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RESEARCHING THE ECOLOGICAL ASPECTS OF ECONOMIC DEVELOPMENT IN BORDER REGIONS BY CONSTRUCTING A COMPOSITE INDEX ON THE EXAMPLE OF RUSSIA, CHINA AND KAZAKHSTAN

Taisiya B. BARDAKHANOVA[1]
Zinaida S. EREMKO[2]
Anna S. MIKHEEVA[3]
Svetlana N. AYUSHEEVA[4]

[1]Baikal Institute of Nature Management, Siberian Branch of the Russian Academy of Sciences, Ulan-Ude, Russia. Corresponding author, tbard@binm.ru.
[2]Baikal Institute of Nature Management, Siberian Branch of the Russian Academy of Sciences, Ulan-Ude, Russia. zina@binm.ru.
[3]Baikal Institute of Nature Management, Siberian Branch of the Russian Academy of Sciences, Ulan-Ude, Russia. asmiheeva@binm.ru.
[4]Baikal Institute of Nature Management, Siberian Branch of the Russian Academy of Sciences, Ulan-Ude, Russia. asvetl@binm.ru.

Abstract: *The concept of a green economy is widely popular and is the basis of sustainable development strategies in many developed and developing countries. However, there is little knowledge on how 'green' priorities are being integrated into regional and local development. The present research evaluates progress in the development of a green economy at the regional level by constructing a composite index (hereinafter CI) which allows to comprehensively characterize and consider the links and interactions between the economy and the environment in specific areas. The research substantiates the choice of 5 directions of assessment and 14 indicators, and an algorithm for assessing the CI is proposed. The CI was calculated for 9 regions of Russia, China and Kazakhstan, adjacent to the territory of the Chinese Belt and Road Initiative (formerly OBOR). The developed toolkit makes it possible to analyze the features of ecological and economic interaction in the regions, to rank them according to the degree of making the economies green.*

Keywords: *green economy, composite index, resource efficiency, environmental efficiency, natural assets, economic damage, environmental investments, Russia, China, Kazakhstan, environmental economics*

INTRODUCTION

A major project for integrating environmental priorities into economic development is the Chinese Belt and Road Initiative (formerly OBOR) aimed to improve communication and deepen cooperation at the transcontinental level and based on the ideas of ecological civilization proclaimed by the Chinese leadership (Suocheng et al., 2015). The initiative carries both a wide range of opportunities (improving access to the area, boosting trade, attracting foreign investment, which will increase growth and income in most countries along the BRI corridors), and environmental risks (greenhouse gas pollution, transport pollution, topographic , hydrological and other damages, as well as changes in the habitat due to the loss of biodiversity, etc.) (Hamilton, 2014; WB, 2019). The scientific literature covers assessments of the environmental impact of high-speed railways (He et al., 2015; Chang, Suocheng, 2017). Numerous works are devoted to regional problems of resource depletion, environmental degradation and institutional factors that become bottlenecks for the economic development of many regions, including those considered in the present research (Bansal, 2015). The need to transform the model of economic development and actively promote environmental progress is justified based on measuring regional industrial environmental efficiency in 31 provinces and cities of China and analyzing the factors influencing it (Xu, Berck, 2014; Mingran, 2020).

The level of environmental efficiency is not only an important guarantee of healthy and sustainable growth of the regional economy but also a key component in measuring regional competitiveness. In (Li et al., 2019), using the DEA method, regional differences in the energy and environmental efficiency of Chinese provinces and cities were investigated. A comprehensive assessment of the ecological and socio-economic situation in the territories that make up the Baikal region (Irkutsk Oblast, the Republic of Buryatia and Zabaykalsky Krai) allowed identifying the features of regional development and design recommendations for positively changing it based on the principles of a green economy (Mikheeva et al., 2016; Bardakhanova et al., 2017; Karnaukh et al., 2018; Bilgaev et al, 2020). An integrated system of indices of urbanization and ecological environment in the Siberian and Far Eastern federal districts of the Russian Federation was proposed for consideration in (Zheng et al., 2020). An attempt was made to identify the relationship between the level of economic development of the regions of Kazakhstan and the prevailing environmental situation in them and to assess the degree of development of the green economy at the meso-level using an integral indicator based on taking into account the adjusted net savings (Varavin, Kozlova, 2018). At the same time, the impact of the large-scale Chinese Belt and Road Initiative on the sustainable development of adjacent territories based on the principles of a green economy on the regional scale remains poorly understood.

It is necessary to study the initial ecological and economic state of the regions where the BRI is being implemented. Regional features are determined by several objective climatic, geographical, economic factors, environmental and ethnic characteristics, as well as historically established territorial and sectoral structures of the economy. These structures do not always correspond to the specialization and natural potential of the territories. Therefore, the present study addresses issues related to the comprehensive analysis of the environmental aspects of the development of border regions and the assessment of their ecological and economic state.

The recent changes in approaches to understanding sustainable development and the paths of transition to a green economy inevitably led to changes in the indicator systems. New conditions dictate the need to create such systems of indicators for the development of territories that allow tracking progress in the development of a green economy and make management decisions. Many environmental, economic and social indicators and different approaches to the development of complex indicators characterize the links and interactions between the economy and the environment: GPI – genuine progress indicator, ANS – adjusted net savings, GGI – green growth indicators, EPI – environmental performance index, GGEI – global green economy index, EPS – Environmental Policy Severity Index, CCPI – Climate Change Performance Index, EVI – Environmental Vulnerability Index, LCEI – Low Carbon Economy Index, etc. (Emerson et al., 2012; Dual Citizen LLC, 2014; UNEP, 2012, 2014). In practice, decisions need to be made on both the approach and the choice of indicators for informing policy-makers, especially since it is costly to measure, process, interpret and communicate information. Detailed environmental, economic and social information can be combined in ways broadly classified along four lines: indicator information sets, composite indicators, footprints, and "adjusted" economic indicators. Each of the four approaches contains information on environmental-economic interactions and has its pros and cons, which are well covered in the literature.

