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Input-output approach as an instrument for estimation of potential national ecological targets

Abstract

Attention to reducing the negative anthropogenic impact, especially carbon dioxide (CO_2) emissions, is an important part of current vision of sustainable global economic development. The participation of most countries of the world in the climate agenda made this process to be an important factor of the world economic dynamics formation. In December 2015 the Paris Agreement was adopted. According to this agreement, each party shall set and achieve nationally determined contributions to the global response to climate change. Still many developing countries are considering the subject of CO_2 emissions limitations as a way to restrict their economic and technological development, as well as to maintain the leadership of developed countries in the world trade. The assessment of the risks and consequences of the climate control measures application is becoming an important factor to form the reasoned position in the international dialogue. The situation is complicated by the existence of different concepts of CO_2 emissions accounting. Existing mechanisms register only production-based emissions and do not take into account the international carbon flows in the form of goods that have been produced in one country, and consumed in another one. Consumption-based method of emissions estimation provides another way to consider the issue about separation of intercountry responsibility to reduce the anthropogenic impact on the climate of the planet. Input-output approach, namely Multi-regional input-output analysis, is the universal way of CO_2 emissions estimating. Given the different scenarios of Russian economy development we calculate the potential amount of associated emissions and assess the feasibility of implementing NDCs claimed. We show that Russia's current climate policy is likely to create real constraints for its economy growth with the rate comparable to at least the world average one.

Keywords: *economic dynamics, environmental impact, anthropogenic emissions, foreign trade, intersectoral interactions, long-term forecast, restrictions of economic development*.

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Issues of current world ecological regulation

Energy resources consumption increases along with world economy development, production expansion and population growth. At present, most of the energy demand is met by burning hydrocarbon fuels – oil, gas and coal – which leads to greenhouse gas emissions (carbon dioxide, methane, nitrogen oxide, etc.). In its latest Assessment Report (2014), the Intergovernmental Panel on Climate Change (IPCC) points to a growing number of facts indicating that it is the increased concentration of greenhouse gases in the atmosphere caused by anthropogenic factors that is a root cause of global climate warming observed since the mid-20th century. Attention to reducing the negative anthropogenic impact, especially carbon dioxide (CO_2) emissions, is an important part of current vision of sustainable global economic development. International collaboration in these areas has led to the adoption of the United Nations Framework Convention on Climate Change (UNFCCC, 1992) and the Kyoto Protocol (1997), which specify the obligations of a number of countries to control and limit their CO_2 emissions. Today the Kyoto Protocol has come to end. Now the Paris Agreement, adopted in December 2015, is the document declaring the world's aspiration to limit the anthropogenic impact on the climate of the planet. A huge achievement of the Paris Agreement was a significant increase in the number of countries that recognized the importance of this problem. However, unlike the Kyoto Protocol, in the Paris agreement there are no quantitative obligations for countries to reduce their emissions. According to this agreement, each party shall set and achieve nationally determined contributions (NDCs) to the global response to climate change. And countries will be expected to review NDCs every 5 years, representing more ambitious targets.

The participation of most countries of the world in the climate agenda made this process to be an important factor of the world economic dynamics formation, directly influencing the development of technology and international trade.

At the same time, approaches worked out in the early 1990s turned out to be far from perfect. The main criticism of the approach which current forms of ecological regulation is based on concerned the fact that it did not adequately take into account the differences between developed and developing countries, thus creating obstacle for countries lacking efficient technologies in the field of the production and consumption of energy resources. This, in part, had hampered the process of negotiating the further development of mechanisms limiting greenhouse gas emissions.

Still many developing countries are considering the subject of CO_2 emissions limitations as a way to restrict their economic and technological development, as well as to maintain the leadership of developed countries in the world trade. The problem is complicated by the fact that developing countries account for almost 70% of world CO_2 emissions. Their awareness about existing risks of the climate initiatives restrictive impact on economic growth remains an obstacle for the world to transit to a low-carbon development trajectory. Thus, an assessment of the ecological regulation measures appliance consequences and the searching for alternative approaches to estimating of different countries contribution to the formation of world anthropogenic emissions is of high practical relevance.

CO_2 emissions accounting approaches

Existing mechanisms of environmental regulations register aggregate CO_2 emissions generated by national production sectors (production-based CO_2 emissions). However, this methodology has a number of shortcomings. For example, it does not take into account the absorption of carbon dioxide by land and ocean biota, which may considerably alter the concept of the countries roles as CO_2 "emitters" and "donors" (*Fedorov, 2014*). Another important distortion is the neglect of international carbon dioxide flows via goods produced in one country and consumed in another one, although up to 25-30% of worldwide CO_2 emissions are concentrated in such operations (*Peters, Minx, Weber, Edenhofer, 2011; Aichele, Felbermayr, 2015*). Besides some countries export more emissions than they consume, or conversely, in many cases the import of emissions is comparable to its production in the country (*Ahmad, Wykoff, 2003*). This raises the important question: who shall be responsible for CO_2 emissions generated during the goods production in developing countries (including such large ones as China), which are subsequently sold to and consumed by other countries? (*Peters, Hertwich, 2008; Sato, 2014*) The bulk of international trade flows moves from developing countries to developed ones. In field of Kyoto agreement, the former was not responsible for reducing CO_2 emissions, while the latter turn out to be consuming more carbon than it was registered. Considering this circumstance, there is a wide field of opportunities for adjusting current approaches of CO_2 registering and shifting to a consumption-based CO_2 emissions estimation methodology.

