Russia and China: comparative analysis of ecological and economic development trends

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Abstract. The purpose of this article is to assess the development trends of Russia and China using the colors of growth framework. It allows us to characterize the dynamics of development as "green", "brown" or "black" growth (or degrowth) in relation to the consequences of economic activity. Based on the data from the World Bank and National statistical services, we evaluated the development trends of these countries, taking into account the resource consumption and environmental pollution. The characteristic of the level of economic development in study is GDP based on purchasing power parity (PPP) in constant prices of 2011. Also, we used the following ecological-economic indicators: eco-intensity of carbon dioxide emission (CO₂) and wastewater discharges; energy intensity level of primary energy. The results of calculations showed that both countries had generally "brown" growth in the context of energy consumption. In China, the situation is slightly worse than in Russia. A more positive dynamics is also observed in Russia in terms of CO₂ emissions and wastewater discharge. It is shown that ecological-economic development trends of some Eastern border regions of Russia are much worse than at the national level. The results of this study can be used to determine priority directions for development at both the national and regional levels. They can also be taken into account in the process of discussing and making decisions on the implementation of investment projects, including Russian-Chinese initiatives.

1. Introduction
Currently, many countries are developing and implementing plans for the transition to a green economy. The key features of green economy are the reduction of environmental pollution and the efficient use of natural resources. China's rapid economic growth causes a high degree of negative impact on the environment, which is most acute in relation to air pollution. China is a leader in the group of the most heavily polluting countries: it has the highest level of CO₂ emissions. The current environmental situation in the Russian Federation is characterized as consistently negative with no clear tendency to improve [1]. Russia ranks fourth in this rating (after China, the United States and India), while the air pollutant emission per capita in the country exceeds the emission levels in many developed countries.

Various models and methods are widely used to study the relationship between economic development and its accompanying negative consequences, and a large number of scientific publications are devoted to their study. A special position among them is taken by the colors of growth framework [2]. Using this model, P. Victor estimated the quality of economic growth in Canada in the period from 1990 to 2011. As the initial parameters, he used the specific indicators of negative impact: CO₂ emissions per unit of GDP. Subsequently, Victor’s model was widely used in a number of
publications. For example, it was used for the assessment of the Chinese economy development dynamic in the context of CO\textsubscript{2} emissions [3]. In the articles of the Russian authors, special attention is paid to the study of the relationship between economic growth and the degree of environmental pollution on the regional level [4, 5]. Modification of Victor’s model was adapted for comparative spatial analysis of Russian regions. On its basis, the dynamics of the regional forest use was studied [6], as well as socio-ecological spatial analysis was performed using the two quantitative factors that characterize the population’s welfare: the total wage fund and the own revenues of the regional budgets per capita [7].

Thus, the research based on the colors of growth framework has become particularly relevant, especially in the conditions of increased anthropogenic pressure. The purpose of this article is to identify and compare ecological-economic trends of the two neighboring countries – Russia and China. The quality of economic growth in the Eastern border regions of the Russian Federation will also be assessed, and is of particular interest in the context of expanding Russian-Chinese cooperation.

2. Models and methods
The colors of growth framework allows us to characterize the dynamics of development as "green", "brown" or "black" growth (or degrowth) in relation to the consequences of economic activity. In doing so, we will use this in a broader context. As a consequence of economic growth, we will consider not only the environmental pollution (as is done in most of the above-mentioned articles), but also the depletion of natural resources. An assessment methodology is described in detail in other papers [2, 4, 6]. Here we will give only a brief description of the zones that are highlighted by the ratio of environmental and economic indicators (table 1).

