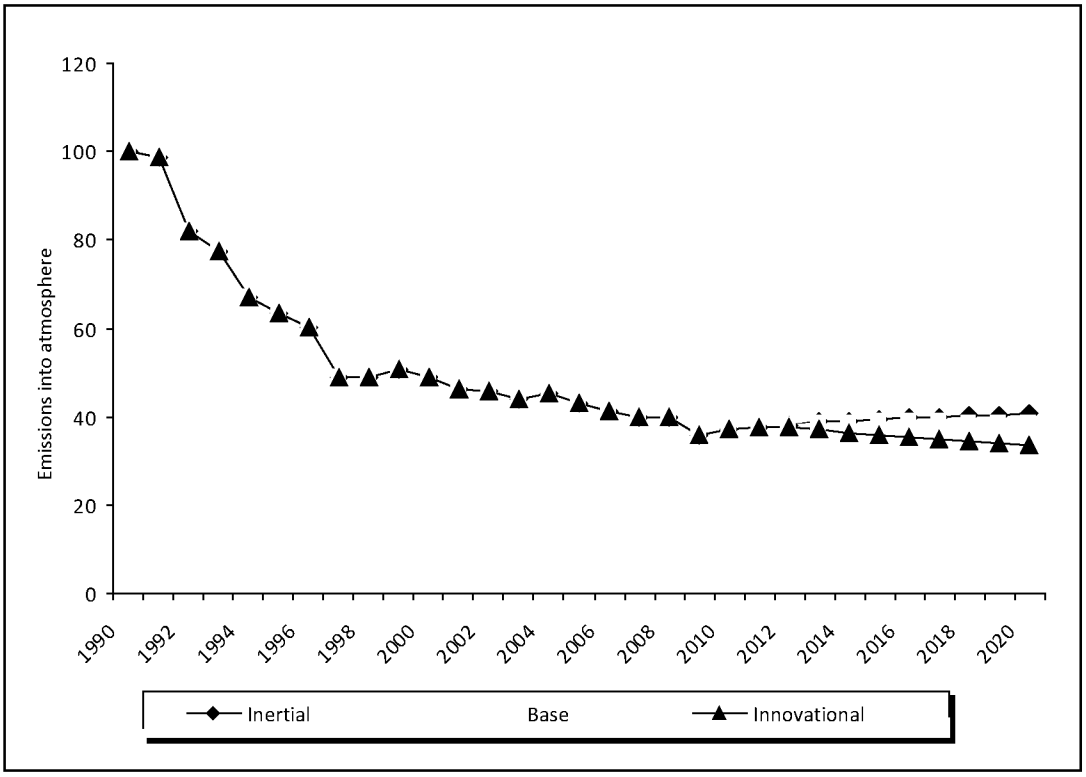
Calculations on the Karelian data with the use as the first parameter of investments into the economy's development confirmed the following conclusions: before the rouble devaluation the environment protection investments practically did not influence ecological characteristics.

The negative influence's change was greatly influenced by the investments rendered into economy. By the results of calculations it is possible to assume, that till 1998 the investments' reduction into the economy's development for 1% resulted in reduction of the ecological parameter approximately for 0.3%, and after 1998 the growth of cumulative environment protection investments for 1% reduced the ecological parameter approximately for 0.2%.

For checking the opportunities of the functions' use the calculations were carried out on the basis of the Strategy of Development of Karelia Republic developed in 2005. Forecasting was carried out according to the function (2) without taking into account neutral ecological progress at $\mu = 0.191$, $\eta = 0.033$, $\nu = -0.042$. Three scenarios represented in the Strategy, were supplemented with simple assumptions about the environment protection activity and the dynamics of the environment protection investments.

In the inertial scenario the investment were reduced to the level of the year of 2003 and then by 2020 reached the level of the year of 2008, in the base scenario they were reduced twice and returned to the level of the year of 2008 by 2018, in the innovational scenario after "falling" they in 1.5 times exceeded the level of the year of 2008 by 2020. The scenarios also include the dynamics of the factorial flexibilities according to the change in the economy's structure.

Figure 3. Forecast of the emissions' volumes into the atmosphere from the stationary sources according to three scenarios of Karelian economic development



Apparently from *figure 3* the innovational scenario (the development of the sectors very weakly influencing the environment and the investments' growth into the environment protection activity) gives the continuation of the developed tendencies of the pollution level's decrease, the others give emissions' growth into the atmosphere.

The offered technique allows operatively estimate ecological consequences the of prospective scenarios of economic development at the stage of planning territories' development.

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