Consumption-based (E_{cons}) and production-based (E_{prod}) CO_2 emissions are related through the following ratio:

$$E_{cons} = E_{prod} - E_{exp} + E_{imp}, \tag{1}$$

where E_{exp} – CO_2 emissions embodied in exports, E_{imp} – CO_2 emissions embodied in imports.

Significant experience on the issue of CO_2 emissions embodied in exports and imports estimating has been accumulated. Detailed review of references on this subject as well as numerical estimates of the above parameters for recent years for Russia are given in (*Makarov, Sokolova, 2014*).

The suitability of consumption-based approach for forming a position in negotiations of future CO_2 emissions limitations is obvious as it allows to share the countries responsibility more elaborately, which may increase the efficiency of international cooperation (*Davis, Caldera, 2010*). With this approach, there are additional incentives for greater investment by developed countries in manufacturing sectors of developing ones for reducing the carbon intensity of imported goods. However, it requires more complicated calculations as well as additional testing demonstrating its effectiveness under conditions of different economic dynamics and structural changes.

Input-output approach allows estimating both production-based and consumption-based CO_2 emissions. Such calculations for different countries and intercountry comparisons may be implemented, for example, on the basis of the WIOD database (Input-Output Tables and Environmental Accounts).

The system of intercountry "input-output" tables may be presented in the following way (*Boitier, 2012*):

$$Ax + f = x, \tag{2}$$

or in a matrix view:

$$\begin{pmatrix} x_1 \\ \vdots \\ x_m \\ \vdots \\ x_N \end{pmatrix} = \begin{pmatrix} A_{11} & \cdots & A_{1v} & \cdots & A_{1N} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ A_{m1} & \cdots & A_{mv} & \cdots & A_{mN} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ A_{N1} & \cdots & A_{Nv} & \cdots & A_{NN} \end{pmatrix} \begin{pmatrix} x_1 \\ \vdots \\ x_m \\ \vdots \\ x_N \end{pmatrix} + \sum_{m=1}^{N} \begin{pmatrix} f_{1m} \\ \vdots \\ f_{vm} \\ \vdots \\ f_{Nm} \end{pmatrix} \tag{3}$$

where $x = \{x_m\}^{\mathrm{T}}$ – column of output vectors for countries $m = \overline{1, N}$; $A = \{A_{mv}\}$ – intersectoral block matrix of input-output coefficients for countries $m = \overline{1, N}$ and $v = \overline{1, N}$ interactions (its element A_{nn} is a matrix of input-output coefficients in country n); $f = \{\sum_v f_{vm}\}$ – matrix of final consumption by countries $m = \overline{1, N}$ of goods and services from countries $v = \overline{1, N}$.

x can be calculated as:

$$x = \sum_m (I - A)^{-1} f_m = \sum_m y_m. \tag{4}$$

Now we can break down (4) into 2 parts: country *m* domestic output for domestic final consumption (y_{mm}) and country *m* domestic output for foreign final consumption in countries v (y_{mv}):

$$x_m = \sum_v y_{mv}, \tag{5}$$

$$y_{mm} = (I - A_{mm})^{-1} f_{mm}, \tag{6}$$

$$y_{mv} = (I - A_{mv})^{-1} f_{mv}. \tag{7}$$

Using WIOD Environmental Accounts we can calculate the specific carbon intensity vector $e_m = \{e_m^i\}$, whose *i* element is CO_2 emissions per one unit of sector *i* output in country *m* and equals to:

$$e_m = \{e_m^i\} = \left\{\frac{CO2_m^i}{x_m^i}\right\}, \tag{8}$$

where $CO2_m^i$ – aggregate CO_2 emissions by sector *i* in country *m*.

