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INDICATORS OF SUSTAINABLE DEVELOPMENT OF A MESOSYSTEM (WITH THE REPUBLIC OF TATARSTAN AS AN EXAMPLE)

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Abstract: *Postindustrialization as a prerogative of the existence of social, ecological and economic systems assumes the creation of a society with a vector of sustainable development. To display the level of development of a particular geographic region, a system of indicators is required that determine the level of sustainability or degree of dysfunctional development. The work proposes indicators for assessing sustainability and dysfunctionality of development of the regional system (mesosystem), which have been studied by the example of a social, ecological and economic system of the Republic of Tatarstan. The work sets boundaries and calculates the normal running processes and dysfunctionality for the social, ecological and economic indicators of the region under study. A multiple regression model is developed, based on the study of the force of interaction of the indicators of sustainable development, taking into account the institutional conditionality of demographic behavior.*

Keywords: *regional system, social, ecological and economic cooperation, sustainable development, institutional approach, model of sustainable development of the regional system, dysfunctional state of the system, force of interaction of the indicators*

1. INTRODUCTION

The priority of the development of a regional system is to achievestable dynamics in variousareas of its functioning, so the mesosystem should be studied as an object of social, ecological and economic relations. An important issue is finding the optimal proportions of reproduction of all subsystems of the regional system that ensure the implementation of the concept of sustainable development *(Evteeva S.A., Pereleta R.A., 1989).* Society with a sustainable path of development is only possible in case of achievement of the optimal proportions of reproduction of the indicators of the status

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of its subsystems, which dictates the need to develop a model that meets the principles of sustainable existence *(Khairullov D.S., Eremeev L.M., 2012).* Postindustrialization as a prerogative of the existence of social, ecological and economic systems does not determine the dominant role of economic growth, but rather assumes an equilibrium interaction of all components of the system *(Popkov V.V., 2007).*

2. METHODOLOGY

2.1. Indicators of sustainable development

Indicators for sustainable development of the territory are the parameters andindicatorsthat allow to display the level of development of a particular geographic region and to draw conclusions about the sustainability or dysfunctionality of this state *(Prokin V.V. et al., 2012).* For the first time, the issue of the establishment of the system of indicators of sustainable development has been raisedin "Agenda 21" adopted by the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, when the recommendations for classification of the indicators by the scope of the territorycoverage were adopted *(Ryazanova O.E.,Gribova E.V., 2016).*

It is important to keep in mind that it is not sufficient to use conventional economic indicators for an objective assessment of the state of sustainability or dysfunctionality. It is desirable that they are not static but dynamic in nature and are correlated with the indicators describing the state of other subsystems. For example, increasing the gross product of the territory or increasing the population is not a sign of sustainability, but their correlation with indicators describing the volume of exploitation of the environment and the cost of its preservation, unemployment level and other indicators givesa complete picture of the sustainability of social, ecological and economic system *(Sychugova E.V., 2010).*

Since the regions of Russia are sufficiently differentiated by the level ofsocio-economic development and the degree of impact on the environment, the assessment of the sustainability and dysfunctionality should be made at three levels: national (macrosystem), regional (mesosystem), municipal (microsystem) *(Melnyk L.G., 2005).*In addition, due to various states of the social, ecological and economic relations,the set of indicators of sustainability and dysfunction can be different for all areas except for macroeconomics, because in this situation a set of indicators should be strictly correlated with the UN recommendations *(Shelekhov A.M., 2002).*

2.2. Development of inequationthat fulfills the principle of sustainable development of the social, ecological and economic system

This works proposes an inequation, and the fulfillment of its conditions indicates the sustainability of the social, ecological and economic system, and thus its failure indicates a violation of the sustainable operation of the system:

$$I_M < I_P < I_{GRP} \quad (1)$$

where I_M is index of mining in the region;

I_p is index of change in population of the region;

I_{GRP} is index of change in the gross regional product

Correspondence of the development of the territory with the principles of sustainable development is ensured by the fulfillment of inequation (1), which is interpreted as follows:

