Evaluating Efficiency of Russian Regional Environmental Management Systems

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Abstract

The purpose of this work is to develop an approach to assess the effectiveness of the environmental management systems of the regions of the Russian Federation. The effectiveness of EMS in this study is proposed to be understood in a purely economic sense: as the ratio of the indicator characterizing the improvement of the environmental aspects of the region's economy to the costs incurred to achieve this improvement over a period of time. The study contributes to the literature in several areas: 1) an approach has been proposed for defining a regional environmental management system as an aggregate of regional institutions that manage budgetary and extrabudgetary funds for environmental protection; 2) a method was proposed for evaluating the effectiveness of regional EMS based on the use of DEA models with negative outputs; 3) an evaluation of the effectiveness of the EMS regions of the European part of Russia was carried out, effective and inefficient regions were identified, the amounts of funds spent inefficiently were determined; 4) the hypothesis was verified that the size of the region's economy (assessed by GRP volume and population size) affects the efficiency of the EMS, and this effect is negative.

Keywords: *regional environmental management systems; comparative eco-efficiency; data envelopment analysis; eco-innovations; circular economy.*

1. Introduction

Modern academic literature on sustainable development assigns the most important role in managing the environmental aspects of economic activities of economic agents to local authorities (Brugmann, 1996). This is due to two main reasons: on the one hand, any negative effects of any economic activity (both production processes and life support processes of the population) are most likely felt at the local level and directly affect the quality of life of people. On the other hand, local authorities have the opportunity to influence people through the formation of environmentally friendly patterns of consumer behavior, sustainable urban planning and land use, information campaigns and educational activities, etc. (Petrosillo et al., 2012).

In the Russian Federation, the basic rules and regulations governing the environmental impact of the economy are established at the federal level, however, the regional authorities play a significant role in carrying out a number of local environmental management functions. Thus, the function of state environmental monitoring and supervision in the field of air protection and waste management is distributed between Federal Service for Supervision of Consumer Rights Protection and Human Well-Being (Rosprirodnadzor) and regional authorities. The functions of state monitoring of the radiation situation, wildlife objects, and the quality of forests are also distributed between federal and regional authorities. All statistical information on the quality of the environment and on financing environmental protection measures is provided to the population in a regional context. All funds collected from economic agents as payment for a negative impact on the environment and as environmental fines for violating the norms of environmental impact are further distributed as follows: 5% of the collected funds go to the federal budget; 40% to the regional budgets and 55% to the budgets of municipalities and urban districts. The function of allocating budget funds for environmental protection and planning measures to improve the ecological status of the region is fully assigned to the regional ministries of ecology and environmental protection.

At the same time, there is no standardized approach to the organization of an environmental management system (EMS) at the regional level in Russia. Out of the several most common environmental management standards in the world, only ISO 14001 is in force in Russia, which defines the structure and functions of an enterprise EMS, but not a regional one (Ratner and Iosifov, 2017). Attempts to apply the principles of ISO 14001 at the regional level in Russia have not yet been made, including the principle of continuous improvement of EMS. Therefore, no systematic assessment of the effectiveness of the activities carried out in the field of environmental management at the territorial level is currently performed.

The purpose of this work is to develop an approach to assess the effectiveness of the environmental management systems of the regions of the Russian Federation based on statistical data on the quality of the environment and funds received for financing environmental protection measures that are publicly available. The effectiveness of EMS in this study is proposed to be understood in a purely economic sense: as the ratio of the indicator characterizing the improvement of the environmental aspects of the region's economy to the costs incurred to achieve this improvement over a period of time. Since the expenses for environmental protection measures are of two types (current and capital) in Russian regions, and the improvement of the environmental aspects of the regional economy can be described by a sufficiently large set of statistical indicators (reduction of air emissions, reduction of pollution of natural water bodies, reduction of waste, etc.), then, to calculate a quantitative measure of the effectiveness of EMS, we used an approach based on the use of Data Envelopment Analysis.