Despite different measurement systems, there is a general understanding that the choice of measurement approaches and indicators should be tailored to the specific needs and conditions of a particular country, as well as the measurement capabilities (Botta, Koźluk, 2014; EaP Green, 2016; Hsu et al., 2016). Approaches to the development of indicators assessing the progress of specific territories of the regional level in the direction of green growth are presented in the works of Russian scientists (Bobylev et al., 2012; Lyapina, 2012; Tereshina, Degtyareva, 2012; Belik, Pryakhin, 2013; Valentey et al., 2014; Yashalova, 2014; Yakovlev, Kabir, 2016; Nikitin et al., 2017; Bardakhanova, Eremko, 2019; Belik, Yachmeneva, 2019; Skobelev, 2019). The present research aims to investigate the environmental aspects of the development of border regions economies by constructing a CI based on the OECD methodological approach (OECD, 2014; Green Growth Indicators, 2017; Capozza, Samson, 2019; OECD, 2020). Scientific novelty and contribution are as follows. First, this is the first study to comprehensively look at the BRI border regions of Russia, China and Kazakhstan from a green economy perspective. Second, for the analysis and assessment of the ecological and economic situation, a methodology for constructing a CI based on a set of indicators characterizing various aspects of the interaction between the economy and the environment in specific territories is proposed.

Third, the results obtained allow taking into account the environmental aspects of economic development and obtaining quantitative estimates of the green dimension of the economies of border regions, which allows comparing them, identifying individual factors affecting the value of the CI, and determining directions for changing the existing approaches in the management of regions, taking into account the development of a green economy. This will allow local authorities to understand the problems the regions face and to formulate reasonable goals and find ways to solve them based on the principles of a green economy.

MATERIALS AND METHODS

Definition of a CI

As noted in (Mazziotta, Pareto, 2013), a single descriptive indicator cannot measure several socio-economic phenomena, instead they must be presented in several dimensions. This combination can be obtained by applying methodologies known as composite indices. OECD Practical Guidelines contribute to a better understanding of the complexity of CI and improve the methods used to construct them. CI can summarize and effectively compare complex, multidimensional realities to support decision-makers; they are easier to interpret than many individual indicators; one can assess the progress of countries over time. At the same time, creating a CI is a complicated task and is associated with difficulties in accessing the source data, the choice of individual indicators, and approaches to their processing for comparison and aggregation. (Salzman, 2003; Nardo et al., 2005; OECD, 2008). Quantification of a CI assumes a comprehensive consideration of various aspects of the assessment, each including a number of indicators (statistical or calculated using different types of data, forms and methods of assessment) (OECD, 2014). Since the present research aims to study the environmental aspects of economic development, indicators characterizing environmental efficiency are distinguished as a separate group. Thus, the CI reflects five aspects and includes the following indicators (Table 1):

1) Resource efficiency is characterized by indicators of energy intensity, water intensity and an assessment of the potential capacity of the environment, which is understood as a generalized characteristic of the territory, quantitatively corresponding to the maximum anthropogenic load that can long be withstood by the aggregate of recipients and ecological systems of the territory without violating their structural and functional properties (Akimova, Khaskin, 1994; Batomunkuev, Ayusheeva, 2015; Bardakhanova et al., 2018).

2) Environmental efficiency is measured by indicators of the volumes of reduced emissions of pollutants into the air, discharges of pollutants in wastewater, and production and consumption waste per GRP unit.

These first two groups of indicators reflect the need for the careful use of the environment and natural resources and cover those aspects of production that economic models and accounting systems rarely quantify.

3) The ecological quality of life is represented by indicators of the population's access to water supply, sewerage and wastewater treatment, and the indicator of economic damage from environmental pollution is used which includes additional costs and losses due to an increase in the incidence of the population and a decrease in life expectancy due to the deterioration of the natural environment (Temporary methodology…1999; Mikheeva, Ayusheeva, 2014).

4) Achieving a balance in environmental management requires maintaining a natural asset base, as its decline puts future growth at risk. It is proposed to include the following three indicators in the group of natural assets: the share of the area covered with forest in the total territory, the yield of agricultural crops and the cost estimate of specially protected natural areas. The cost estimate of protected areas is determined through the under-received volume of GRP, since the territory of these areas is completely or partially withdrawn from the economic turnover.

5) It is proposed to include four indicators in the group of institutional factors that help assess the effectiveness of policies aimed at ensuring a balance in the use and conservation of environmental resources: per capita income, the ratio of budget expenditures on education to GRP, the ratio of economic damage from environmental pollution to environmental protection, and environmental and economic index. Comparison of the economic damage from environmental pollution with the volume of investments in nature protection aimed at preventing or eliminating negative impacts gives an idea of the effectiveness of the existing economic mechanism of environmental

management. The ecological-economic index, based on the indicator of true savings in the economy, is relevant for resource-oriented countries and regions, which include Russia, Kazakhstan, and China. This indicator allows assessing the influence of the volumes of the extractive industry on the size of the gross regional product (GRP), the level of environmental pollution and the degree of degradation of ecological systems and revealing the formation structure of adjusted net savings (Bobylev et al., 2012).