CO_2 emissions embodied in country *m* domestic consumption E_m^d equals to:

$$E_m^d = e_m * (I - A_{mm})^{-1} f_{mm}, \tag{9}$$

CO_2 emissions embodied in country *m* exports E_m^{exp}:

$$E_m^{exp} = \sum_{v \neq m} e_m * (I - A_{mv})^{-1} f_{mv}, \tag{10}$$

and CO_2 emissions embodied in country *m* imports E_m^{imp}:

$$E_m^{imp} = \sum_{v \neq m} e_v * (I - A_{vm})^{-1} f_{vm}. \tag{11}$$

Now production-based CO_2 emissions in country m E_m^{prod} equals to:

$$E_m^{prod} = E_m^d + E_m^{exp} + E_m^h, \tag{12}$$

where E_m^h is emissions from households' final consumption. Or for forecasting given exogenous e_m and x_m modeled we can use

$$E_m^{prod} = e_m * x_m. \tag{13}$$

Consumption-based CO_2 emissions in country m E_m^{cons} equals to:

$$E_m^{cons} = E_m^d + E_m^{imp} + E_m^h, \tag{14}$$

and, finally:

$$E_m^{cons} = E_m^{prod} - E_m^{exp} + E_m^{imp}. \tag{15}$$

The method described is known as Multi-regional input-output analysis, MRIO (Peters, 2007). It allows to estimate CO_2 emissions embodied in intercountry trade flows along the full production chain with considering intersectoral interactions. However, it is characterized by some disadvantages occurring because of sector is quite a large aggregate for economy and trade describing, since CO_2 emissions are carried by goods and processes. Thus, applying specific carbon intensity of the whole sector to export is not exactly correct, because the goods production structure and the structure of their exports may differ. However, attempts to estimate CO_2 emissions embodied in goods using detailed foreign trade and production statistics do not allow to consider the full costs – at best, expanded direct costs are obtained. In addition, there are difficulties with the correct consideration of transportation processes, because this requires tracking of the logistical chains for each good crossing the country's border (*Shirov, Kolpakov, 2016*).

Estimation of Russia's consumption-based CO_2 emissions

Using MRIO method we calculated CO_2 emissions embodied in Russia's exports and imports, as well as production- and consumption-based emissions (see Figure 1).

Institute of Economic Forecasting of Russian Academy of Sciences (RAS IEF) releases up-to-date input-output tables for the national economy (*Uzyakov, Maslov, Gubanov, 2006*) and uses them for forming macrostructural models for forecasting the dynamics and structural characteristic of the economy in the long term (*Shirov, Yantovsky, 2014*). That is why WIOD data for Russia is replaced by own results in the calculations. Input-output coefficients matrix for Russia's intercountry interactions was based on WIOD data (Release 2013).

Figure 1. Russia's CO_2 emissions in 2013, $mtCO_2$,

Source: authors

According to our estimates CO_2 emissions embodied in Russia's exports in 2013 amount to 582 $mtCO_2$; in imports – 125 $mtCO_2$. Consequently consumption-based emissions amount to 1280 $mtCO_2$, being 26% lower than production-based ones (which are equal to 1737 $mtCO_2$).

Figure 2 presents the sectoral structure of CO_2 emissions embodied in Russia's exports and imports in 2011. It is of note that here responsibility for the presented CO_2 emissions is assumed by all sectors participating in the production processes taking into account intersectoral interactions (not by sectors producing final goods for foreign-trade operations).

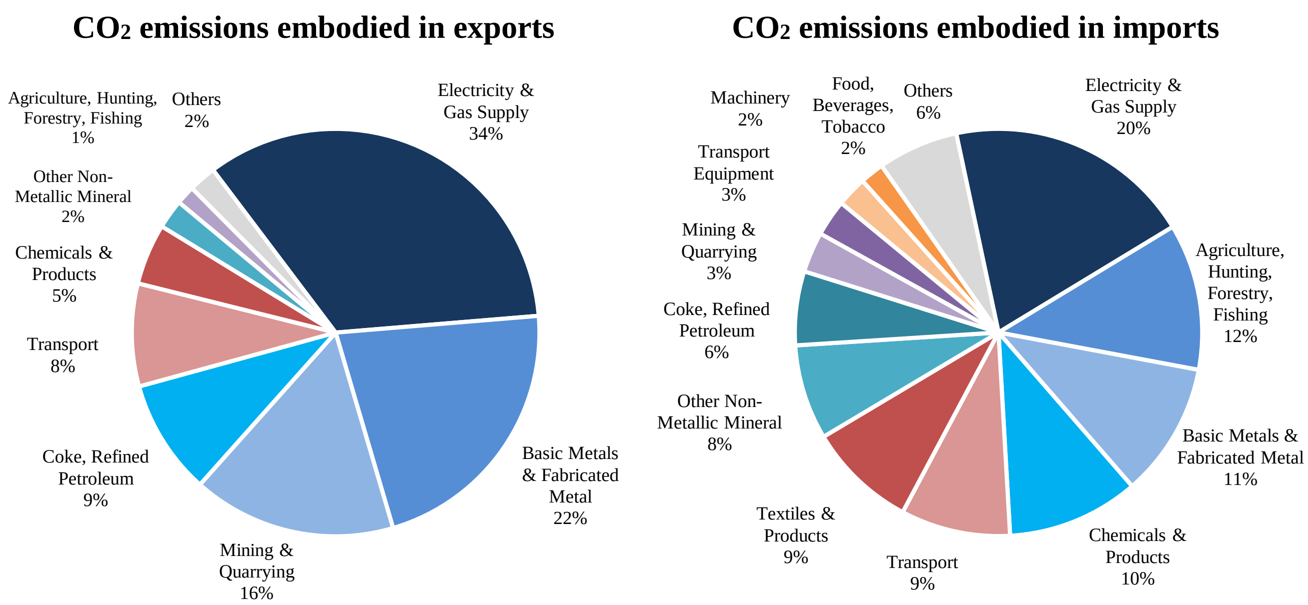

Figure 2. Economic activities structure of CO_2 emissions embodied in Russia's exports and imports in 2011,

