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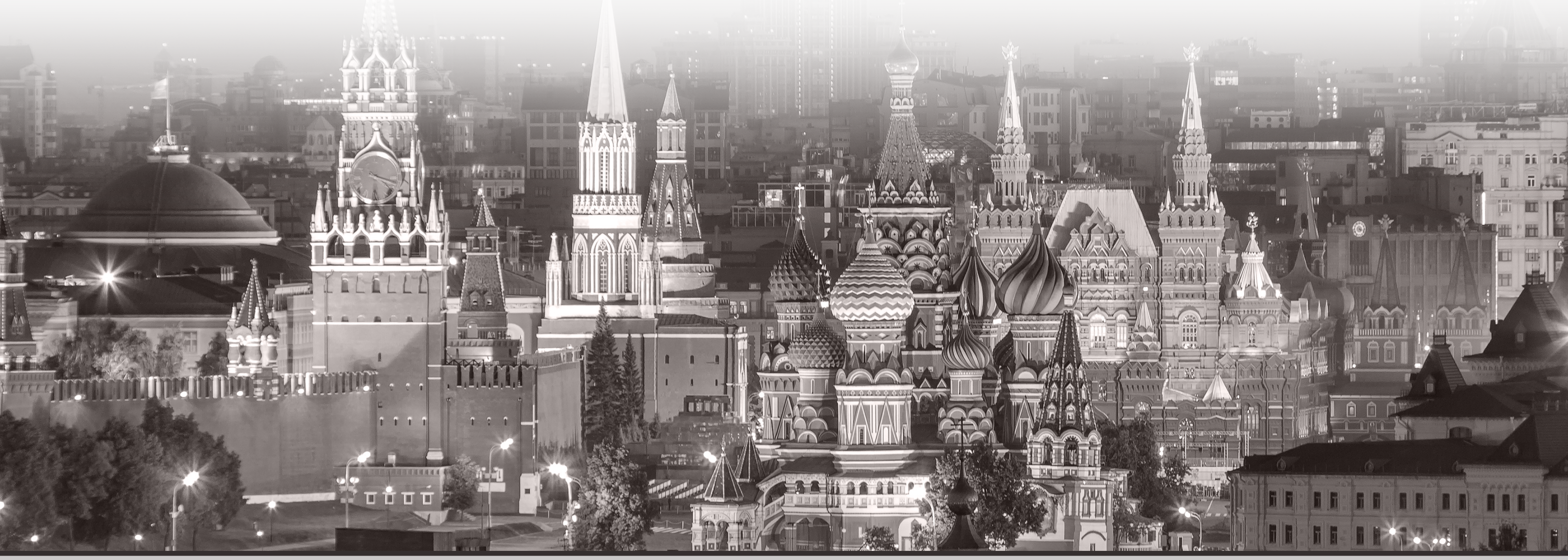

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FINDING ITSELF IN THE POST-PARIS WORLD: RUSSIA IN THE NEW GLOBAL ENERGY LANDSCAPE

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Abstract

The Russian budget relies heavily on exports of fossil fuels, which are the major source of greenhouse gas (GHG) emissions. Climate-related policies that target a reduction in GHG emissions substantially affect the Russian economy. We apply the MIT Economic Projection and Policy Analysis (EPPA) model to assess the impacts of the Paris Agreement on the Russian economy and find that climate-related actions outside of Russia lower Russia's GDP growth rate by about a half of a percentage point. In addition, Russia faces the risks of market barriers for its exports of energy-intensive goods as well as risks of falling behind in development of new energy technologies that become standard in most of the world. In order to address these risks, the country needs a new comprehensive development strategy taking into account the Post-Paris global energy landscape. We offer suggestions for key elements of such a strategy, including diversification of economy, moving to low-carbon energy, and investing in human capital development. We simulate three simple diversification scenarios showing that redistribution of incomes from energy sector to the development of human capital would help avoid the worst possible outcomes.

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1. Introduction

The Paris Agreement (UN, 2015) that was passed in December 2015 at the 21st Conference of Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) and came into force in November 2016 is a key document that provides a framework for coordination of national policies regarding climate change including greenhouse gas (GHG) emissions reduction, adaptation and technology and money transfers. Unlike the Kyoto Protocol (UN, 1998) that preceded it, the Paris Agreement does not include any binding commitments on emissions reduction. Instead, the parties have specified indicative targets in the form of Nationally Determined Contributions (NDCs), generally set for 2030.

Although the Paris Agreement establishes a goal of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursuing efforts to limit it to 1.5°C (UN, 2015), the implementation of NDCs in their current forms are likely to be insufficient to meet these goals. Usually, researchers reference the resulting temperature increase in different scenarios with respect to its level in 2100 (IPCC, 2014), while the Paris Agreement mostly specifies emission targets only up to 2030. The ultimate temperature impact of the Paris Agreement depends on the assumptions about the post-2030 actions. For example, Climate Action Tracker uses a methodology where the level of the post-2030 efforts depends on the relative position of the emissions pathways and this approach leads to a 50% chance of warming of 2.8°C or higher by 2100 (Climate Action Tracker, 2017). Another analysis assuming the Paris Agreement pledges are not increased in their stringency in the post-2030 period projects the global mean surface temperature to rise 3.1-5.2°C above the pre-industrial levels by 2100 (MIT Joint Program, 2016). Meeting the 2°C target requires a substantial increase in emission mitigation efforts after 2030.