Table 1. Directions of assessment and indicators for calculating the CI

General index	Directions of assessment	Indicators
CI X	Resource efficiency X_1	Energy intensity (volume of electricity consumption per unit of GRP), kW * hour/USD X_{11}
		Water capacity (volume of water consumption per unit of GRP), m^3/USD X_{12}
		Assessment of the potential capacity of the environment, thous. TOE X_{13}
	Environmental efficiency X_2	Volume of emissions of pollutants into the air per unit of GRP, TOE/USD X_{21}
		Volume of discharges of pollutants in wastewater per unit of GRP, TOE/USD X_{22}
		Volume of production and consumption waste per unit of GRP, TOE/USD X_{23}
	Ecological quality of life X_3	Economic damage from environmental pollution, mil. USD X_{31}
	Natural assets X_4	Share of forested area in the total territory, % X_{41}
		Productivity, c / ha X_{42}
		Cost estimate of protected areas, bil. USDX_{43}
	Institutional factors X_5	Ratio of economic damage and environmental investment, times X_{51}
		Per capita income (GRP/population, USD) X_{52}
		Ratio of budget expenditures on education to GRP (%) X_{53}
		Ecological and economic index,% X_{54}

Source: Developed by the authors using the OECD approach (OECD, 2014)

Methodology for quantifying a CI

The general list of indicators for calculating the CI consists of 14 points, the calculation formulas for which are presented in Table 2.

Table 2. Formulas for calculating the initial indicators

Indicators	Calculating formula
Energy intensity (volume of electricity consumption per unit of GRP), kW * hour/USD X_{11}	$E_i = \frac{V_{eabs}}{GRP}$, where E_i –is Energy intensity, $V_{e\,abs}$ is volume of electricity consumption, GRP is gross regional product
Water capacity (volume of water consumption per unit of	$W_c = \frac{V_{wabs}}{GRP}$,

GRP), m^3/USD X_{12}	where W_c is water capacity, $V_{w\,abs}$ is volume of water consumption, GRP is gross regional product
Assessment of the potential capacity of the environment, thous. TOE X_{13}	$E = V \times C \times F$, where E is ecological capacity, V is the extensive parameter determined by the size of the territory, km^2 and its volume km^3, C is the content of the main ecologically significant substances in the environment, t/km^3, t/km^2, F is the rate of multiple renewal of the volume or mass of the environment, year
Volume of emissions of pollutants into the air per unit of GRP, TOE/USD X_{21}	$I_{SEP} = \frac{P_{abs}}{GDR}$, where I_{SEP} is specific emissions of pollutants into the air, $P_{abs.}$ is the absolute value of the indicator of the emission of pollutants into the air, GDP is the gross domestic product
Volume of discharges of pollutants in wastewater per unit of GRP, TOE/USD X_{22}	$I_{spec} = \frac{WW_{abs}}{GDP}$, where I_{spec} is specific discharges of contaminated wastewater into water bodies, WW_{abs} the absolute value of the indicator of discharge of polluted wastewater into water bodies, GDP is the gross domestic product
Volume of production and consumption waste per unit of GRP, TOE/USD X_{23}	$I_{Wspec} = \frac{O_{abs}}{GDP}$, where I_{Wspec} is specific volumes of production and consumption waste, O_{abs} the absolute value of the indicator of the volume of production and consumption waste, GDP is the gross domestic product
Economic damage from environmental pollution, mil. USD X_{31}	$ED = D_{spec} \times m$, where D_{spec} is the indicator of specific damage to atmospheric (water, land) resources caused by a unit of the reduced mass of pollutants, USD/TOE, m is the reduced mass of emission (discharge, placement) of pollutants, TOE
Share of forested area in the total territory, % X_{41}	I for = S for / Sterr, where S_{for} is the forested area, S_{terr} is the terriory
Productivity, c/ha X_{42}	statistical indicator
Cost estimate of protected areas, bil. USDX_{43}	$SPNL = \frac{GRP}{(100 - shareSPNL\%)} \times shareSPNL\%$, where GRP is the volume of the gross regional product, USD, protected areas are the share of specially protected natural land in the total territory,%
Ratio of economic damage and environmental investment, times X_{51}	$I = \frac{ED}{I_{envir}}$, Where ED is economic damage from environmental pollution, USD, $I_{envir.}$are environmental investments, USD
Per capita income (GRP/population, USD) X_{52}	GRP / population

Ratio of budget expenditures on education to GRP (%) X_{53}	Budget spending on education / GRP
Ecological and economic index,% X_{54}	$$EEI = \frac{ANS}{GRP} \times 100\%,$$ where EEI is environmental-economic index, %, ANS is adjusted net savings, USD $$ANS = GCF - I_{extr} - C_{Vextr} - ED + EHC + CEEP + PA,$$ where GCF is gross fixed capital formation, $I_{extr.}$ is investments in fixed assets from extraction of minerals, $G_{Vextr.}$ is volume of gross value from extraction of minerals, ED is damage from environmental pollution, EHC is budget expenditures for the development of human capital, CEEP is capital expenditures for environmental protection (USD), PA is cost estimate of protected areas

Source: developed by the authors

Table 3 summarizes the main stages for evaluating the CI. At Stage 1, initial data are calculated by groups of indicators (Tables 1, 2). At Stage 2, the obtained initial indicators are normalized according to the proposed formula. Further, to take into account the probabilistic nature of the statistical data that are used in the calculations, the entropy of the indicators is calculated. Taking into account the obtained value of entropy, quantitative estimates of indicators for each group are subsequently calculated and then normalized, and at the last stage, the sum of their weighted values gives a quantitative estimate of the CI.