| Ecological-economic zones	extsuperscript{a} | Economic result | Total environmental pressure or resource consumption | Specific environmental pressure or resource consumption |
|---------------------------------------------|-----------------|------------------------------------------------------|------------------------------------------------------|
| “Green” zone (Gr+)                          | Growth          | Degrowth                                             | Degrowth                                             |
| “Brown” zone (Br+)                          | Growth          | Growth                                               | Degrowth                                             |
| “Black” zone (Bl+)                          | Growth          | Growth                                               | Growth                                               |
| “Black” zone (Bl–)                          | Degrowth        | Growth                                               | Growth                                               |
| “Green” zone (Gr–)                          | Degrowth        | Degrowth                                             | Degrowth                                             |
| “Absolutely green” zone (AGr–)              | Degrowth        | Degrowth                                             | Degrowth                                             |

\textsuperscript{a}The "+" and "–" symbols indicate zones where economic growth or degrowth was observed, respectively.

The characteristic of the level of economic development in our study will be the GDP based on PPP in constant prices of 2011, and the indicators of environmental pressure are the volume of wastewater discharge and CO\textsubscript{2} emissions (produced during consumption of solid, liquid, and gas fuels and gas flaring). The volume of primary energy consumption will be taken into account when analyzing the countries’ development trends in the context of natural resources using efficiency.

Key ecological-economic indicators used in this work are the following:
- Energy intensity level of primary energy (the indicator shows how much energy is used to produce one unit of GDP);
- Eco-intensity, which is defined as the amount of negative impact on the environment per unit of economic result [8] (in our study this is the amount of CO\textsubscript{2} emissions and wastewater discharges per unit of GDP).

The study used official data of the World Bank and the National statistical services of the Russian Federation (Federal State Statistics Service) and China (National Bureau of Statistics of China).
3. Results and Discussion

3.1. Economic growth and recourse consumption

When moving towards a green economy, special attention should be paid to the issue of improving the efficiency of the natural resources use. The problem of reducing energy resources consumption per unit of economic result is also relevant for the Russian Federation, since it has energy-intensive economy [9]. Let's analyze the dynamics of the “energy intensity level of primary energy” indicator for some countries, including Russia and China (figure 1). A decrease in this indicator means an increase in the efficiency of primary energy use in the production of economic goods and services. Over the period from 1990 to 2015, all the analyzed countries had begun to consume a lesser amount of primary energy per unit of GDP. The most significant decrease in the indicator (by 68% compared to 1990) was observed in China, whose energy intensity level in 1990 exceeded that of other countries by 1.8-3.6 times.

![Figure 1. Energy intensity level of primary energy for some countries.](image)

In Russia, there was also a positive tendency: the indicator decreased by 30% over the same period. However, since 2010 the Russian economy has been steadily lagging behind other countries (including China) in terms of the analyzed indicator. In 2015, the energy intensity level of primary energy in our country was 2.2 times higher than in Norway, which is characterized by similar climatic conditions.

Using the colors of growth framework, we will analyze the ecological-economic trends of the Russian Federation and China. Table 2 shows the parameters of the starting point $I_0$, relative to which the trajectory of further development is estimated in the context of primary energy consumption and environmental pressure.

The results of the analysis showed that in the period from 2000 to 2015 both countries had generally "brown" character of growth, and that against the background of a decrease in specific indicators of energy intensity there was an increase in the total consumption of primary resources (figure 2). It should be noted, that in China the situation is slightly worse than in Russia. In 2004 and 2005 there was "black" growth observed in the country: the total and specific energy consumption was higher than in the base period. Thus, we can conclude that the transition trends in the analyzed countries to the green growth zone are not yet observed.
Table 2. The parameters of the base point $I_0$: primary energy consumption and environmental pressure.