1) $I_M \rightarrow$ min, $I_M < 100$ – fulfillment of this condition determines the realization of the principle of environmental sustainability, as anthropogenic impact on the environment is reduced. But this condition is difficult to realize in the situation of resource-dependent economy, as it will negatively affect the formation of the gross product.
2) $I_P > 100$ –realization of this condition describes the enlarged reproduction of the population, which can be achieved through reducing mortality and increasing the total birth rate; the environmental sustainability will be achieved in case of fulfillment of the ratio $I_M < I_P$.
3) increasein population welfare in the territory under study will be achieved if$I_p < I_{GRP}$. $I_{GRP} > 100$ will be received in the case of economic growth, the nature of which in the conditions of ecologization of the economy must be intense.

Let's determine how the conditions of inequation (1) are met by the Republic of Tatarstan for the period of 2000-2014 (which corresponds to the sample). The source of information is the Statistical collection "Regions of Russia. Socio-economic indicators" *(www.gks.ru).*

Table 1 allows to judge: the period of 2000-2006 is described by the failure of the inequation, which defines functioning of the social, ecological and economic system of the Republic of Tatarstan as unstable. The main negative thing is a narrowed type of reproduction of the region's population, which is caused by an increase in mortality at low birth rate. The principle of environmental sustainability is not realized during this period either, because the region increases the volume of extraction of natural resources each year, which, of course, ensures the economic growth of the region in the conditions of the resource-dependent economy. In 2007-2008, the volumes of the gross product also grow due to increased anthropogenic load on the environment, but the positive thing is increase in the birth rate. In 2009, inequation (1) is not fulfilled in full, which is based on the projection of the crisis phenomena in the international community on the regional economy;the inconsistency of the environmental sustainability was also revealed: the growth rate of resource extraction exceeds the rate of increase in the demographic factor. At year-end 2010, the functioning of the social, ecological and economic system of the RT can be considered sustainable: when the economic growth was achieved, the rates of the anthropogenic load did not exceed the value of the previous year, whichoccurred in the case ofincreasein demographic

Table 1
Definition of fulfillment of the inequation that describes the sustainability of the social, ecological and economic system of the Republic of Tatarstan for 2000-2014

Year	*Definition of fulfillment of conditions of inequation(1)*	*Fulfillment of conditions of inequation*	
		Fulfilled	*Not fulfilled*
2000	103.7 > 99.9 < 107.0		■
2001	103.6 > 99.9 < 111.0		■
2002	101.4 > 99.9 < 103.6		■
2003	101.5 > 99.9 < 107.4		■
2004	102.7 > 99.9 < 105.3		■
2005	102.5 > 99.8 < 105.5		■
2006	101.9 > 99.97 < 108.5		■
2007	102.0 > 100.1 < 110.7		■
2008	101.0 > 100.2 < 107.7		■
2009	100.6 > 100.3 > 96.6		■
2010	100.0 < 100.1 < 104.3	■	
2011	100.5 > 100.4 < 105.7		■
2012	100.5 < 100.6 < 105.5	■(?)	
2013	100.5 > 100.4 < 102.4		■
2014	100.7 > 100.4 < 102.1		■

indicators. In 2011, only non-observance of inequation $I_M < 100$ determined the loss of the sustainable state of the mesosystem. According to mathematical calculations in 2012, we can determine that inequation(1) is fulfilled, since the rates of economic growth exceeded the birth rate, which was higher than the environmental component, but this claim is conditional, as there was increase in the rate of mining. In 2013-2014, the Republic of Tatarstansaw economic growth, birth rate exceeding death rate, but the principle of environmental sustainability was violated. Whilethe demographic component was the main cause of inequationfailure in the period of 2000-2006, in subsequent periods the annual buildup of anthropogenic impact on the environment is a central issue of non-fulfillment of the principles of sustainable existence of the system.