Emission reduction policies will affect fossil fuels prices (Paltsev, 2012) and, as a result, energy-exporting countries, like Russia, may face a substantial reduction in energy exports. For example, Paltsev (2014) estimates that the policy that aims at cutting 80% of GHG emissions in the European Union can lead to almost a 75% reduction in Russia's natural gas exports to Europe by 2050 relative to the no climate policy scenario. Russia is a country for which fossil fuels are one of the main drivers of the economy. Rising oil prices in the 2000-s is credited as a major factor for Russia's rapid economic growth (Idrisov et al., 2015). In 2016, even after the drop in oil prices, oil and gas sector provided 36% of Russian federal budget revenues (Russian Federal Treasury, 2017) and accounted for 58% of exports (Russian Customs Service, 2017). In addition, other major exporting industries (metals, chemicals and fertilizers) are all energy-intensive benefitting from the country abundant fossil fuel resources (Russian Customs Service, 2017).

Russian business and political elites express concerns regarding the potential implications of the Paris Agreement for the global energy landscape. Russia has signed the Agreement in 2016 and now it needs to be ratified by the Russian Parliament (the State Duma and the Council of Federation) and then signed by the Russian President. There is a wide debate in Russia on what should be its reaction to the Paris Agreement. A significant number of the large Russian companies opposes even to its ratification, while others consider it as a document with no significant impact even if Russia ratifies it, given the commitments are non-binding. As a result, even with some statements of support for the Paris Agreement from President Putin and several Russian government officials, the official decision on Russian ratification is postponed to 2019-2020 (TASS, 2016). However, whether Russia ratifies the Paris Agreement or not it will face the risks associated with the post-Paris changes of the global energy landscape.

The goal of this paper is to assess the impacts of the Paris Agreement on the Russian economy using the MIT Emissions Prediction and Policy Analysis (EPPA) model (Paltsev et al., 2005; Chen et al., 2016), a general equilibrium model of the world economy. We consider several scenarios of Russia's participation in the global climate policy process including decisions to not pursue climate policy, or to continue with its current pledge under the Paris Agreement, or to increase the stringency regarding its GHG emission levels.

The paper is organized in the following way. Section 2 provides a review of Russian climate policy. Section 3 describes the model and specifies three examined scenarios. Section 4 reveals key trends of the post-Paris evolution of global energy markets and estimates their intensity in each of scenarios. Section 5 focuses on major risks for the Russian economy associated with these changes, including 1) risks for fossil fuel exports, 2) risks for access of Russian energy-intensive exports to foreign markets, and 3) risks of staying with an outdated energy technology. Section 6 concludes with policy recommendations.

2. Evolution of Russian climate policy

The scale and the structure of its economy make Russia an important participant in the international climate change regime. This country is the fourth largest GHG emitter among national economies. It was Russia's ratification of the Kyoto protocol that let the agreement enter into force in 2005. Due to the post-Soviet transitional crisis, Russia had achieved by 2012 the largest absolute reduction of GHG emissions of any country in the world, counting from 1990 as the base year. The reduction was about 2 Gigatonnes of CO_2-equivalent gases ($GtCO_2e$) or about 50% of its 1990 GHG emissions (UNFCCC, 2017). Russia is the world's largest exporter of fossil fuels. Moreover, it possesses the world largest forest areas, an important component of the global carbon cycle.

Russia's position in negotiations on climate change has been relatively passive. Russia has seen climate negotiations as an avenue to achieve other goals. For example, the Kyoto Protocol's Joint Implementation (JI) scheme was seen primarily as a way to attract foreign investment to Russia (Andonov and Alexieva 2012; Makarov, 2016). Russia has also pointed to its large post-1990 emission reduction as a success in low-carbon development, expecting other countries to demonstrate similar reductions. However, most analysis has concluded that the emission reductions were determined primarily by the transitional crisis while national climate policy showed very little progress (Safonov, Charap 2010; Korppoo and Vatansever 2012; Kokorin and Korppoo 2013; Grigoryev, Makarov, and Salmina 2013).

The first steps in the development of national climate policy were completed in 2008-2009. In 2009, the first official document addressing climate change, the "Climate doctrine of the Russian Federation" was approved by President Medvedev. It was a framework document that stated Russia's readiness to cope with climate change but it included no details about specific measures. These were to be listed in a separate document for the doctrine implementation. An implementation plan was adopted in 2010, but it contained just a summary of various Russian federal programs only indirectly connected to climate and no additional funding was provided for its implementation (Grigoryev, Makarov, and Salmina, 2009).

Some progress was achieved in the area of setting measurable goals in the areas of renewable energy deployment and energy efficiency, one of the main priorities of Dmitry Medvedev's presidency in 2008-2012. A Presidential decree signed in 2008 set a goal to reduce energy intensity by 40% between 2007 and 2020 (later changed to a reduction of 44% between 2005 and 2030). However, in 2015 the subsidies to regional governments that were the primary source of funding of the energy-efficiency program were abolished due to budget sequestration. The other decree signed in 2009 set the targeted share of renewable electricity production at the level of 2.5% in 2015 and 4.5% in 2020. Later, the target was declared to be unachievable and was revised to 2.5% in 2020 (Climate Action Tracker, 2017).