| Indicators                          | Designation of the indicator on the figures | Russian Federation | China$^a$  |
|------------------------------------|---------------------------------------------|---------------------|------------|
| Coordinate values for point $I_0$ on the vertical axis |                              |                     |            |
| GDP based on PPP (in constant price of 2011), bln. $       | $GDP_{2000}$ | 2079.28              | 4659.12 in 2000 |
| $GDP_{2011}$ | 2011 | 13919.13 in 2011 |
| Coordinate values for point $I_0$ on the horizontal axis |                              |                     |            |
| Energy intensity level of primary energy, MJ per $2011$ PPP GDP | $\text{EnI}_{2000}$ | 12.59                | 10.23      |
| Eco-intensity of CO$_2$ emission, kg per 1000 $\$ 2011$ PPP GDP | $\text{EI}_{CO_2\ 2000}$ | 749.25               | 730.86     |
| Eco-intensity of wastewater discharge, tons per 1000 $\$ 2011$ PPP GDP (China); cubic meters per 1000 $\$ 2011$ PPP GDP (Russian Federation) | $\text{EI}_{ww\ 2000}$ | 9.76                   | 4.74 in 2011 |
| $\text{EI}_{ww\ 2011}$ | 2011 | 4.74 in 2011 |

$^a$ The base period in our study is 2000. Due to changes in China’s statistical accounting system, assessing the quality of economic growth in the context of wastewater discharge was performed for the period from 2011 to 2017.

Figure 2. Color of economic growth in the context of energy intensity level of primary energy.

3.2. Economic growth and environmental pressure

According to the data from the World Bank the global volume of CO$_2$ emissions in 2014 was 36.1 billion tons. The world leader in CO$_2$ pollution is China, which significantly exceeds Russia in terms of this type of environmental pressure (figure 3). In 2014 China accounted for 28.5% of the global emissions. The growth rate number in the amount of emissions in this country is also significantly higher than in Russia: 190.5% and 11.2% for the period from 2000 to 2016, respectively.

In 2000-2002, the Russian Federation and China emitted approximately the same amount of CO$_2$ per unit of economic result. In subsequent time periods, a gap in the analyzed indicator appeared between the countries. In Russia, there was a positive trend: the eco-intensity of CO$_2$ emissions decreased (the overall reduction for the period from 2000 to 2016 was 36.2%). In China, a steady
reduction in the specific indicator of environmental pressure began only in 2011 (the decrease for the same period was 31.7%). In 2016 China and Russia again reached about the same level in terms of this indicator: 499 and 478 kg of CO₂ emission per 1000$ GDP, respectively.

![Figure 3. The dynamics of volume and eco-intensity of CO₂ emissions: China and the Russian Federation, 2000-2014.](image)

The results of development trajectories analysis showed that in recent years, the development of the Chinese economy corresponded to the vector of "brown" growth, but from 2003 to 2006 there was "black" growth, which is characterized by an increase in the economic result with an increase in both the specific and total negative impact (figure 4a). In the Russian Federation, a similar situation is observed: most points are concentrated in the "brown" growth zone. The exception is 2001 and 2002, which were in the "green" growth zone (figure 4b). We can conclude that the ecological-economic trends in the Russian Federation during the analyzed time period was noticeably more positive than in China.

![Figure 4. The Color of economic growth: eco-intensity of CO₂ emission.](image)

a) China

b) Russian Federation
The problem of surface water bodies contamination is very relevant for the reviewed countries. Although the results of the joint monitoring of water quality of transboundary objects conducted in 2011 showed a decrease in the concentration of some pollutants, the level of water pollution in certain sections of the Amur, Ussuri and Argun rivers remains high and very high [10]. From the data presented in figure 5, it can be seen that there was no significant change in the amount of wastewater discharges in China between 2011 and 2017. More positive trends in this type of environmental pressure are observed in the Russian Federation: the volume of polluted wastewater and eco-intensity have significantly decreased – by 33% and 62% compared to the level of 2000, respectively.

![Figure 5. The dynamics of volume and eco-intensity of waste water discharge: China (2011-2017) and the Russian Federation (2000-2018).](image)

Figure 6 shows the development trends for the countries, obtained using the colors of growth framework. The results of calculations showed that only "brown" growth was observed in China. The situation in Russia is more favorable. During the analyzed time period this country demonstrated only "green" growth.