Source: authors

Electric power industry is the dominant sector in terms of CO_2 emissions exports from Russia with a share of 34%. This is since electricity is used in all production processes, although the export of electricity as a commodity is insignificant. Other significant sectors in the structure of CO_2 emissions embodied in Russia's exports are metallurgy (22%), mining and quarrying (16%), production of coke and refined petroleum (9%) and chemical production (5%). Transportation processes account for 8% of emissions.

The structure of CO_2 emissions embodied in Russia's imports appears to be more differentiated. Apart from the similar leaderships of the electric power sector, other sectors are presented as follows: agriculture (12%), metallurgy (11%), chemical production (10%), textile manufacturing (9%), other non-metal minerals (8%), production of coke and refined petroleum (6%), mining and quarrying (3%), production of transport equipment (3%) and machinery (2%). Transportation processes account for nearly 9% of emissions.

Table 1 shows the structure of CO_2 emissions exports to countries being Russia's goods buyers in 2011. Italy is the leader, accepting 10.8% emissions taken out of Russia. China accounts for 9.6% of carbon flows from Russia, the US – 6.2%, Netherlands – 4.7%, France – 4.6%, Japan – 4.4%, Germany – 4.2%.

Table 1. Country structure of CO_2 emissions embodied in Russia's exports in 2011

Country	Share	Country	Share	Country	Share
Italy	10.8%	Germany	4.2%	Sweden	1.8%
China	9.6%	Poland,	3.5%	Hungary	1.8%
USA	6.2%	Finland	2.7%	Turkey	1.5%
Netherlands	4.7%	Great Britain	2.2%	Belgium	1.3%
France	4.6%	South Korea	2.2%	Greece	1.1%
Japan	4.4%	Spain	2.1%	Other	35.2%

Source: authors

Table 2 shows the country structure of CO_2 emissions imported by Russia in 2011. China, South Korea and Germany are the leading countries accounting for 18.3%, 8.7% and 6.6% emissions respectively. Large importers are also Poland (5.0%), India (3.5%), Turkey (3.5%) and the United States (3.2%). A high share of other countries (32.3%) is explained by the fact that this category includes Ukraine and Kazakhstan.

Table 2. Country structure of CO_2 emissions embodied in Russia's imports in 2011

Country	Share	Country	Share	Country	Share
China	18.3%	Japan	2.7%	Indonesia	1.1%
South Korea	8.7%	Italy	2.4%	Netherlands	1.1%
Germany	6.6%	Great Britain	1.8%	Slovakia	1.0%
Poland	5.0%	Czech Republic	1.7%	Rumania	1.0%
India	3.5%	France	1.6%	Spain	1.0%
Turkey	3.5%	Finland	1.3%	Hungary	0.9%
USA	3.2%	Lithuania	1.2%	Other	32.3%

Source: authors

Estimates obtained with different methods generate different perceptions of the countries responsibility degree for CO_2 emissions. More importantly, they can be used to formulate the concept of the distribution between countries of effort amounts that should be implemented to reduce the environmental impact. Particularly strong sensitivity to the chosen method appears when determining emission restriction targets in absolute / gross values.

One may give as an example the principle of "climate justice", which repeatedly arised on UNFCCC conferences. Though this principle is not clearly defined, a number of developing countries interpret it as providing equal rights to the GHGs emissions for every living person (*Silvestrov, Roginko, 2016*).

Figure 3 shows estimates of CO_2 emissions per capita for different countries.