A domestic GHG emissions reduction target was set in 2013 for the first time. Vladimir Putin signed a decree according to which Russia should cut its GHG emissions to 75% of the level of 1990 by 2020. The decree did not specify whether the declared emission target includes or excludes land-use and land-use change and forestry emissions (LULUCF). According to the UNFCCC (2017), in 1990 Russian GHG emissions were about 3,700 MtCO$_2$e without LULUCF and about 3,900 MtCO$_2$e with LULUCF (**Figure 1** and **Figure 2**). In 2015, they were reduced to about 2,700 $MtCO_2e$ and 2,100 $MtCO_2e$, correspondingly. These reductions lead to the 2015 GHG emission levels without LULUCF at 70% of the 1990 levels and the 2015 GHG emissions with LULUCF at 55% of the levels of 1990.

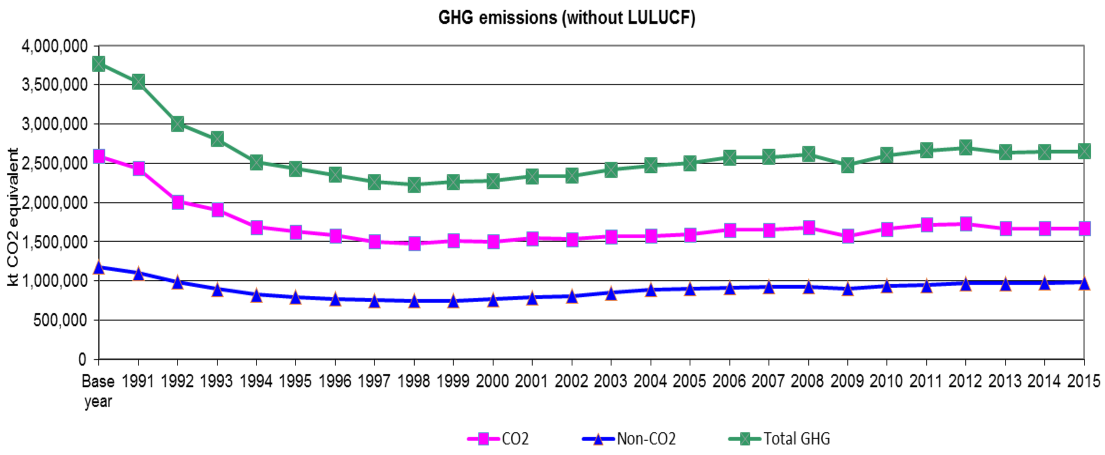

Figure 1. Russia's GHG emissions without land-use related emissions. Source: UNFCCC (2017).

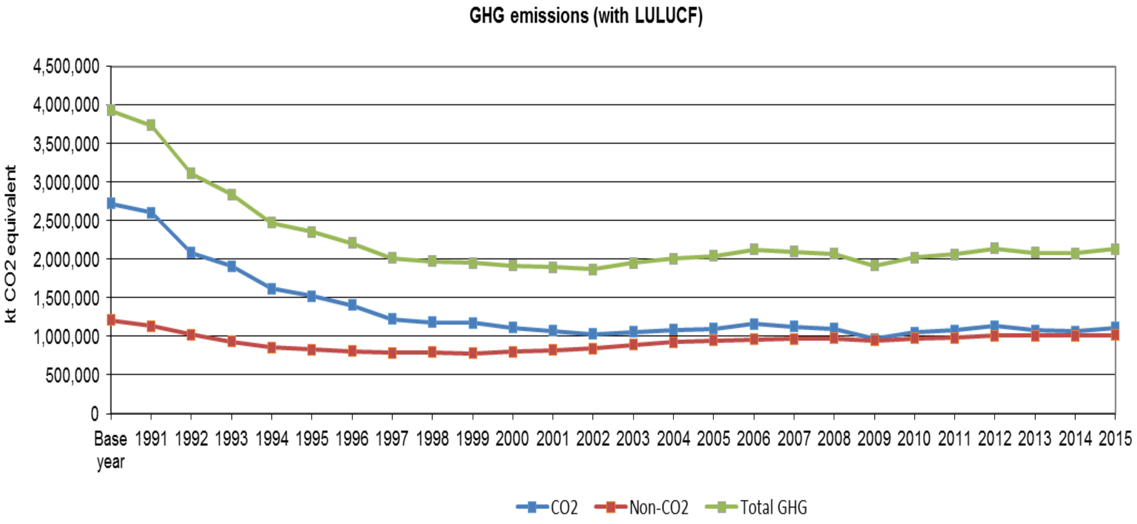

Figure 2. Russia's GHG emissions including land-use related emissions. Source: UNFCCC (2017).

Regardless of the LULUCF inclusion, the targeted level was higher than the emissions when the decree was signed, providing Russia an opportunity to increase rather than to decrease its emissions. Many experts suggested that the declared target corresponded to the business-as-usual scenario (see, for example, Kokorin and Korppoo, 2015). Deterioration of Russian economic growth in the later period reinforced the fact that the target would be achieved without any additional efforts.

Following the presidential decree, the government developed a roadmap of measures to reduce emissions. It includes such important points as the development of a monitoring, reporting and verification system, the elaboration of guidelines for enterprises and regions to account their emissions, and finally, the development of a carbon regulation scheme to be designed by the end of 2017. However, given that the target set for 2020 can be achieved without additional efforts, the future of carbon regulation in Russia is uncertain.