Table 3. The main stages quantitatively assessing the CI

Stage	Calculation formulas	Legend
Stage 1. Calculating the baseline indicators	Baseline indicators are presented in Table 7	
Stage 2. Standardizing the indicators	– for variables of Type 1* $x'_{ij} = \frac{x_{ij} - x_{j\,min}}{x_{j\,max} - x_{j\,min}}$ – for variables of Type 2* $x'_{ij} = \frac{x_{i\,max} - x_j}{x_{j\,max} - x_{j\,min}}$	i is index of model territories (i = 1,..., m); j is index of indicators (j = 1,..., n); x_{ij} is the value of the j-th indicator in the i-th territory; x_{jmax} express the maximum of x_{ij}; x_{jmin} express the minimum of x_{ij}.
	* Note: variables of Type 1 mean indicators with positive dynamics, variables of Type 2 those with negative dynamics	
Stage 3. Calculating the entropy as a measure of the uncertainty of the indicators system	$N_x = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij}$, $p_{ij} = \frac{x'_{ij}}{\sum_{j=1}^{n} x'_{ij}}$	where N_x expresses the entropy of the indicator j, and p_{ij} expresses the fraction of the j-th indocator, k = 1/lnm

Stage 4. Multiple assessments for each group of indicators (X_{1i}, X_{2i}, X_{3i}, X_{4i}, X_{5i})	$X_{qi} = \sum_{j=1}^{n} v^j x'_{ij}$, $v^j = \frac{b^j}{\sum_{j=1}^{n} b^j}$ $\mathbf{bj = 1 - Nx}$	where v^j is the weight of entropy for indicator j; b^j is information value; q is the index of groups of indicators (q = 1,..., 5)
Stage 5. Normalizing the obtained multiple estimates of indicators	$X_{qi}^{1} = \frac{I_{qi} - I_{q\,min}}{I_{q\,max} - I_{q\,min}}$.	X_{qmax} express the maximum of X_{qj}; X_{qmin} express the minimum of X_{qj}.
Stage 6. Quantifying the CI	$H_i = \sum_{q=1}^{5} \mathbf{X}_{q1}^{1} w_q$	where w_q expresses the weight of each group of indicators (the significance of groups of indicators may differ)

Source: developed by the authors based on (Nardo et al., 2005; OECD, 2008)

Model territories

Approbation of the proposed methodological approach was carried out on the example of nine border territories of Russia, China and Kazakhstan, which have checkpoints as points of intersection of transport corridors, ensuring the creation of strategic reference points for the development of internal border regions. The model territories with corresponding checkpoints included: five constituent entities of the Russian Federation, namely, the Republic of Buryatia (Kyakhta-Altanbulag), Altai Republic (Tashanta-Tsagaannuur), Amur Oblast (Blagoveshchensk-Heihe), Zabaykalsky Krai (Zabaikalsk-Manchuria) and Altai Krai (Mikhailovka-Uba); two autonomous regions of China, namely, Xinjiang (Alashankou-Dostyk) and Inner Mongolia (Manchuria-Zabaikalsk); two regions on the territory of Kazakhstan, namely, East Kazakhstan Region (Dostyk-Alashankou) and East Kazakhstan region (Uba-Mikhailovka).

The initial data for the selected model territories were obtained from state reports on the socio-economic situation and the state of the environment of the constituent entities of the Russian Federation, the People's Republic of China and the Republic of Kazakhstan, information materials of Rosstat on the territorial bodies, documents of ministries and departments, literature and Internet sources (World and regional statistics, Unified interdepartmental information and statistical system, Federal State Statistics Service, National Bureau of Statistics of China). All the used indicators were brought into a comparable form. The value units of the various countries were quoted in current international dollars based on the 2015 purchasing power parity round according to the World Bank (https://databank.worldbank.org).

RESULTS AND DISCUSSION

Calculation of baseline indicators and a comparative assessment of the ecological and economic state of the model territories

Table 4 presents the main characteristics that allow comparing the model territories of Russia, China and Kazakhstan.

Table 4. Comparative socio-economic characteristics of model territories (2015)

Regions	Area, thousand km²	Population (as of 01.01.2016), thousand people	GRP volume, thousand USD	GRP volume, USD/person	Population density, people/ km²	Ratio of urban and rural population
The Republic of Buryatia, Russia	351.3	982.3	3047.1	3102	2.8	59 / 41
Zabaykalsky Krai, Russia	431.5	1083	3714.1	3429	2.5	65 / 35
Altai Republic, Russia	92.6	215.2	689.4	3203	2.3	29 / 71
Altai Krai, Russia	169.1	2376.8	7345.4	3090	14.1	56 / 44
East Kazakhstan Region, Kazakhstan	283.2	1 395.8	12582.3	9014	4.9	61 / 39
Almaty Region, Kazakhstan	223.9	2021.6	13609.3	6732	9.0	23 / 77
Xinjiang, China	1665	22980	145700000	6510	13.8	44 / 56
Inner Mongolia, China	1183	25110.4	278617343.8	11095	21.2	60 / 40

Source: statistical data (World and regional statistics, national data, maps and ratings, n.d.; World Bank, 2019; Xu, Berck, 2014; Yakovlev, Kabir, 2016; Yashalova, 2014) and materials of reports prepared within the framework of the state assignment of the Baikal Institute of Nature Management of the Siberian Branch of the Russian Academy of Sciences.