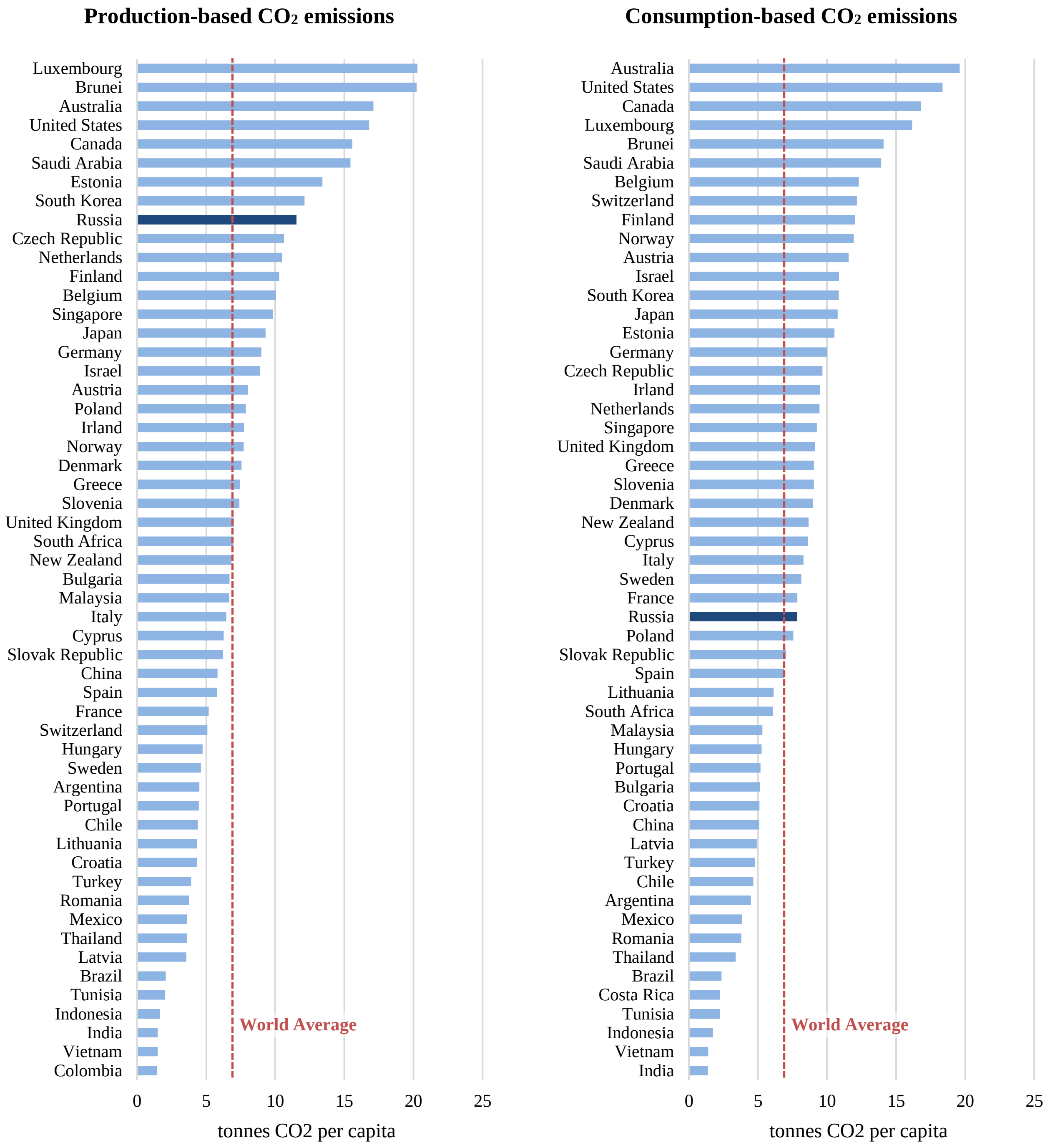

Figure 3. CO_2 emissions per capita in 2011 for different approaches,

Source: OECD

With production-based approach (left part of Figure 3) Russia is in the top-10 countries with emissions per capita of 11.5 tCO_2, being 60% higher the world average level. If one uses consumption-based approach, the situation will change dramatically. Russia shifts to the top-30, and emissions per capita are approximately equal to the world average level, being only 8% higher of it.

It should be noticed that for many countries the choice of emissions registering method does not matter. The United States, Canada, Australia, Luxembourg, Brunei and Saudi Arabia are the top-6 countries in emissions per capita in both cases. However, for Russia the choice of approach is significant, since it forms different perceptions about the role of the country in international environmental impact. Consumption-based approach appears to be more favorable for Russia.

Forecast of national CO_2 emissions for different scenarios of Russia's economic development

This section presents estimates of the prospective CO_2 emissions in Russia. We also analyze potential risks of restrictions on economic growth to appear due to current national climate policy.

Two scenarios of Russia economy development up to 2030 were considered: Inertial (Reference) scenario and Scenario of accelerated modernization. The key objective of the calculations was to form different development dynamics of the country's economy for testing the possible dynamics of Russia's CO_2 emissions under changing economic conditions.

Calculations were performed using the intersectoral macroeconomic model (*Shirov, Yantovsky, 2014*) based on national input-output tables, in which indicators of capital intensity by sectors, budget limitations and ruble exchange rate were the most important exogenous parameters.

The differences between two scenarios were created by parameters of the country's national economic policy. Thus, the dynamics of key foreign-economic parameters for different scenarios remained the same. Its characteristics are shown in Table 3.