In the process leading to the Paris Agreement negotiations, countries submitted their initial Intended Nationally Determined Contributions (INDCs). After the Paris Agreement, countries are converting them into NDCs. Russia submitted its INDC, but its NDC is still not available. The INDC sets its emissions target for 2030 at the level of 70–75 per cent against the 1990 level "subject to the maximum possible account of absorbing capacity of forests" (Russia INDC, 2015). The statement concerning forests is vague and may be interpreted in different ways. Even without taking into consideration the statement about forests, Russia's INDC is close to the BAU scenario (Climate Action Tracker, 2017; Kokorin, 2016).

Despite the gap between the Paris Agreement stated goal (2°C stabilization) and targets specified by its parties, the Paris Agreement reflects the consensus of the world community on the necessity to shift towards the low-carbon development. This may lead to the substantial changes in the global economy in coming decades. The largest changes are expected in energy sector as fuel combustion is responsible for more than 70% of global emissions (IPCC, 2014). Among the main projected changes are decreasing use of coal; gradual stabilization of oil consumption; a rise in gas use in the short- and medium-term with a reduction in the longer-term; rapid development of renewables; and shift of market power from energy suppliers to energy consumers. The speed of these changes remains highly uncertain but their general direction is recognized by most of experts (IEA and OECD, 2015; Mitchell and Mitchell, 2016; Farid et al., 2016; Paltsev 2016).

3. Methodology and model specification

For the new analysis we present here we use the MIT Economic Projection and Policy Analysis (EPPA) model, a recursive-dynamic multi-regional computable general equilibrium (CGE) model of the world economy (Chen et al., 2016; Paltsev et al., 2005). The GTAP data set (Narayanan et al., 2012) provides the base information on Social Accounting Matrices and the input-output structure for regional economies, including bilateral trade flows, and a representation of energy markets in physical units. We aggregate the GTAP data into 18 regions and 14 sectors. EPPA also incorporates data on greenhouse gas (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) and air pollutant emissions (SO_2, NO_x, black carbon, organic carbon, NH_3, CO, VOC), the data on GHG and air pollutants are documented in Waugh et al. (2011).

Tables 1-3 presents the regions, sectors and advanced energy technologies represented in the EPPA model. Among factor inputs are both depletable (oil, natural gas, coal) and renewable natural inputs (solar, wind, hydro), as well as produced capital and labor. EPPA also disaggregates the GTAP data for transportation to include household transport (i.e. personal automobile), and further detail on technologies that produce electricity from fuels and natural resources and fuels from unconventional sources such as liquid fuels from biomass and shale oil resources; and gas from coal or unconventional gas resources. To represent such technologies, detailed bottom-up engineering studies are used to parameterize production functions for each. The parameterization of these sectors is described in detail in Chen et al. (2016) and Paltsev et al. (2005).

Table 1. Regions and abbreviations.

Abbr.	Region	Abbr.	Region	Abbr.	Region
USA	United States	**ROE**	Eastern Europe & Central Asia	**IND**	India
CAN	Canada	**RUS**	Russia	**BRA**	Brazil
MEX	Mexico	**REA**	East Asia	**AFR**	Africa
JPN	Japan	**KOR**	South Korea	**MES**	Middle East
ANZ	Australia, New Zealand & Oceania	**IDZ**	Indonesia	**LAM**	Latin America
EUR	European Union+[a]	**CHN**	China	**ASI**	Rest of Asia

[a] The European Union (EU-28) plus Norway, Switzerland, Iceland, and Liechtenstein.

Table 2. Sectors and abbreviations.

Abbr.	Sector	Abbr.	Sector	Abbr.	Sector
CROP	Agriculture - Crops	**ROIL**	Refined Oil	**ELEC: hydro**	Hydro Electricity
LIVE	Agriculture – Livestock	**GAS**	Gas	**EINT**	Energy-Intensive Industries
FORS	Agriculture – Forestry	**ELEC: coal**	Coal Electricity	**OTHR**	Other Industries
FOOD	Food Products	**ELEC: gas**	Gas Electricity	**DWE**	Dwellings
COAL	Coal	**ELEC: petro**	Petroleum Electricity	**SERV**	Services
OIL	Crude Oil	**ELEC: nucl**	Nuclear Electricity	**TRAN**	Commercial Transport

Table 3. Advanced technologies in the energy sector.

First generation biofuels
Second generation biofuels
Oil shale
Synthetic gas from coal
Hydrogen
Advanced nuclear
Advanced coal w/ CCS
Advanced gas
Advanced gas w/ CCS
Wind
Bio-electricity
Wind power combined with bio-electricity
Wind power combined with gas-fired power
Solar generation

The base year of the EPPA version used here (EPPA6) is 2007. EPPA simulates the economy recursively for the year 2010 and then at 5-year intervals to 2100. Economic development in 2010 and 2015 is calibrated to the actual data on GDP, and through 2020 on short-term GDP projections of the IMF. The model is formulated in a series of mixed complementary problems (MCP) including mixtures of equations and inequalities (Mathiesen, 1985; Rutherford, 1995). It is written and solved using the modeling languages of GAMS and MPSGE (Rutherford, 1999).