2.3. Adjustment of the inequation, the fulfillment of which implements the principle of sustainable development of the social, ecological and economic system, taking into account the "lagging" reaction of demographic behavior

A key factor in inequation (1) is an indicator describing the dynamics of demographic behavior. The demographic behavior of the population can be regarded as an integral part of behavior aimed at adapting to the rapid and often adverse changes in the institutional environment *(Eliseeva I.I., Klupt M.A., 2006).* Institutional approach to the explanation of the trend of the development of demographic indicators identifies the impact of formal and informal institutions as the causes of narrowed reproduction of the Russian national system *(Odintsova M.I., 2009).* It can be concluded that the main driving force behind the dynamics of the demographic behavior of both the domestic national system and some of its comprising mesosystems is their institutional conditionality. Projecting an institutional approach on demographic behavior allows to argue that its dynamics is a response to changes in the institutional environment. Given this fact, as well as the human physiology in the perinatal period, it can be argued that demographic behavior is of "lagging" nature (by 0.75 years, which corresponds to 9 months). It follows that it seems appropriate for the analysis of the state of the system in the period under study using inequation (1) to take the actual values of ecological and economic factors (i.e. in the period t), and take the values of the demographic factor from the period following the reporting period (period t+1). On this basis, the inequation (1) takes the following form:

$$I_{Mt} < I_{Pt} < I_{GRPt+1} \quad (2)$$

where I_{Mt} is index of mining in the region in the analyzed period*t;*

I_{Pt} is index of change in population of the regionin the period following the analyzed*t+1;*

I_{GRPt+1} is index of change in the gross regional product in the analyzed period*t*.

Let's define the fulfillment of the inequation that takes into account the offset of the demographic component by one period forward and use the data on birth rates in 2015 (100.8) to calculate figures for 2014.

Table 2
Determination of the fulfillment of the inequation that describes the sustainability of the social, ecological and economic system of the Republic of Tatarstan for 2000-2014 (with the "lagging" reaction of demographic behavior)

Year	*Definition of fulfillment of conditions of inequation(1)*	*Fulfillment of conditions of inequation*	
		Fulfilled	*Not fulfilled*
2000	103.7 > 99.9 < 107.0		■
2001	103.6 > 99.9 < 111.0		■
2002	101.4 > 99.9 < 103.6		■
2003	101.5 > 99.9 < 107.4		■
2004	102.7 > 99.8 < 105.3		■
2005	102.5 > 99.97 < 105.5		■
2006	101.9 > 100.1 < 108.5		■
2007	102.0 > 100.2 < 110.7		■
2008	101.0 > 100.3 < 107.7		■
2009	100.6 > 100.1 > 96.6		■
2010	100.0 < 100.4 < 104.3	■	
2011	100.5 <100.6 < 105.7	■(?)	
2012	100.5 > 100.4 < 105.5		■
2013	100.5 > 100.4 < 102.4		■
2014	100.7 < 100.8 < 102.1	■(?)	

Table 2 allows to judge that in comparison with the results of Table 1, the characteristics of the research have changed in the period since 2011. In 2011 and 2014, the mathematical essence of the inequationis fulfilled, but increasing the volume of mining contradicts to the condition of sustainable development of the social, ecological and economic system. In 2012, the situation worsened: given the stable rates of mining,the dynamics of demographic and economic factors showed decline.

3. RESULTS

3.1. Determining the borders of dysfunctionality and sustainability of the existence of the social, ecological and economic system

Theoretically, the sustainable development in determined by the optimal values of the functioning of all the elements of the system, and therefore the state different from the optimal can be considered dysfunctional, with varying degrees of deviation. Besides, the conditions of sustainable existence can be identified through the system deviation from its optimal criterial deviation *(Demyanova O.V., 2010)*. The applied research in the field of sustainable development and dysfunctionality must be based on the study of the criteria that are formalized in nature *(Radkovskaya E.V., 2011).* In this situation, indicators of dysfunction and sustainability for different mesosystems will be differentiated in nature, which determines the degree of well-being or instability of their existence. The main parameters for assessment will be the factors of inequation (1), which fulfills the principle of sustainable development of the social, ecological and economic system. Interpretation of the inequation is that the ecological factor must adhere to the declining trend, while the demographic and economic components must be describedby the growing trend. The extent of variation between the actual values and set of favorable indicators will determine the degree of dysfunctionality of development.