Table 3. Constant foreign-economic parameters

	2020	2025	2030
Average annual World GDP growth rate, %	3.5	3.2	3.1
World oil price, USD/bbl	75.2	87.7	106.0
USD exchange rate, rubles/USD	76.5	76.1	73.9
Specific capital intensity in economy by 2015, %	109.2	123.5	137.4

Source: RAS IEF

Reference scenario of the Russian economy development draws from the current conservative projections formed by the Ministry of Economic Development of the Russian Federation. It suggests that the quite low rates of economic growth in Russia will continue up to 2030 (average annual GDP growth rate will be roughly 1.5 percentage points lower than the expected one for the world economy). In such conditions, the sectoral structure of Russian economy conserves, since the growth rates of the raw-material sector lag insignificantly from those of the rest of economy.

Accelerated modernization scenario is based on a potential to focus all types of resources (primarily financial) on technological modernization of the key sectors of the Russian economy. This leads to the increase of average annual growth rates of capital investment in 2021-2025 to 7.9% and to the increase of capital accumulation rate to 27-29%. In this case, the average annual Russian GDP growth rate in 2016-2030 increases to 3.6% (from 2.1% in reference scenario), being approximately at the same level as the average world one.

Comparison of the key indicators of the Russian economy for the scenarios considered are given in Table. 4.

Table 4. Average annual growth rates of key economic indicators in Russia in different scenarios, %

	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2016-2030
	Reference scenario					
GDP	2.5	1.4	2.5	2.2	1.6	2.1
Exports	2.0	1.0	1.7	2.5	2.4	2.2
Imports	3.1	-1.6	4.8	2.9	2.2	3.3
Capital investments	5.1	-0.8	3.9	5.2	3.4	4.2
Household consumption	6.3	1.7	1.7	1.5	0.6	1.3
	Accelerated modernization scenario					
GDP	2.5	1.4	2.9	4.1	3.8	3.6
Exports	2.0	0.9	1.7	2.3	2.3	2.1
Imports	3.1	-1.6	4.3	6.0	5.9	5.4
Capital investments	5.1	-0.8	4.1	7.9	7.9	6.6
Household consumption	6.3	1.6	2.8	5.5	4.3	4.2

Source: RAS IEF

Accelerated modernization scenario differs from the inertial not only by higher GDP growth rates, but also by the occurring qualitative changes in the production structure and the efficiency of the economy. In particular, due to higher growth rates of capital investments, the share of medium- and high-tech industries in the production structure will increase from 18.8% to 23.5% in 2010-2030 (Table 5). This scenario assumes a more significant development of processing and knowledge-intensive sectors, while share of mining and quarrying, agriculture and trade declines. At the same time, in accelerated modernization scenario along with a higher energy demand one should expect significantly higher growth rates of energy efficiency.

It should be noticed that in the model calculations there is a direct relationship between the capital investments and the dynamics of changes in costs for primary types of resources (including energy). This procedure is based on the economic indicators of developed countries that have already passed the relevant stages of technological development. Details about the method of calculating the efficiency of primary resources use and its appliance in the modeling tool can be found in (*Uzyakov, 2011; Shirov, Yantovsky, 2014*).

Table 5. Production structure by sectors in Russia, %

Activity	Reference scenario					Accelerated modernization scenario		
	2010	2015	2020	2025	2030	2020	2025	2030
Agriculture, forestry, hunting, and fishing	4.2	5.0	5.1	5.0	5.0	5.0	4.5	4.0
Mining and quarrying	7.6	7.6	7.0	6.5	6.1	6.9	5.8	4.9
High-tech industries	1.2	1.3	1.4	1.5	1.6	1.4	2.0	2.6
Medium-tech high-level industries	7.3	7.0	7.6	8.5	9.0	7.5	9.0	10.5
Medium-tech low-level industries	10.3	10.8	10.9	10.3	10.0	10.6	10.4	10.4
Low-tech industries	9.5	9.8	10.5	10.4	10.2	10.5	9.2	8.7
Production and distribution of electricity, gas and water	4.8	4.8	4.5	4.2	3.9	4.6	4.3	4.1
Construction	6.7	6.6	7.1	7.8	8.4	7.1	7.7	8.4
Wholesale and retail, repair	15.6	15.3	15.3	15.7	16.0	15.6	15.1	14.3
Hotels and restaurants	1.0	1.0	0.9	0.9	0.9	0.9	1.0	1.1
Transportation and storage	7.7	7.0	7.0	6.8	6.7	7.0	7.0	6.9
Telecommunications	1.1	1.1	1.1	1.1	1.1	1.1	1.5	2.0
Finance and insurance	2.8	2.6	2.6	2.7	2.8	2.6	2.6	2.6
Real estate, services	6.6	6.7	6.5	6.5	6.4	6.7	6.9	7.1
Research and development	1.3	1.2	1.2	1.2	1.3	1.2	1.8	1.9
Other business services	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Public administration, defense, compulsory social insurance	5.4	5.3	5.0	4.8	4.7	5.1	4.8	4.3
Education	2.0	2.0	1.8	1.7	1.7	1.8	1.9	1.9
Healthcare	2.8	2.8	2.6	2.5	2.4	2.7	2.6	2.5
Other public, social and private services	1.8	1.8	1.7	1.6	1.6	1.8	1.7	1.6
Total	100	100	100	100	100	100	100	100