The paper is organized as follows: in Section 1 we give a brief literature review on the topic of territorial environmental management systems and their efficiency. Section 2 describes the methodology of research and the choice of input and output indicators for DEA model (2.1) as well as the way of dealing with the negative outputs in DEA model (2.2). In Section 3 we present the results of calculation of efficiency coefficients of regional EMSs in the European part of Russian Federation (as the most populated area) and discuss a possible policy application of proposed methodology and obtained results. The main conclusions are found in Section 4.

2. Efficiency of Regional EMS: Literature Review

The concept of regional EMS is still being debated in the literature. In much of existing literature, regional EMSs are understood as either cooperative EMSs of individual enterprises (Ammenberg and Hjelm, 2003) or EMSs of public authorities (Daddi et al., 2011; Mazzi et al., 2012; Petrosillo et al., 2012; Domingues et al, 2015; Wangel et al., 2016; Bennett, et al., 2016).

One of the first examples of interfirm cooperation for creation and certification of a joint EMS by a group of enterprises can be found in (Ammenberg and Hjelm, 2003). In this example, the initiative to form the EMS and to go through the process of certification according to ISO 14001 came "from the bottom" – from business, while the regional authorities were not any driving force. 26 small and medium enterprises (16 enterprises less than 10 employees, 7 enterprises with the number of employees from 11 to 50 people and three enterprises with the number of employees from 50 to 80 people) in Sweden (Hackefors Industrial District) divided the costs of certification and management and organized joint collection and disposal of waste. As a result of introducing and certifying EMS, relationships with potential business partners (reputation increased) and customers (usually large companies that demonstrate their commitment to their environmental policies through the selection of suppliers certified to ISO 14001) have improved. In addition, by conscientious efforts, the network of enterprises was able to achieve improvements in the local power supply system – a transition was made from boilers heated by oil fuel to a centralized heat supply system, which is more environmentally friendly and energy efficient. Any attempts to quantify the effectiveness of such a network EMS (for example, as the ratio of the total cost of implementing the EMS and the benefits derived from the EMS) have not been made due to the fact that they are difficult to measure and assess.

Examples of introducing and certifying EMS in accordance with ISO 14001 or EMAS standards by local municipalities are more common in the literature (Lozano and Valles, 2007; Mascarenhas et al, 2010; Daddi et al., 2011; Mazzi et al., 2012; Petrosillo et al., 2012; Domingues et al., 2015; Wangel et al., 2016; Bennett, et al., 2016; Mazzi et al., 2017). In the narrow sense of the municipal EMS, it is understood as the EMS of the municipality itself as an organization that produces a certain impact on the environment: it consumes energy and other types of resources, discharges sewage, uses emission-producing vehicles, etc. These types of negative environmental impacts are referred to in the literature as direct environmental aspects. In a broader sense, the environmental aspects of a municipality's activities are understood as the consequences of such activities as urban planning, land use, organization of energy and water supply, etc. The environmental effects of the management activities of the municipal authorities are called indirect environmental aspects. The literature often notes that the indirect environmental aspects of the activities of local authorities are difficult to identify and measure. In addition, the literature emphasizes that the larger the territory managed by local authorities, the more difficult it is for them to monitor and manage indirect environmental aspects (Emilsson and Hjelm, 2005).

Another example of a regional EMS could be the EMS of eco-industrial parks. Many authors define the eco-industrial park as the community of manufacturing and service businesses seeking enhanced environmental and economic performance by collaborating in the management of environmental and reuse issues. By working together, the community of businesses seeks a collective benefit that is greater than the sum of individual