Let's recognize the limit value for the factors of the sustainable development from inequation (1) equal to 100 as a reference level used for the establishment of sustainability and dysfunctional development. In this situation, the parameters of the periods that lie above the limit value can be recognized as conditionally sustainable, while the periods with coordinates located below the limit value can be defined as the conditionally dysfunctional. Based on the interpretation of inequality (1), the dynamics of economic and demographic factors will correspond to the proposed conditions, but the dynamics of the ecological component of the model will be interpreted differently: overriding of the limit value characterizes the dysfunction, while lower values characterize a state of sustainability.

To establish the boundaries of the normal processes and dysfunctionality, let's use the rule of "three sigma σ"*(Piskunov N.S., 1985)*. The rule is that virtually all of the values of the random variable with normal distribution are found in the range $[\mu-3\sigma;\ \mu+3\sigma]$. Let's choose values $N \pm n \cdot \sigma$ as the boundaries of the level of the state, where $n = 1, 2, 3$; N is a limit value equal to 100 (for all factors of inequation (1)). Thus, we define three levels in the area of conditionally sustainable and conditionally dysfunctional periods. The conditionally sustainable levels are defined as low sustainable, medium sustainable and highly sustainable; conditionally dysfunctional levels are defined by analogy: low dysfunctional (i.e. experiencing minor symptoms of dysfunction) medium dysfunctional, highly dysfunctional (with significant symptoms of dysfunction).

3.2. Calculation of theboundaries of the area of sustainability and dysfunctionality of the social, ecological and economic system of the Republic of Tatarstan

Let's calculate the boundaries of the area of sustainability and dysfunctionality of the social, ecological and economic system of the Republic of Tatarstan for the sample of 2000-2014 using the rule of "three sigma σ", which requires the calculation of the standard deviation (σ), but since the calculation is conducted using the sample, the standard deviation (s) will be applied:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_t - N\right)^2} \tag{3}$$

where x_t isthe actual value of the factor of sustainable development for the period t;

N isthe limit value of the factors of sustainable development equal to 100 (according to inequation (1)) *(Eliseeva I.I., 2011)*.

Let's calculate the standard deviation of the factors of sustainable development of the RT for 2000-2014 using formula (4) and the data in Table 1. The calculations result in the following: s of the ecological factor is 1.97; s of the demographic factor is 0.28; s of the economic factor is 6.79. According to the rule of "three sigma σ", the proposed approach to graduation of the periods of the regional system is to calculate the criteria that allow to include the value of the factor for a certain time in one of three levels in conditionally sustainable or conditionally dysfunctional, the results of calculations are presented in Table 3.

Let's present the results of the distribution of actual values of factors of sustainable development of the Republic of Tatarstan with respect to the calculated boundaries of sustainable and dysfunctional state in Table 4.

Table 3
Calculation of the boundaries of the area of sustainability and dysfunctionality of the social, ecological and economic system of the Republic of Tatarstan(by the sample)

Areas /factors	*Ecological*	*Demographic*	*Economic*
Low dysfunctional area	100.00-101.97	100.00-99.72	100.00-93.21
Medium dysfunctional area	101.98-103.94	99.71-99.44	93.20-86.42
Highly dysfunctional area	103.95-105.91	99.43-99.16	86.41-79.63
Low sustainable area	100.00-98.03	100.00-100.28	100.00-106.79
Medium sustainable area	98.02-96.06	100.29-100.56	106.80-113.58
Highly dysfunctional area	96.05-94.09	100.57-100.84	113.59-120.37