Future scenarios in EPPA are driven by economic growth that results from savings and investments and exogenously specified productivity improvement in labor, capital, land, and energy. Growth in demand for goods produced from each sector including food and fuels occurs as GDP and income grow. Stocks of depletable resources fall as they are used, driving production to higher cost grades. Sectors that use renewable resources such as land compete for the available flow of services from them, generating rents. These together with policies, such as constraints on the amount of greenhouse gases, change the relative economics of different technologies over time and across scenarios. The timing of entry of advanced technologies, such as cellulosic biofuels, is endogenous when they become cost competitive with existing technologies. Chen et al. (2016) provides detailed description of the dynamics in EPPA.

4. Major changes in the emissions and energy landscape after Paris

We consider the following main scenarios through a model simulation horizon of 2050: A *Reference* scenario, which assumes continuation of the current energy and climate policies. In this scenario we do not include the mitigation pledges made by the countries in their submissions for the Paris Agreement; a *Paris Forever* scenario, which assumes that the Paris pledges are met and retained for the post-2030 period; and two versions of a *Paris2C* scenario, where mitigation efforts are increased after 2030 to be on a trajectory to stabilization at 2°C. In one version, called *Paris2C_RussiaBAU,* Russia does not impose any emission reductions. In the other version, called *Paris2C_RussiaPolicy,* Russia pledges not to increase its emissions higher than 60% from the 1990 levels.

One issue that raises uncertainty of future emissions is how Russian land use change emissions will be accounted. Some studies argue that current high level of carbon sinks (about 500 $MtCO_2e$ in 2015) determined by the drop in logging during the transition crisis of the 1990s will decrease significantly in future (Zamolodchikov et al., 2013). However, given the variety of methodologies of land use change emissions accounting and condition of "maximum possible account of absorbing capacity of forests" provided in Russia's INDC, we assume that the reported net land use change emissions in Russia stay constant in 2015-2050 at their 2015 levels. We also take the global emission constraint in the scenario of stabilization at 2°C from Sokolov et al. (2017).

Figure 3 provides the resulting GHG emissions in these scenarios. It also shows Russia's historic GHG emissions inventory reported by UNFCCC (2017) and historic CO_2 emissions related to fossil-fuel combustion reported by BP (2017). Fossil-related CO_2 emissions provide a useful reference as they are estimated by the use of energy in Russia, while other historic GHG emissions are known with less certainty. The historic trajectories show that in the last two decades Russian emissions are more or less at the same level, about 2,000 $MtCO_2e$ for the total GHG and about 1,500 $MtCO_2e$ for fossil fuel-related CO_2.

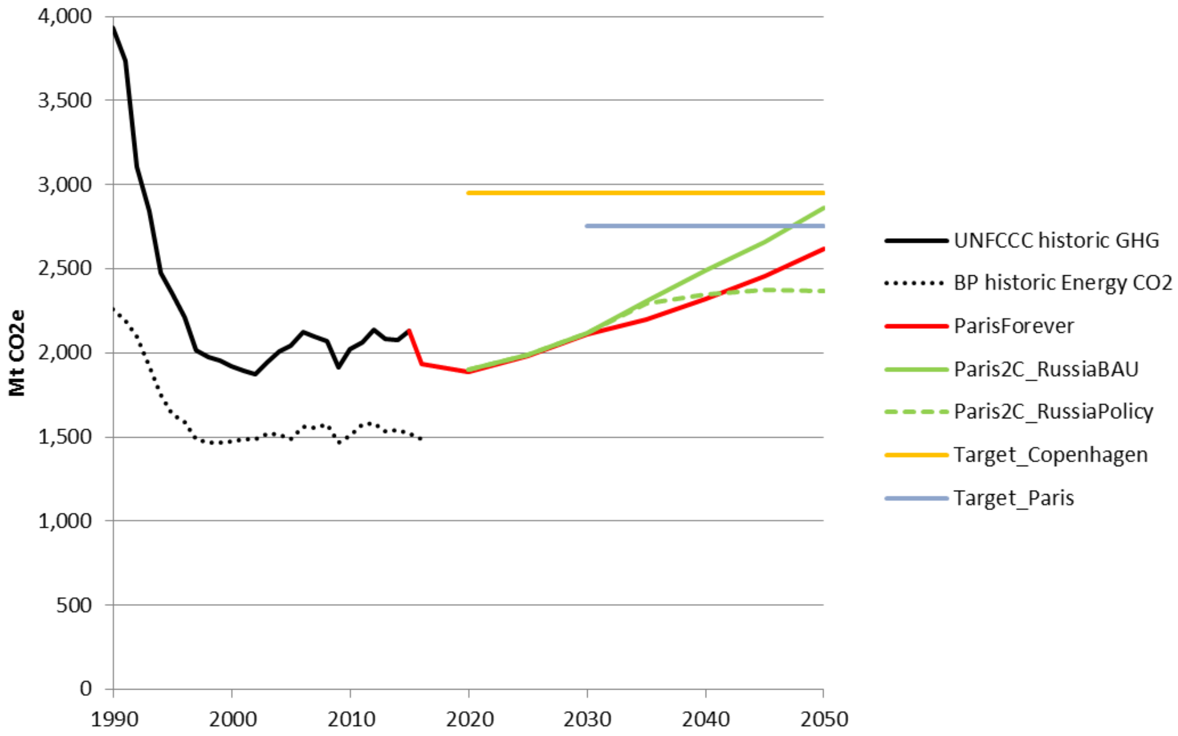

Figure 3. Russia's GHG emissions (including land-use related emissions) in different scenarios.