Source: RAS IEF

Figure 4 presents estimations of CO_2 emissions embodied in Russia's exports and imports. Accelerated modernization scenario will be associated with the growth of domestic demand for a number of potentially export goods, primarily metallurgy and chemistry products. This will lead to a reduction of the prospective exports volumes (its average annual growth rate in 2016-2030 will be 2.2% instead of 2.1% in reference scenario) and, consequently, of exported CO_2 emissions by about 15 million tons.

At the same time, more dynamic Russian economy development, increased capital investments and households consumption (average annual growth rates of these indicators in 2016-2030 will be 3.6%, 6.6% and 4.2% respectively, compared to 2.1%, 4.2% and 1.3% in reference scenario) will provide additional demand for imported products. The maximum imports growth rates occur in 2021-2025, when import of technological equipment increases significantly due to high capital accumulation rate. The average annual imports growth rate in 2016-2030 will grow up to 5.4% in accelerated modernization scenario, in comparison with 3.3% in reference scenario. Consequently, there is a significant acceleration of imported CO_2 emissions after 2020, which will amount to 124 $mtCO_2$ in 2025 and 149 $mtCO_2$ in 2030 (compared to 111 $mtCO_2$ and 113 $mtCO_2$ in reference scenario).

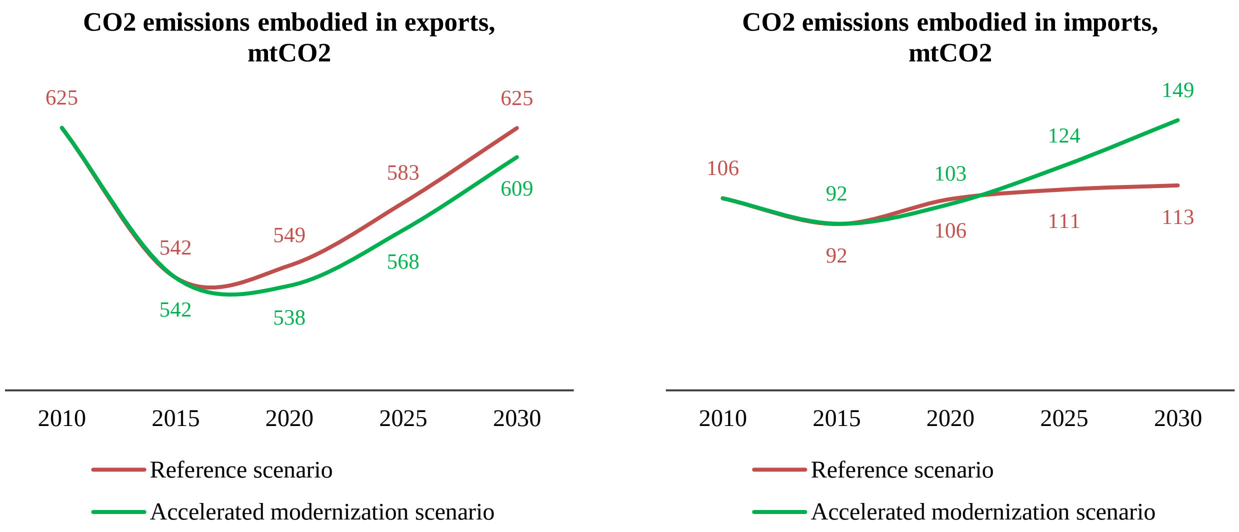

Figure 4. Estimations of CO_2 emissions embodied in Russia's exports and imports up to 2030,

Source: authors

Figure 5 presents estimations of Russian production-based and consumption-based CO_2 emissions up to 2030 in comparison with several indicators. First, Russia being a party of the Kyoto Protocol has set the target to restrain emissions below the 1990 level, which is 2590 $mtCO_2$, according to the National inventory report about anthropogenic emissions (*Ministry of Natural Resources of Russian Federation, Rosgidromet, 2015*). Secondly, Russia being a party of the Paris Agreement (2015) set the target (NDCs) to keep emissions below 70-75% of 1990 level, taking into account the absorbing capacity of its forests. For clarity, we will consider only 75% level, and also exclude from consideration the additional Russia's forests condition, since a clear value or approach for this indicator to calculate have not been determined.

Different approaches of CO_2 emissions registering generate different 1990 levels – 2590 $mtCO_2$ of production-based emissions and 2184 $mtCO_2$ of consumption-based ones. Then 75% of 1990 level are 1943 $mtCO_2$ and 1638 $mtCO_2$ respectively.