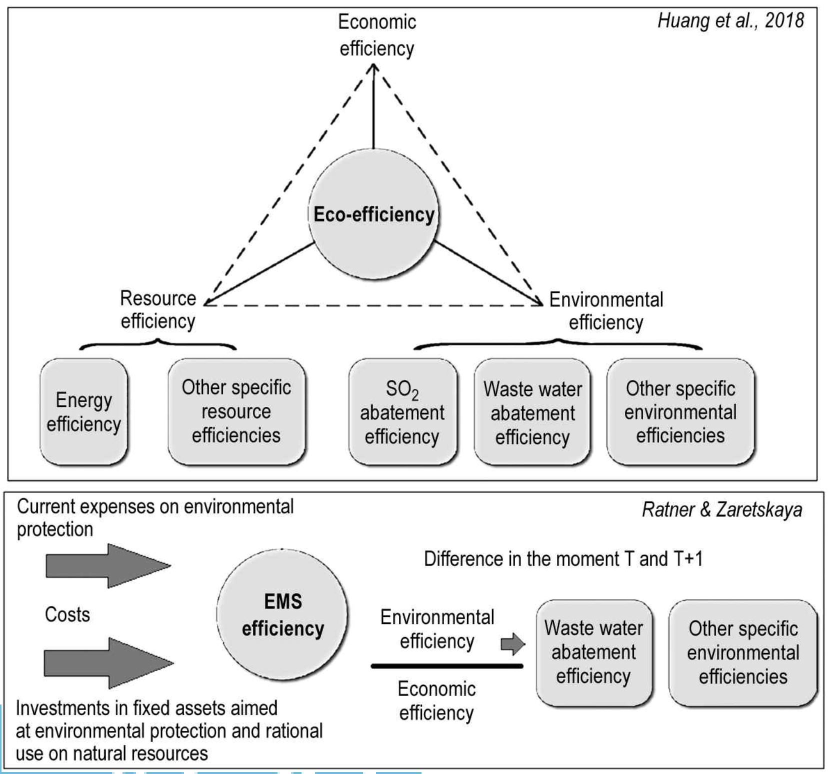

Figure 1.
The difference in assessment of regional eco-efficiency and regional EMS efficiency

benefits each company would obtain if it optimized its individual performance only (Martin, 1996). As a rule, such cooperation, first of all, is aimed at maximizing the use of by-products and therefore reducing the production waste (Daddi et al., 2016). Examples of introducing standards for the certification of a territory as an eco-industrial park (EIP) can be found in the papers (Geng et al., 2009; Geng et al, 2012; Daddi et al., 2016), but we have not identified examples of quantitative evaluation of EMS' efficiency in eco-industrial parks.

Evaluation of various types of efficiency of production systems, including systems of regional scale, with the help of the DEA has become mainstream in the scientific literature in recent years (Bian et al., 2010; Zhang et al., 2013; Wang et al., 2013; Zang et al., 2016; Deng et al., 2016; Gómez-Calvet et al., 2016; Ratner and Ratner, 2017; Huang et al., 2018; Nguyen Hoang et al., 2018). In these studies, environmental efficiency is considered as the ability of a production system to minimize undesirable outputs (negative externalities of production activities) with fixed values of inputs (material and human resources) and desirable outputs (GDP or other economic performance indicator of the production system). In our approach, we also propose using the DEA as a well-proven method, however, assess the effectiveness of environmental management in the region, i.e. management efficiency. Unlike the work (Huang et al., 2018), we consider not just environmental results and economic results as outputs separately, but their ratio as well, which in itself can be an assessment of the environmental efficiency of the production system (fig.1). In addition, following the definition of eco-efficiency proposed by the World Business Council for Sustainable Development (WBCSD, 2000), we consider eco-efficiency as a process of continually reducing negative environmental impacts, i.e. take into account the dynamics of changes in environmental performance.

As inputs of DEA model, we consider, following the traditional approach (Charnes et al., 1981), the cost of creating a result, in this case, an environmental result: differences in the intensity of the environmental impact of regional economy.

3. Methodology and Data

Practical applications of the Data Envelopment Analysis methodology are currently being actively developed, both in foreign and Russian scientific literature, covering all new areas of management and new classes of management tasks (Wang et al., 2017; Ratner and Ratner, 2017; Zhou et al., 2018; Liu et al., 2018). The main features of DEA, which make it an attractive tool for supporting management decision-making, are the following: 1) the ability to assess the performance of economic agents, having minimal knowledge about the production functions and technologies they use only from statistical data on the resources they consume and the volumes of output produced; 2) the opportunity to study various aspects of the functioning of complex systems, varying the choice of outputs and outputs in DEA model; 3) the ability to choose benchmarks for each inefficient economic agent (or system) and optimize their strategy for achieving efficiency; 4) the ability to use well-developed software (including open access software) to calculate the efficiency of the objects under study and make decisions regarding inefficient objects.