Figure 3 also shows two horizontal lines that represent the largest potential reductions for the GHG emission targets submitted for the Copenhagen Accord at 25% below 1990 levels (labeled *Target_Copenhagen*) and for the Paris Agreement at 30% below 1990 levels (labeled *Target_Paris*). The 2020 target for the Copenhagen Accord constitutes a range of 15-25% reductions relative to 1990. This target is also legally-binding as it is established (at the level of 25% reduction) by a decree of the President of Russian Federation and act of the Government of

Russian Federation. The Paris Agreement goal requires further elaboration and regulatory and legislative acts (Russia INDC, 2015).

In the scenarios with a median setting for GDP growth (**Figure 4**), Russian GHG emissions approach the Paris Agreement targets only by 2045-2050. The results depend on assumptions about an increase in mitigation efforts after 2030. If the world decides not to increase further the emission mitigation efforts after the Paris Agreement, then Russian total GHG emissions grow to about 2,600 MtCO$_2$e by 2050, which is still below the current Russian pledge for the Paris Agreement. Although the INDCs presented by Paris Agreement parties are not sufficient to hold the rise of temperature at the level of 2°C, the document reflects consensus of its parties on the necessity of fundamental changes in global economy and energy systems associated with their turn towards less carbon-intensive technologies.

If the countries of the world decide to increase the emission reduction efforts to be consistent with the 2°C goal, then Russian GHG emissions will be higher due to a phenomenon called *carbon leakage* (Paltsev, 2001; Babiker, 2005), which is driven by the associated competitive effects that may lead to reallocation of energy-intensive production to the countries that have mild or non-existent emission reduction policies. In this case, GHG emissions reach either about 2,850 MtCO$_2$e by 2050 or if the Paris pledge is extended to 2050, then they are constrained at about 2,750 MtCO$_2$e (consistent with the Paris Agreement pledge of 30% reduction relative to 1990). If Russia also decides to take on more stringent emission targets of a 40% reduction relative to 1990 levels, then the constrains becomes binding from about 2035.

Our median GDP growth assumptions are consistent with projections provided by the IMF (IMF, 2017) and Russian government (Ministry of Economic Development, 2017). They both foresee a relatively low economic growth driven by structural imbalances of the Russian economy, low oil prices and, partly, by continuing sanctions by the Western countries.

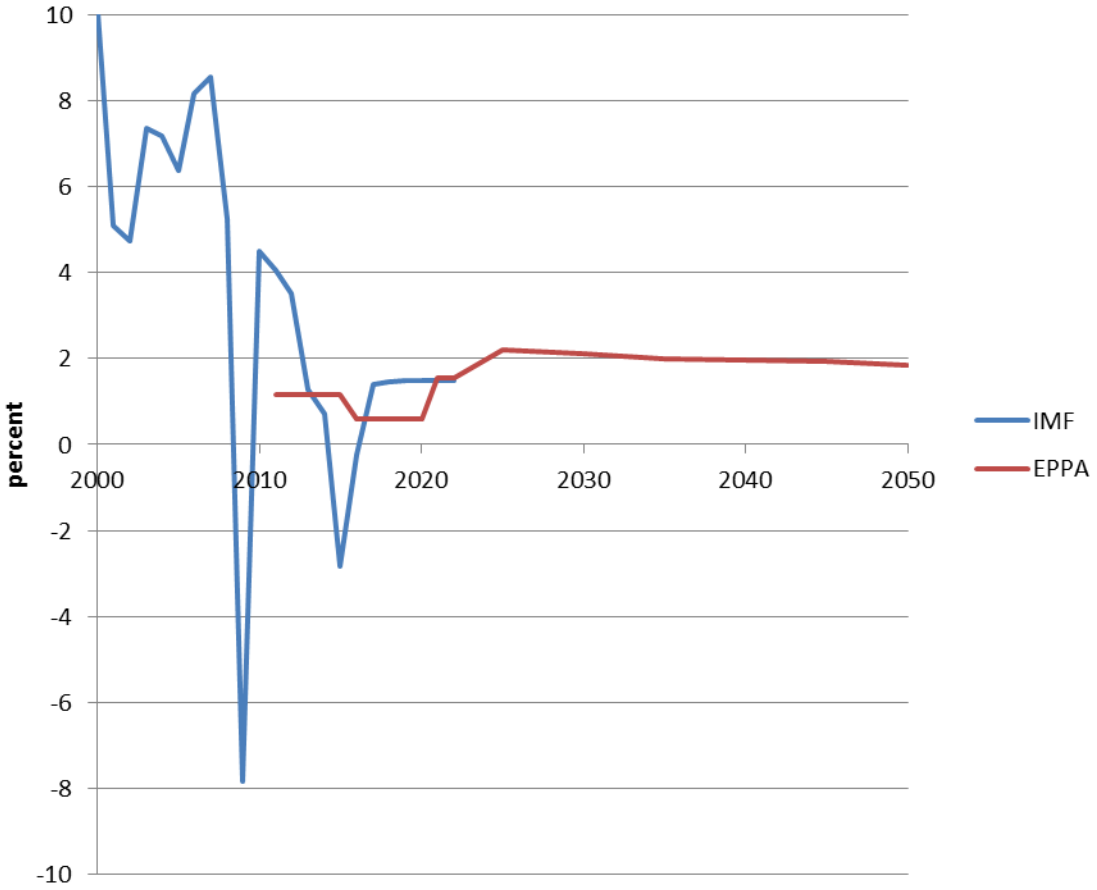

Figure 4. Russia's real GDP growth. Blue line represents historic numbers for 2000-2016 and projections for 2017-2022 from IMF. The EPPA model (red line) uses 5-year average growth rates.