As we can see, Russia will not reach the 1990 level of CO_2 emissions in any scenario. By 2030, the gap between production-based emissions and 1990 level will be 465 $mtCO_2$ in accelerated modernization scenario and 811 $mtCO_2$ in reference scenario. For consumption-based emissions the gaps, and hence the available growth potential, will be about 11-12% higher amounting to 518 $mtCO_2$ and 916 $mtCO_2$ respectively.

When implementing the Paris targets, the situation becomes more difficult. If the Russian economy grows at low rate (reference scenario), current climate policy will not create any restrictions. However, if Russia's GDP growth rate reaches at least the world average level (which is a modest result for the developing country), production-based CO_2 emissions will exceed its limitation level already in 2025; and consumption-based emissions – in 2030.

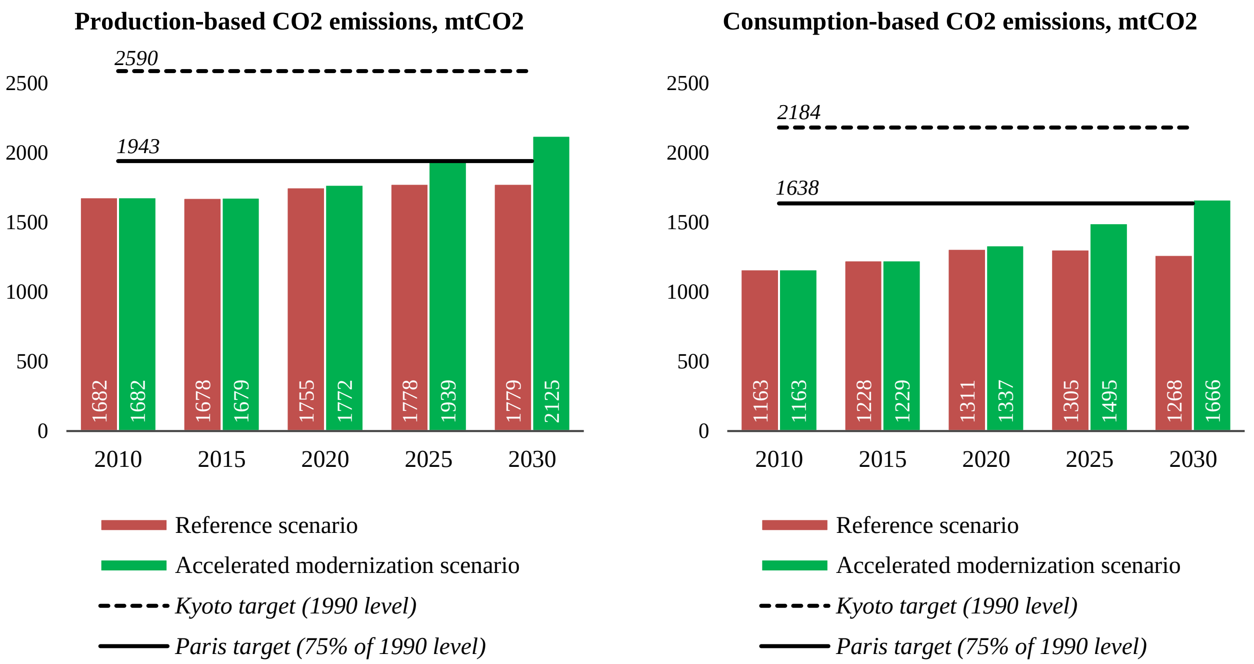

Figure 5. Estimations of Russian production-based and consumption-based CO_2 emissions up to 2030

Source: authors

Thus, the application of the Paris targets will create the obstacles for realization of the favorable accelerated modernization scenario. In such circumstances, there is a significant risk that only an inertial development scenario will be applicable for Russia, which means the forced containment of economic growth in the country. Moreover, with production-based approach for CO_2 emissions registration inertial scenario of Russian economy development proves to be almost the highest possible.

Key conclusions

1. The debate concerning the limitation of greenhouse gas emissions is directly influencing the formation of the global macroeconomic dynamics, shaping world trade conditions and requirements to new technologies. That is why this factor needs to be taking into consideration when designing a national long-term economic development strategy.

2. For developing counties there are risks of appliance of excess obligations to lower emissions, which may become a restraining factor for economic dynamics, leading to a growth of capital intensity in production and a reduction of economic growth rates.

3. Different approaches of emissions calculating generate different perceptions of the countries responsibility degree for global environmental impact. This should be taken into account for generating of compromise solutions, which will facilitate the world economy to transit on the path of low-carbon development.

4. Input-output approach allows to estimate the consequences of ecological regulation measures appliance. This useful tool should be used to formulate and justify the parameters of global climate policy.

5. Russia's current climate policy is not balanced in terms of ensuring a sustainable long-term development of the country, as it creates restrictions on economic growth. It should be reviewed or supplemented with specific balanced measures to achieve the targets declared.

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