At the same time, the basic DEA models implemented in software, as a rule, have some limitations on the type of input and output values (Wang et al., 2017). In particular, in the basic CCR model (with a constant effect of scale) and BCC model (with a variable effect of scale) the inputs and outputs cannot take negative values. In reality, negative output values are possible in the situation when the useful result of the production activity of the economic agent under study (for example, profit or market capitalization), despite the resources spent, is not achieved.

Issues of this kind are often encountered in corporate and regional environmental management: funds spent on environmental protection measures or environmental monitoring and certification do not always achieve the desired goal – reducing emissions of various types of pollutants. In such cases, the difference in emissions of pollutants at the final and initial moments of the EMS implementation may be negative, which does not allow applying the basic DEA models to study the current situation. At the same time, the potential application of these models is significant. As shown in (Ratner and Ratner, 2017; Nguyen et al., 2018; Huang et al., 2018), varying the inputs and outputs by which the environmental management system can be described allows not only to study in detail certain aspects of its work, but also to conclude on the type of development of the economic object as a whole (linear, circular, sustainable), as well as the level of its eco-innovation activity (Jesus et al., 2018).

This paper proposes an approach to overcoming the above-mentioned limitations thanks to the procedures for normalizing and shifting the scale in which the performance indicators of the regional EMS (REMS) are measured.

3.1. DEA-model for regional EMS: inputs and outputs

Let's consider regional environmental management systems of the Central, Southern and North-Western Federal Districts (most populated and developed regions in European part of Russian Federation) as DMUs. We will use two statistical indicators as inputs for these DMUs: 1) current expenditures on environmental measures (in million rubles); 2) the volume of investments in fixed assets aimed at reducing pollution (in million rubles).

According to Federal State Statistic Service (http://www.gks.ru) we acknowledge the following as the current expenses on environmental protection: all expenses on environmental protection and rational use of natural resources, carried out at the expense of own or borrowed funds of an enterprise, or from the state budget. These include the following costs: the maintenance and operation of fixed assets for environmental protection; measures for the preservation and restoration of the quality of the natural environment disturbed as a result of production activities; measures to reduce the harmful effects of industrial activity on the environment; on the treatment of production and consumption wastes; on the organization of control over emissions (discharges), production and consumption wastes into the environment and over the qualitative state of the environmental components; for research work and work on environmental education personnel. It does not include funds paid to other enterprises (organizations) for wastewater reception and treatment, storage and disposal of waste, as well as depreciation deductions accrued to fixed assets for environmental protection.

As investments in fixed assets aimed at environmental protection and rational use of natural resources we consider the expense of all sources of financing both in newly built enterprises and in existing enterprises. These include the cost of construction, reconstruction (including the expansion and modernization) of facilities, which lead to an increase in their initial cost, the purchase of machinery, equipment, vehicles, production and household equipment, accounting of which is carried out in the manner prescribed for the accounting of investments in non-current assets.

As outputs, we consider indicators of a decrease in the level of pollution of the atmosphere and water, i.e. the difference in emissions before investment in fixed capital and the cost of environmental measures and after. In the case of efficient use of financial funds, this difference will be positive, in the case of ineffective – negative or zero.

In order to eliminate the impact on the volume of emissions of such a factor as expansion of production (creation of new production facilities in the region, more complete utilization of existing production capacity), we will consider the difference in *specific* emission indicators, i.e. indicators of intensity of impact on the environment – emissions into the atmosphere per unit of output (in rubles) and the share of polluted wastewater in the total volume of discharge (in %). Besides, as an additional indicator of water quality, we consider the indicator "the share of water samples that meet quality standards, %". It is obvious that the expenditure of funds to improve this indicator of environmental quality can be considered effective if the value of indicators increases. Then, in contrast to the two previous indicators of outputs of each RSEM, the third indicator of output should be formed as the difference after investment (time $T+1$) and before (time T):

$$\begin{aligned} y_{1,i} &= \Delta_i^{air} = V_{T,i}^{emissions} - V_{T+1,i}^{emissions} \\ y_{2,i} &= \Delta_i^{sew} = S_{T,i}^{sew} - S_{T+1,i}^{sew} \\ y_{3,i} &= \Delta_i^{water\_quality} = S_{T+1,i}^{water\_quality} - S_{T,i}^{water\_quality} \end{aligned} \quad (1)$$