![Figure 6. The Color of economic growth: eco-intensity of wastewater discharge.](image)
In recent years, Russia and China have paid great attention to the economic development of their border territories (in China – North-Eastern regions and in the Russian Federation – Eastern regions). Various strategic and program documents have been developed, and some Russian-Chinese investment projects are being implemented. However, many researchers note the negative trends emerging in the Russian Eastern border regions, which include the strengthening of the raw material orientation of regional economies [11], the occurrence of environmental risks in the implementation of investment projects [12], and the significant migration losses of the population [13].

From the data presented in table 3, it can be seen that in some border regions of the Russian Far East, the ecological-economic dynamics are much worse than at the national level. For example, the calculation for Amur region revealed the black character of growth in the context of carbon emissions in the period 2005, 2007-2017. In 2005 "black" growth was observed in Trans-Baikal Territory, and in the subsequent periods the points were located in the zones of "brown" and "green" growth.

### Table 3. Eastern border regions of the Russian Federation: color of growth

| Regions                  | Green growth (Gr+) | Brown growth (Br+) | Green growth (Br+) | Brown growth (Br+) | Black growth (Bl+) |
|--------------------------|--------------------|--------------------|--------------------|--------------------|------------------|
| Waste water discharge    | Carbon monoxide emissions (CO) |
| Amur Region              | 2006-2017          | 2005               | –                  | 2006               | 2005; 2007-2017  |
| Jewish Autonomous Region | 2006-2008; 2013-2017 | 2005; 2009-2012   | 2005-2009; 2013-2017 | 2010-2012          | –                |
| Khabarovsk Territory     | 2005-2017          | 2005-2009; 2011-2013; 2015-2017 | –                  | –                  |
| Primorye Territory       | 2006-2009; 2011-2017 | 2005; 2010        | 2006-2017          | 2005               | –                |
| Trans-Baikal Territory   | 2006-2009; 2010-2013; 2011-2017 | 2007-2009; 2011-2012 | 2005               |

*a The characteristic of the economic development level of regions is GRP in 2004 prices.

*b Due to the fact that the Federal State Statistics Service does not provide information on CO₂ emissions by the regional level, we used data on CO emissions, which are presented in full.

In relation to the discharges of polluted waste water, most of the Eastern border regions have been consistently in the "green" growth zone since 2000 (although it should be noted that production controls are not perfect, so the real picture may be worse). However, the trajectories for Amur Region, Jewish Autonomous Region, Primorye Territory, and Trans-Baikal Territory also contain some points of "brown" growth.

### 4. Conclusion

Based on the results obtained, we can note the following. In recent years, environmental and economic indicators in Russia and China have improved noticeably: energy intensity level of primary energy and the eco-intensity of the considered negative impacts have decreased. Nevertheless, the problem of increasing the efficiency of resource use in production processes remains relevant for China as well as Russia, whose economy is recognized as one of the most energy-intensive. Comparison of the ecological-economic trends in China and the Russian Federation using the colors of growth framework showed that the countries had generally "brown" growth in the context of primary energy consumption. In China, the situation is slightly worse than in Russia (in some years there was a "black" growth). Russia also shows a more positive development vector in the context of negative environmental impact, especially with regard to wastewater discharges (all points were located in the
"green" growth zone. However, some border regions of the East of the Russian Federation experience a high anthropogenic pressure on the environment. For example, calculations for Amur region revealed the black character of growth in the context of carbon emissions in the period 2005-2017. The strengthening of raw orientation of Russian border territories economies, which is clearly seen in recent years, does not improve the dynamics of their development in the context of the concept of green growth.

The results of this study can be used to determine the priority directions for development at both the national and regional levels. They can also be taken into account in the process of discussing and making decisions on the implementation of investment projects, including Russian-Chinese initiatives.

Further research prospects are related to the assessment and comparative analysis of development trends in some border regions of the Russian Federation and China.

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