The economy of the Russian regions under consideration is based on the manufacturing industry – machine building and metalworking, mining (gold, coal, and uranium), building materials industry, forestry, electrical equipment manufacturing, as well as food and light industries. Almaty Region has no significant reserves of mineral resources. There are the light and food industries, mechanical engineering, the construction industry, etc., yet in general it is characterized by an agricultural orientation. The East Kazakhstan region is focused on the development of industry: the economy is based on energy, mechanical engineering, forestry, etc. In the GRP structure of Inner Mongolia, the share of manufacturing and construction significantly decreased in recent years, and the role of wholesale and retail trade, hotel and restaurant services, and financial intermediation increased. In the western part of Inner Mongolia, the mechanical engineering and chemical industries are traditionally developing, and production of new and high technologies based on the use of rare earth metals is developing (Namzhilova, 2016). Xinjiang is an agricultural region where livestock farming, cotton and fruit production are well developed, it has rich natural resources (oil, coal, polymetals, etc.), and industry and services are intensively developing here. The analysis of the natural environment in terms of specific indicators of pollution allowed identifying areas with the greatest load on the components of the natural environment. The volume of the reduced mass of pollutants into the atmosphere in Xinjiang and Inner Mongolia is much higher than similar Russian and Kazakh indicators (Tables 5 and 6).

Table 5. Economic damage from emissions of pollutants from stationary sources in the regions of the Russian Federation and the Republic of Kazakhstan (2015)

Regions	Reduced weight of pollutants, TOE	Economic damage from pollution, thousand RUR	Pollution payment, thousand RUR	Ratio of economic damage and pollution payment, times
The Republic of Buryatia, Russia	1181.8	365542.9	31448	11.6
Zabaykalsky Krai, Russia	1044.1	339098.0	19492	17.4
Altai Republic, Russia	42.4	16843.3	n/d	n/d
Altai Krai, Russia	1416.4	562359.0	14585	38.6
East Kazakhstan Region, Kazakhstan	1209.6	374132.4	673072.9	0.6
Almaty Region, Kazakhstan	332.1	102731.2	177704.4	0.6

Source: statistical data (World and regional statistics, national data, maps and ratings, n.d.; World Bank, 2019; Xu, Berck, 2014; Yakovlev, Kabir, 2016; Yashalova, 2014) and materials of reports prepared within the framework of the state assignment of the Baikal Institute of Nature Management of the Siberian Branch of the Russian Academy of Sciences.

According to the official information of the China Bureau of Statistics on emissions of pollutants from stationary sources, data are available only on emissions of sulfur dioxide, nitrogen oxides and solid substances (Table 6).

Table 6. Emissions of pollutants into the atmosphere of the autonomous regions of the PRC (Xinjiang and Inner Mongolia) (2015)

Pollutants	Coefficients of environmental and economic hazard	Xinjiang		Inner Mongolia	
		Pollutants, thousand t	Pollutants, thousand TOE	Pollutants, thousand t	Pollutants, thousand TOE
sulfur dioxide	20	778.3	15566.6	1061	21220
nitrogen oxides	16.5	73.7	1215.2	864.6	14265.9
solids	2.7	595.9	1609.0	656.7	1773.09
TOTAL:			18390.8		37258.99

Source: statistical data (World and regional statistics, national data, maps and ratings, n.d.; World Bank, 2019; Xu, Berck, 2014; Yakovlev, Kabir, 2016; Yashalova, 2014) and materials of reports prepared within the framework of the state assignment of the Baikal Institute of Nature Management of the Siberian Branch of the Russian Academy of Sciences.

An assessment of the economic damage for emissions of pollutants shows that in comparison with the payment for air pollution, a damage prevails overcompensation payments in Russian regions, ad in Kazakhstan the payment for atmospheric pollution is comparable to the economic assessment of the damage caused. Table 7 shows the indicators of pollution density per area unit and per person in the regions of Russia and Kazakhstan.

Table 7. Specific indicators of the reduced mass of pollutant emissions in the regions of the Russian Federation and the Republic of Kazakhstan

Regions	t/km²	t/person
The Republic of Buryatia	3.4	1.2
Zabaykalsky Krai	2.4	1.0
Altai Republic	0.5	0.2
Altai Krai	8.4	0.6
East Kazakhstan Region	4.3	0.9
Almaty Region	1.5	0.2

Source: statistical data (World and regional statistics, national data, maps and ratings, n.d.; World Bank, 2019; Xu, Berck, 2014; Yakovlev, Kabir, 2016; Yashalova, 2014) and materials of reports prepared within the framework of the state assignment of the Baikal Institute of Nature Management of the Siberian Branch of the Russian Academy of Sciences.

The largest volume of emissions is in Altai Krai (8.4 t/km^2), the lowest in Altai Republic (0.5 t/km^2). The maximum value of emissions per person in 2015 among the considered regions was in the Republic of Buryatia – 1.2 t/person. Table 8 presents the calculated indicators of pollution fluxes (t/km^2 and t/person), an estimate of the economic damage from atmospheric air pollution, its ratio with GRP, as well as the volume of investments in the protection of atmospheric air in the autonomous regions of the PRC.