In addition to the three formed outputs, using formulas (1), we will also form indicators of the level of development of the circular economy (Korhonen et al., 2018) in the region as the difference in the intensity of waste generation at the moments T and $T+1$, and the difference in the share (%) of recycled waste at the moments $T+1$ and T:

$$\begin{aligned} y_{4,i} &= \Delta_i^{waste} = V_{T,i}^{waste} - V_{T+1,i}^{waste} \\ y_{5,i} &= \Delta_i^{recycle} = S_{T+1,i}^{recyvle} - S_{T,i}^{recycle} \end{aligned} \quad (2)$$

With such a set of inputs and outputs in the basic model of DEA CCR, the solution of the following optimization problem:

$$\max_{u,v} \sum_{m=1}^{M} u_m y_{m0} \quad (3)$$

s.t.

$$\sum_{m=1}^{M} u_m y_{mk} - \sum_{n=1}^{N} v_n x_{nk} \le 0 \quad k = 1,2,\cdots K,$$

$$\sum_{n=1}^{N} v_n x_{n0} = 1,$$

$$u_m, v_n \ge 0 \quad m = 1,2,\ldots M \quad n = 1,2,\ldots N$$

where
0 – index of DMU under consideration; X – vector of inputs, dimension N ($N=2$); Y – vector of output, dimension M ($M=5$); K – number of DMUs

will allow to identify regions that, with a minimum amount of investment in fixed assets, aimed at environmental protection and a minimum amount of current expenditures on environmental protection measures, achieve maximum values of indicators formed in accordance with expressions (1) and (2). Obviously, this can only be achieved if eco-innovations are implemented, including in the area of production systems design that meet the concept of circular economy (maximum product reuse, recycling) (Korhonen et al., 2018).

3.2. Dealing with negative outputs

The values of output indicators for the RSEM of the Central Federal regions, calculated according to the formulas (1) and (2) for the period 2013 - 2014, are presented in Table 1. The values of outputs for the regions of Southern and North-Western Federal Districts are not included due to limited size of the paper.

On the data given in Table 1, it can be seen that with our proposed approach to the formation of inputs and outputs of the CCR model for the RSEM regions of the Central Federal District, a number of outputs have negative values, which indicate that spending on improving the quality of the environment is not efficiently performed everywhere. None of the studied regions has achieved an improvement in the environmental situation in all five indicators included in the consideration. A similar situation is observed for the regions of the North-Western and Southern Federal Districts.

In this case, the identification of more and less efficient regions in the sense of the functioning of the regional EMS through solving CCR optimization problem and the calculation of efficiency scores is impossible due to the presence of the aforementioned problem – negative inputs.

Region	Y_1	Y_2	Y_3	Y_4	Y_5
Belgorodskiy	-0.027	-5.3	1.3	-27.758	1.5
Bryanskiy	-0.008	4.4	-0.8	-0.454	-2.7
Vladimirskiy	-0.044	0.2	3.9	-0.147	0.2
Volonezhskiy	0.007	1.1	-0.7	-0.988	5.1
Ivanovskiy	-0.04	0.1	1.3	0.019	10.8
Kaluzhskyi	-0.031	-0.9	1	-1.794	2.5
Kostronmskoy	-0.03	0.3	-0.6	-2	-6.7
Kurskiy	0.048	-0.7	0	-7.711	1.6
Lipetskiy	0.041	-0.7	-0.1	1.653	-0.5
Moscovskiy	-0.011	-0.4	1.1	-0.714	-69.9
Orlovskiy	0.019	9.4	1.7	-4.634	2.6
Ryazanslyi	-0.018	-0.8	0.8	0.687	3.4
Smolensriy	0.098	1.7	3	0.024	-31.6
Tambovskyi	0.026	0	0.8	-0.955	5.4
Tverskoy	-0.007	1	0.4	-0.667	10.8
Tulskiy	-0.068	0.2	0.8	-0.719	3.3
Yaroslavlskiy	0.007	0	4.9	0.035	-1
Moscow City	0	4.4	0.4	0.068	-16.8