Table 4
of actual values of factors of sustainable development of the Republic of Tatarstan for 2000-2014*

	Area of sustainability			*Area of dysfunctionality*		
Year	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
2000		♦		▲	■	
2001		♦		▲	■	
2002	♦			■▲		
2003		♦		■▲		
2004	♦			▲	■	
2005	♦			▲	■	
2006		♦		■▲		
2007	▲	♦			■	
2008	▲	♦		■		
2009		▲		■♦		
2010	■▲♦					
2011	♦	▲		■		
2012	♦		▲	■		
2013	♦	▲		■		
2014	♦	▲		■		

* ■ is ecological factor; ▲ is demographic factor; ♦ is economic factor.

There is mainly the ecological factor in the area of dysfunctional state, since there is a buildup of mining in the analyzed period, 2010 was the only year when the pace of environmental mediation did not grow, which reflected on the state of the value which has been determined in the low sustainablearea. Since there was decline in the population of the region in 2000-2006, the position of the demographic factor in the period related to the area of low dysfunction;the demographic component is in sustainable state due to the prevalence of birth over mortality. Sincethe economy of the RT was described with growth in the analyzed period (except for 2009), the values of economic factors were included in the area of sustainability.

3.3. Calculation of the boundaries of the area of sustainability and dysfunctionality of the social, ecological and economic system of the Republic of Tatarstan, taking into account the "lagging" reaction of demographic behavior

Let's define the boundaries of the area of sustainability and dysfunctionality according to the conditions of inequation, which takes into account the offset of the demographic component for one period forward, and use the data of the birth rate in 2015 (100.8) to make calculations for 2014. Standard deviation is 0.35.

Let's present the results of the distribution of actual values of factors of sustainable development of the region, taking into account the offset of the demographic component.

Due to the high rate of population growth in 2014 (in fact in 2015), the criteria for including indicators in a specific area have changed. Changes have occurred in the direction of strengthening the sustainable position in 2006, 2010 and 2014, while the

Table 5
Calculation of the boundaries of the area of sustainability and dysfunctionality of the social, ecological and economic system of the Republic of Tatarstan (taking into account the "lagging" reaction of demographic behavior)

Areas/factor	*Demographic (with offset)*
Low dysfunctional area	100.00-99.65
Medium dysfunctional area	99.64-99.30
Highly dysfunctional area	99.29-98.95
Low sustainable area	100.00-100.35
Medium sustainable area	100.36-100.70
Highly dysfunctional area	100.571-101.05

Table 6
Distribution of the actual values of factors of sustainable development of the Republic of Tatarstanfor 2000-2014* (taking into account the "lagging" reaction of demographic behavior)

	Area of sustainability			*Area of dysfunctionality*		
Year	*Medium*	*High*	*Medium*	*High*	*Medium*	*High*
2000		♦		▲	■	
2001		♦		▲	■	
2002	♦			■▲		
2003		♦		■▲		
2004	♦			▲	■	
2005	♦			▲	■	
2006	▲	♦		■		
2007	▲	♦			■	
2008	▲	♦		■		
2009	▲			■♦		
2010	■♦	▲				
2011	♦	▲		■		
2012	♦	▲		■		
2013	♦	▲		■		
2014	♦		▲	■		

*■ is ecological factor; ▲ is demographic factor; ♦ is economic factor.

weakening of the sustainability of the demographic system was observed in 2009 and 2012.

4. DISCUSSION

In the history of the world economy, it has been thought for a long time that there is a direct correlation between the well-being of population and its size. By the end of the twentieth century, it becomes known that this relationship has an ecologicalconditionality, and this factor has a limiting development for the demographic and economic behavior. It is necessary to clarify the modern type of relationship in the social, ecological and economic relations on the basis of regression analysis *(Kabitova E.V., 2015).* The presence of three factors in the model of sustainable development determines the calculation of their mutual influence based on the equation of multiple linear regression *(Prosvetov G.I., 2006).* Let's take the pace of population growth *(y)* as a resulting indicator, which has a certain degree of reaction to changes in the pace of mining(x_1) and the pace of regional economic growth (GRP) (x_2) – they will be taken as influencing factors. To determine whether there is a linear relationship between the factors of sustainable development and how strong it is, let's find a sample equation of multiple linear regression; the volume of the sample corresponds to the period of 2000-2014 (Table 1).