Table 8. Economic damage from air pollution in autonomous regions of the PRC (Xinjiang and Inner Mongolia) (2015)

Regions	Reduced weight of pollutants, TOE	Economic damage from pollution, thousand RUR	Economic damage relative to GRP, %	Investments aimed at air protection, thousand USD
Xinjiang, China	18390.8	93869.9	0.06	208810.9

t/km2	11.05			
t/pers	0.8			
Inner Mongolia, China	37259.0	190176.3	0.07	574360.9
t/km2	31.50			
t/pers.	1.5			

Source: statistical data (World and regional statistics, national data, maps and ratings, n.d.; World Bank, 2019; Xu, Berck, 2014; Yakovlev, Kabir, 2016; Yashalova, 2014) and materials of reports prepared within the framework of the state assignment of the Baikal Institute of Nature Management of the Siberian Branch of the Russian Academy of Sciences

In Xinjiang and Inner Mongolia, there are high levels of air pollution per area unit – 11.05 and 31.05 t/km^2, respectively, while pollution indicators per person are comparable to Russian and Kazakhstan indicators. In the considered regions of the PRC, investments aimed at protecting the atmosphere significantly exceed the economic damage from atmospheric pollution. Economic damage from air pollution relative to GRP is 0.06-0.07%. Table 9 shows the volumes of discharges of pollutants into the water resources of in Xinjiang and Inner Mongolia.

Table 9. Discharge of pollutants into the water bodies of the autonomous regions of the PRC (Xinjiang and Inner Mongolia) (2015), thousand tons

	Coefficients of Environmental and economic hazard	Xinjiang	Inner Mongolia
Chemical oxygen demand	0.3	660.3	835.6
Ammonia	20	45.6	46.9
Nitrogen	1	155.4	189.3
Phosphorus	1	13	21.5
Oil	20	4.06	1.21
Phenol	550	91.3	0.15
Lead	11	0.14	11.87
Mercury	15000	0.02	0.038
Cadmium	250	0.02	1.62
Chromium	550	8.24	0.56
Arsenic	60	0.62	19.66
Hexavalent chromium	550	0.53	0.03
Total, TOE		6577.2	4115.9
Economic damage from water bodies pollution, thousand USD		8 036 232.7	5 028 874.5

Investments directed to wastewater treatment, thousand USD		34 414.1	61 825

Source: statistical data (World and regional statistics, national data, maps and ratings, n.d.; World Bank, 2019; Xu, Berck, 2014; Yakovlev, Kabir, 2016; Yashalova, 2014) and materials of reports prepared within the framework of the state assignment of the Baikal Institute of Nature Management of the Siberian Branch of the Russian Academy of Sciences.

In the structure of environmental investments (Table 10), the largest share belongs to investments aimed at combating industrial pollution – 50%. In Xinjiang, the share of investments directed to wastewater treatment was 7%, in Inner Mongolia – 4.5%, and investments in the protection of atmospheric air are 41.9-42.2%.

Table 10. The structure of environmental investments in the autonomous regions of the PRC (Xinjiang and Inner Mongolia), 2015

Investment directions	Xinjiang		Inner Mongolia	
	thousand USD	%	thousand USD	%
Investments to tackle industrial pollution	247285.9	50.0	685835.9	50.0
Investment in wastewater treatment	34414.1	7.0	61825	4.5
Investments to tackle exhaust gases	208810.9	42.2	574360.9	41.9
Investment in solid waste treatment	512.5	0.1	16243.75	1.2
Investments To tackle noise pollution	-	-	498.4	0.001
Investments to tackle other types of pollution	3548.4	0.7	32907.81	2.4
Total environmental investments	247285.9	100	1371672	100

Source: statistical data (World and regional statistics, national data, maps and ratings, n.d.; World Bank, 2019; Xu, Berck, 2014; Yakovlev, Kabir, 2016; Yashalova, 2014) and materials of reports prepared within the framework of the state assignment of the Baikal Institute of Nature Management of the Siberian Branch of the Russian Academy of Sciences

In the model territories of China, high values of economic damage from pollution of water resources were revealed, which far exceed the amount of investments for their protection. Estimated indicators of water capacity for the production of GDP worth 1000 USD per m^3 were in Russia (0.004), China (0.055), Mongolia (0.015), Kazakhstan (0.110), and showed twice as large water consumption in Kazakhstan compared to China. Thus, in the considered model territories, economic growth is ensured by the intensive use of natural resources, which leads to an increase in financial losses associated with environmental pollution and the need to increase compensation costs for resource restoration.

Quantifying the CI

To quantify the CI, a set of baseline indicators calculated according to the formulas of Table 2 and presented in Table 11 was used. Further, according to the methodology (Table 3, Stage 2), the initial data were normalized. At the next stage, the entropy of the indicators was calculated. Thus, for X_{11} it is 0,692, for X_{12} – 0,784, for X_{13} – 0,639, X_{21} – 0,770, X_{22} – 0,785, X_{23} – 0,772, X_{31} – 0,759, X_{41} – 0,678, X_{42} – 0,584, X_{43} – 0,618, X_{51} – 0,581, X_{52} – 0,635, X_{53} – 0,627, X_{54}– 0,658. At Stage 4, multiple scores of indicators were calculated. The summation of multiple assessment indicators gives the index value for each of the five groups of indicators. At the next stage, the value of the multiple assessment of the index by groups of indicators was normalized. Next, the CI was calculated for each model area. The results of the quantitative assessment of the CI are shown in Figure 1.