Table 1. The values of the indicators of outputs for the CCR model, formed to assess the level of eco-innovative development of the regions of the Central Federal District for the period 2013-2014

In order to translate negative outputs into positive ones, which allow applying the basic DEA models to determine the level of development of eco-innovation activity in the regions, we will carry out procedures for shifting the scales in which the outputs are measured according to the following formula:

$$z_{i,j} = y_{i,j} + \left|\min y_{i,j}\right| + 0{,}001 \quad (4)$$

The introduced transformation allows to get rid of the negative values of the outputs, without disturbing the common logic of the formation and solution of DEA model.

4. Results and Discussion

The results of the calculation of the efficiency scores according to the input-oriented CCR model for the regional environmental management systems of all regions of the European part of Russia (Central, North-West and South) are shown in Table 2. In addition, the table shows the target values of the inputs for each region, at which its EMS becomes efficient, as well as the difference between the actual and the required value of each input indicator.

As a result of solving the input-oriented CCR optimization problem the systems of regional environmental management of Ivanovskiy, Orlovskiy, Pskovskiy regions, as well as the Republic of Adygea and the Republic of Kalmykia, are recognized as efficient. In these regions, the minimum investment and current expenditures on environmental protection are used as efficiently as possible, which indicates the introduction of eco-innovation. In this case, product, process and organizational eco-innovations are not separated, although in principle such a division can also be taken into account when solving the DEA task: for this, DEA problem can be divided into two and consider the efficiency of investments in fixed capital and the efficiency of current expenditures separately that investments in fixed assets, as more long-term, contribute to the implementation of process eco-innovations, and current costs – the introduction of organizational eco-innovations.

The REMS cities of St. Petersburg and Moscow, as well as Belgorodskiy, Moscovskiy, Leningradiy, Astrakhanskiy and Rostovskiy regions, are considered the least effective. In these regions, the maximum volume of investments in fixed capital and current expenditure bring only insignificant improvements in the environmental situation which indicates a formal approach to environmental management and a weak development of eco-innovation activity. At the same time, the difference between the

Region	Score	Target value for investments in fixed assets	Target value for current expenses	Difference between target and real investments in fixed assets	Difference between target and real current expenses
Belgorodskiy	0.041	71.22	210.40	-1665.68	-4920.87
Bryanskiy	0.749	42.28	405.42	-14.20	-136.13
Vladimirskiy	0.347	52.18	432.72	-98.12	-813.66
Volonezhskiy	0.130	47.01	384.63	-314.10	-2570.32
Ivanovskiy	1	60.60	356.95	-0	-0
Kaluzhskyi	0.185	216.04	123.95	-951.56	-545.91
Kostronmskoy	0.874	13.63	460.22	-1.97	-66.42
Kurskiy	0.215	10.13	414.36	-36.87	-1508.76
Lipetskiy	0.124	134.95	284.83	-949.36	-2003.80
Moscovskiy	0.043	53.23	369.14	-1179.47	-8179.54
Orlovskiy	1	6.80	429.67	-0	-0
Ryazanslyi	0.183	148.59	251.69	-664.11	-1124.97
Smolensriy	0.564	48.36	426.36	-37.44	-330.01
Tambovskyi	0.221	200.97	156.96	-708.45	-553.28
Tverskoy	0.448	24.195	454.11	-29.81	-559.41
Tulskiy	0.137	76.86	323.96	-485.14	-2044.91
Yaroslavlskiy	0.219	45.41	656.59	-161.89	-2340.88
Moscow City	0.023	191.153	188.44	-8029.65	-7915.85
Karelskaya Resp.	0.877	88.08	1475.55	-12.32	-206.35
Komy Resp.	0.035	174.81	72.26	-6721.45	-2013.14
Arhangelskiy	0.655	623.42	1838.70	-328.58	-969.10
Vologodskiy	0.056	189.15	150.99	-3181.55	-2539.71
Kaliningradskiy	0.410	133.28	311.46	-191.52	-447.54
Leningradskiy	0.033	147.08	182.66	-4296.52	-5335.84
Murmanskiy	0.383	207.33	2322.10	-334.26	-3743.70
Novgorodskiy	0.387	125.72	348.85	-199.38	-553.25
Pskovskiy	1	53.4	483.9	-0	-0
St.Peterburg	0.019	160.68	76.07	-8471.12	-4010.53
Adygeya Resp.	1	165.1	68.6	-0	-0
Kalmykiya Resp.	1	71.2	19	-0	-0
Krasnodarskiy	0.166	83.08	785.35	-417.32	-3944.85
Astrahanskiy	0.039	162.19	113.56	-3934.21	-2754.55
Volgogradskiy	0.162	147.73	557.79	-762.97	-2880.71
Rostovskiy	0.064	171.56	220.14	-2510.04	-3220.76