$$y_t = 93{,}253 + 0{,}209x_{1t} + 0{,}136x_{2t}$$

The resulting equation of multiple linear regression shows that an increase only in the pace of mining x_1 (at constant x_2) by 1 point leads to an increase in the value of reproduction of the population y by an average of 0.209 points; an increase only in the pace of economic growth x_2 (at constant x_1) by 1 point also leads to an increase in the demographic factor by an average of 0.136 points.

Using the data in Table 1, let's make calculationstaking into accountthe "lagging" of the reaction of demographic behavior on the institutional environment. Let's also assume that there is a linear relationship between the indicators and find an analytical expression for this dependence, that is build a linear regression equation *(Kabitova E.V.,Uvarova A.I., 2016).*

$$y_t = 255{,}1 + 1{,}283x_{1t} + 1{,}277x_{2t}$$

The resulting equation of multiple linear regression shows that an increase only in the pace of mining x_1 (at constant x_2) by 1 point leads to an increase in the value of reproduction of the population y by an average of 1.283 points; an increase only in the pace of economic growth x_2 (at constant x_1) by 1 point also leads to an increase in the demographic factor by an average of 1.277 points. The results of calculations allow to define that the degree of influence of factors is stronger in the second case, when the reaction of demographic behavior is taken into account.

5. CONCLUSION

Let's calculate the standardized coefficients using the regression coefficientsfrom the model defined by the actual values of the factors of sustainable development:

$$b_1' = b_1 \bullet \frac{S_{x_1}}{S_y} = 0,209 \bullet \frac{1,126}{0,240} = 0,981$$

$$b_2' = b_2 \bullet \frac{S_{x_2}}{S_y} = 0,136 \bullet \frac{3,488}{0,240} = 1,976$$

Standardized coefficients b_1' and b_2' show by how many values of S_y the dependent variable y is changed on average in case of the increase of only x_1 (or x_2) of the explanatory variable by S_{x_1} (or S_{x_2}) at a constant average level of other explanatory variables *(Novikov A.I., 2006).*

In contrast to the coefficientsb_j, which are not comparable with each other, coefficients $b_1^{'}$ and $b_2^{'}$ can be compared with each other, and variables can be defined by theinfluence on the variable *y:* the greater the value of the coefficient (in absolute value), the greater *y* is influenced bythe variable corresponding to the standardized coefficients *(Nazarov M.G. et al., 2008).*

$$t_y = 0,981 t_{x_1} + 1,976 t_{x_2}$$

It turns out that the demographic behavior is less influenced by the ecological factor (with the "power of influence" of 0.981) than the pace of economic growth (with the "power of influence" of 1.976).

Let's carry out the research and identify how the institutional environment is reflected in the demographic behavior of the regional system. Let's calculate standardized coefficients using the regression coefficients:

$$b_1^{'} = b_1 \bullet \frac{S_{x_1}}{S_y} = 1,283 \bullet \frac{1,126}{0,287} = 5,033$$

$$b_2^{'} = b_2 \bullet \frac{S_{x_2}}{S_y} = 1,277 \bullet \frac{3,488}{0,287} = 15,520$$

It follows from the calculations that the "power of influence" of the economic factor is 15.52, the environmental factor has less influence of 5.033. It was found that the model taking into account the institutional support of demographic behavior is indicative of a stronger relationship between the factors. The birth rate is more connected with the overall economic prosperity of the regional economy.

The model taking into account the "lagging" reaction of the demographic system revealed a direct link between the studied indicators of social, ecological and economic sustainable development of mesosystem, which confirms the institutionalization of their state and dynamics.

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