Table 11. Initial data for calculating the CI, 2015

	Resource efficiency			Ecological efficiency			Ecological quality of life	Natural assets			Institutional factors			
Regions	X_{11}	X_{12}	X_{13}	X_{21}	X_{22}	X_{23}	X_{31}	X_{41}	X_{42}	X_{43}	X_{51}	X_{52}	X_{53}	X_{54}
Buryatia	1.71	0.160	14.5	0.35	0.0003	11.83	145.52	62.30	7.70	358.10	3420	0.0044	31.03	14.4
Altai Republic	0.77	0.010	1.2	0.06	0.0004	0.002	125.58	44.40	11.10	264.00	3203	0.0034	17.02	66.2
Altai Krai	1.45	0.050	0.9	0.19	0.0004	0.17	4.89	26.40	10.90	430.80	3090	0.0103	30.57	21.6
Zabaykalsky Krai	1.89	0.060	12.7	0.25	0.0005	8.36	16.64	68.20	11.00	269.30	3792	0.0030	5.78	14.5
Amur Oblast	1.68	0.020	39.4	0.08	0.0003	0.11	3.26	35.00	14.60	593.70	5392.7	0.0022	2.01	25.8
Almaty Region	0.09	0.003	0.9	0.02	0.0004	0.02	29.99	8.30	23.50	830.00	6732	0.0026	1.87	112.9
East Kazakhstan Region	0.30	0.010	22.4	0.10	0.0004	0.01	24.27	7.00	13.50	2212.80	9014	0.0070	121.34	96.4
Xinjiang	1.48	0.400	25.04	0.13	0.0450	0.02	1.83	4.20	62.70	4.40	6510	0.0160	0.41	84.5

Inner Mongolia, China	0.91	0.070	47.3	0.13	0.0150	0.01	1.17	21.10	48.70	7.50	11095	0.0070	0.09	77.7

Source: statistical data (World and regional statistics, national data, maps and ratings, n.d.; World Bank, 2019; Xu, Berck, 2014; Yakovlev, Kabir, 2016; Yashalova, 2014) and materials of reports prepared within the framework of the state assignment of the Baikal Institute of Nature Management of the Siberian Branch of the Russian Academy of Sciences.

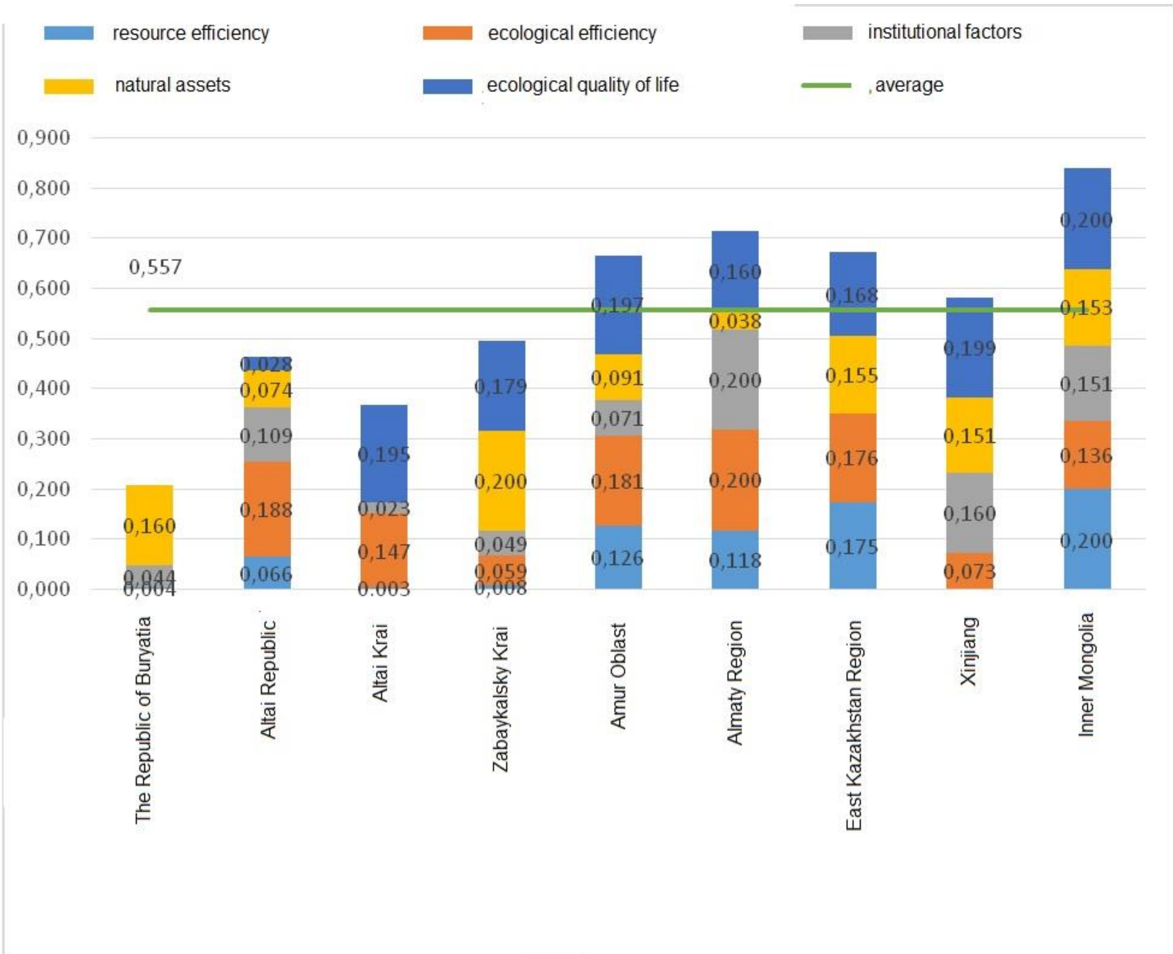

Figure 1. CI characterizing progress in the development of a green economy in the border regions of Russia, China and Kazakhstan
Source: developed by the authors.