Table 2. Results of the solution of the DEA problem (CCR, input-orientated)
for the regions of the Central, Southern and North-Western Federal Districts of Russian Federation

target and real values of investments in environmental protection and current expenditures on environmental protection can be estimated as the amount of funds spent ineffectively.

In addition, we tested the hypothesis put forward in the paper (Emilsson and Hjelm, 2005) that the larger the territory, the more difficult it is for regional authorities to carry out environmental management functions on it. To do this, we calculated the nonparametric correlation coefficients of Spearman and Kendall between the score of the EMS efficiency of a region and a) the number of its population; b) the volume of GRP. Nonparametric correlation was applied because the data on the number of population and the volume of GRP in the regions of the European part of Russia do not have a normal distribution. The calculation results showed that all coefficients are statistically significant at the level of 0.05 and negative (Table 3).

	Spearman Rank Order Correlation	Kendall Tau Correlation
Score and Population	-0.707	-0.539
Score and GRP	-0.839	-0.672

Table 3. Correlation between the efficiency score of REMS and the size of the region

Thus, indeed, it can be recognized that the authorities of the larger regions (in terms of population and size of the economy) do less well with the functions of environmental management.

5. Conclusions

The study contributes to the literature in several areas: 1) an approach has been proposed for defining a regional environmental management system as an aggregate of regional institutions that manage budgetary and extrabudgetary funds for environmental protection; 2) a method was proposed for evaluating the effectiveness of regional EMS based on the use of DEA models with negative outputs; 3) an evaluation of the effectiveness of the EMS regions of the European part of Russia was carried out, effective and inefficient regions were identified, the amounts of funds spent inefficiently were determined; 4) the hypothesis was verified that the size of the region's economy (assessed by GRP volume and population size) affects the efficiency of the EMS, and this effect is negative.

The proposed method of setting the outputs of the DEA model for its application to solving problems of assessing the level of development of eco-innovation activities in a region can also be used for models with a variable return to scale. In the latter case, the economic and managerial interpretation of obtained results will be more complicated, since it will be necessary to interpret not only the calculated efficiency scores, but also the direction and magnitude of the economies of scale.

It is also necessary to stipulate specifically one noticeable limitation of the practical example for calculation efficiency scores of regions: the annual period taken into consideration is likely to be too short to draw reasonable conclusions about the effectiveness of investments in fixed assets aimed at improving the environmental situation. However, this drawback is a shortage of the calculated example and is not a drawback of the developed approach to specifying and converting the outputs of the model. To eliminate it, it is necessary to identify the value of time lag between investments in fixed capital and return on investment (which is possible with the help of traditional econometric models) and include this lag in the period for which the difference in environmental quality indicators is calculated. The construction of the necessary econometric models is not included in this paper due to limitations on the size of the article.

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