Carbon policies affect fossil energy prices by making them more expensive for consumers as the prices include carbon charges. At the same time, producers of fossil fuels face lower demand for their products and receive lower prices because their producer prices are net of carbon charges (Paltsev, 2012). In our scenarios, the resulting producer prices for oil and natural gas are substantially lower in 2050 in the *ParisForever*, *Paris2C_RussiaBAU* and *Paris2C_RussiaPolicy* cases in comparison to the *Reference* case. For example, the oil price in all scenarios is about $55/barrel in 2020. The Paris Agreement actions reduce the oil price in 2030 to $59/barrel from $66/barrel in the *Reference*. The oil price in 2050 drops from about $80/barrel in the *Reference* scenario to about $70/barrel in the *ParisForever* scenario, and it is further decreased to about $55/barrel in the *Paris2C* scenarios. Reduction in demand for natural gas (mostly from the EU) leads to a decrease in natural gas export revenues. These changes lead to GDP and welfare impacts in Russia. **Figure 5** shows the impacts on Russian GDP growth rates, where climate policy outside of Russia lowers Russia's GDP growth rate in 2020-2030 by

0.2-0.3 of a percentage point. The increasing ambitions in the global GHG emission reductions after 2030 add almost a half of a percentage point to a negative impact on Russia's GDP growth rate in 2035-2050.

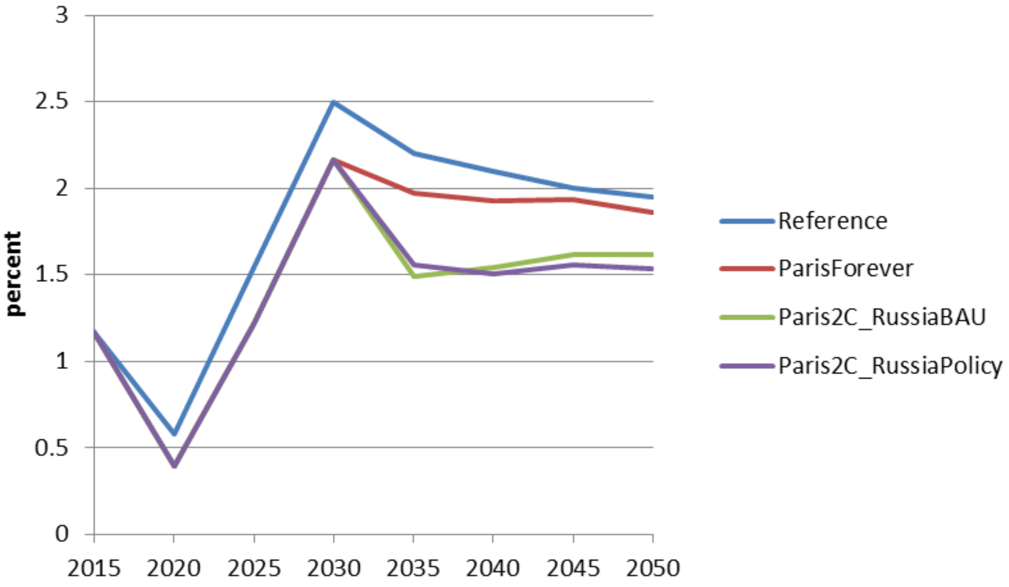

Figure 5. Impacts of climate policy on Russia's real GDP growth.

The impacts of the slower economic growth accumulate over time. The EPPA model estimates a change in welfare for the regions of the model. Welfare change in EPPA is measured as "equivalent variation" and can be loosely interpreted as the amount of extra income consumers would need to compensate them for the losses caused by the policy change (For a discussion of different cost concepts for climate policy assessments, see Paltsev and Capros (2013)). We report economic impacts in terms of changes in macroeconomic consumption, measured as equivalent variation. In the model setting used for this study, an annual consumption change is equal to the annual welfare change. For the scenarios considered here, we found that GDP impacts are similar to the changes in macroeconomic consumption when both are calculated as percentage changes. The *ParisForever* scenario results in welfare costs of about 4% in 2030, 6% in 2040, and 6.5% in 2050 relative to the *Reference* setting in the corresponding years. The welfare costs of the *Paris2C_RussiaBAU* and *Paris2C_RussiaPolicy* cases are higher. These scenarios lead to about 10% reduction in welfare in 2040 and about 12% reduction in welfare in 2050 relative to the *Reference* setting.