The calculations of the CI revealed: a significant excess of the average value of the index (0.557) in Inner Mongolia (1.5 times) and Almaty region (1.3 times). At the same time, these territories are characterized by an almost even distribution of all the factors for the development of a green economy, except for the factor of natural assets (the indicator of forest area in Inner Mongolia is higher than in Almaty region); CI of the East Kazakhstan (0.673) and Amur (0.667) regions and Xinjiang (0.583) are close to the average value, but the structure of the index in the East Kazakhstan region differs in terms of the influence of natural assets factor and of the institutional factor for a high assessment of the cost of protected areas and a significant excess of economic damage over the level of environmental investments; The group of regions with an index value below the average includes 4 border regions of Russia. In all these regions, the same low values of resource efficiency are observed. The minimum value of the composite index is in the Republic of Buryatia (0.208). Even though the Republic of Buryatia has a relatively high potential for environmental capacity and a large area of forests, the final value of the composite indicator was negatively affected by the minimum values of environmental and resource efficiency, a high level of waste generation, and a significant excess of economic damage over the level of environmental investments.

CONCLUSION

1. Analysis of the natural environment in terms of specific indicators of environmental pollution allowed identifying areas with the greatest load on the components of the natural environment: the largest volume of emissions per sq. km was in Altai Krai (8.4 t/km^2), the lowest in the Altai Republic (0.5 t/km^2). The maximum value of emissions per 1 person in 2015 among the regions under consideration was observed in the Republic of Buryatia - 1.2 t/person; in Xinjiang and Inner Mongolia, the highest indicators of atmospheric pollution per area unit are observed – 11.05 and 31, 05 t/km^2, respectively, while pollution rates per person are comparable to Russian and Kazakhstan indicators; the largest volume of emissions for a mono-pollutant in 2015 is in Inner Mongolia (37258.99 thousand TOE), the lowest value in Altai Republic (42.4 thousand TOE); the mass of pollutants in terms of mono-pollutant in Inner Mongolia is almost 2 times higher than in Xinjiang, which is associated with the location of manufacturing enterprises (mechanical engineering and metalworking); the volumes of the reduced masses of pollutants into the atmosphere in Xinjiang and Inner Mongolia are much higher than similar Russian and Kazakhstan indicators.

2. Comparing quantitative assessment of economic damage for emissions of pollutants with the amount of payment for atmospheric air pollution showed that damage exceeded compensation payments in the Russian regions, while in Kazakhstan the payment for atmospheric pollution is comparable to the economic assessment of the damage caused.

3. In the considered regions of the PRC, investments aimed at protecting the atmosphere significantly exceed the economic damage from atmospheric pollution. The economic damage from air pollution in the GRP is 0.06-0.07%. At the same time, in these model territories of China, the values of economic damage from pollution of water resources are much higher than the amount of investments for their protection. This situation indicates the need to change the priorities in environmental financing.

4. A quantitative assessment of the CI allowed distinguishing 3 types of regions: a) high values of the CI were in Inner Mongolia and the Almaty region have the highest CI ((0.839 and 0.716), 1.5 and 1.3 times higher than the average (0.557). These regions are even in almost all the aspects of developing the green economy; b) the values of the CI close to the average were obtained by the East Kazakhstan region (0.673), Amur Oblast (0.667) and Xinjiang (0.583). The East Kazakhstan region differs in terms of the greater share of natural assets and the institutional factor due to the high assessment of the cost of protected areas, and economic damage is significantly larger than environmental investments; c) in four border regions of Russia (The Republic of Buryatia, Altai Republic, Altai Krai, Zabaykalsky Krai) due to equally low values of resource efficiency, the CI is below average. The minimum value of the CI is in the Republic of Buryatia (0.208) despite its relatively high potential for environmental capacity and large forest area of forests. The final CI was negatively affected by the minimum values of environmental and resource efficiency, a high level of waste

generation, and economic damage being larger than environmental investments, which indicates low efficiency of the environmental regulation of economic activities in the Baikal region.

5. The results of calculating the CI confirm the earlier conclusion that the model territories considered in the study provide economic growth due to high natural assets. Resource efficiency is extremely low, especially in Russian regions. Financing of environmental protection measures is insufficient, which leads to an increase in financial losses associated with environmental pollution and indicates the need to improve institutional relations in terms of developing economic incentives to reduce economic damage from environmental pollution.

6. The calculations performed according to the developed methodology for quantitative assessment of the CI allow obtaining estimates of the starting level of the green economy development in the regions under consideration, as well as obtaining tools for monitoring indicators in dynamics and developing recommendations for making management decisions in the future.

7. The results of the study indicate that the methodological approach to calculating and quantitatively assessing the CI, based on a multilevel system of indicators, allow analyzing the ecological and economic state at the regional level, comparing the model territories for different groups of indicators and identifying the best ones. This experience can be practical and valuable for regions that seek to create the basis for the development of a green economy.

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