In the *Paris2C* scenarios, Russia's emission targets are less stringent than for the rest of the world that faces global economy-wide carbon prices of \$70/tCO_2 in 2035, \$90/tCO_2 in 2040, \$110/tCO_2 in 2045, and \$130/tCO_2 in 2050. Imposing these carbon prices on Russia would lead to larger reductions of its GHGs than those set by the *Paris2C_RussiaPolicy* scenario. By the scenario design, most of the impact on Russian economy would be from the actions outside of Russia rather than from its own mitigation policies. Paltsev and Kalinina (2014) explored the impacts on Russia of a scenario where carbon prices of a similar magnitude (growing up to \$160/tCO_2 in 2050) are imposed on all world regions including Russia and concluded that these prices may lead to substantial GDP growth impacts (up to 10%-20% reduction in GDP relative to the no policy scenario). Here our interest is in the scenarios where Russia has no or very limited carbon policy but is still affected by other countries.

Figure 6 illustrates the driving forces for the welfare results. In the *ParisForever* scenario, Russian energy exports in 2030 are 20% lower (in energy terms) relative to the *Reference* scenario. By 2050 the corresponding reduction reaches 25%. While Figure 6 (panel *a*) displays that exports of all fossil fuels are growing in the *Reference* scenario, Figure 6 (panel *b*) shows in the *ParisForever* scenario coal exports face some decreases over time, oil exports are relatively stable and natural gas exports are substantially growing with almost doubling by 2050 relative to 2010 export levels. However, refined oil and natural gas exports are growing slower in the *ParisForever* than in the *Reference* scenario. In the *Reference* scenario, in 2050 Russia's natural gas exports are 19 exajoules (EJ) and refined oil exports are 6 EJ, while in the *ParisForever* scenario the corresponding numbers are 17 EJ and 5.7 EJ. Coal exports in 2050 are decreased from 6.4 EJ in the *Reference* case to 1.1 EJ in the *ParisForever* case. Figure 6 (panel *c*) depicts dramatically different picture for Russia's energy exports in the *Paris2C_RussiaPolicy* scenario (the *Paris2C_RussiaBAU* scenario results are similar). Tightening the global climate policy after 2030 significantly decreases demand for fossil fuels and Russian energy exports. While compared with the *ParisForever* level, refined oil exports do not exhibit considerable decline, crude oil exports in the *Paris2C_RussiaPolicy* scenario are reduced by more than half by 2050. The corresponding reductions for coal are natural gas are about 65% and 49%, respectively.

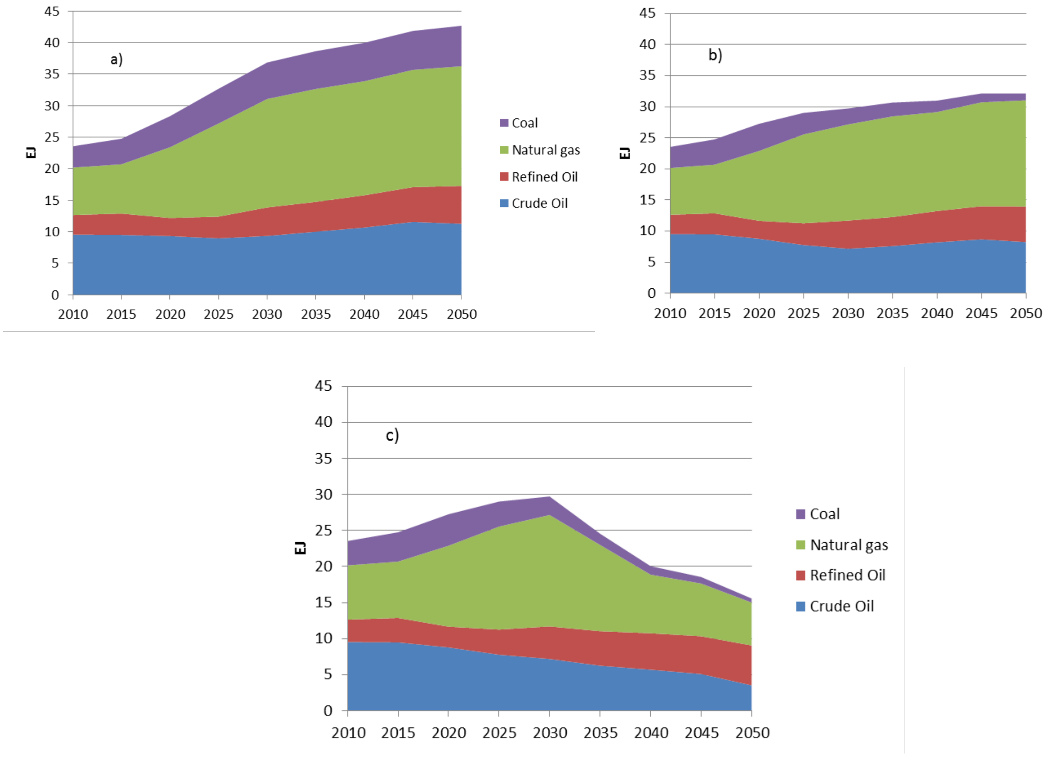

Figure 6. Russia's energy exports in: a) the *Reference* scenario; b) the *ParisForever* scenario; c) the *Paris2C_RussiaPolicy* scenario (Exajoules).

These results are illustrative but the welfare implications may be amendable with the forward-looking policy. The magnitudes of the future global GHG reductions and the necessary for them reductions in fossil fuel use are highly uncertain, but the need for actions to mitigate climate change risks is recognized by the overwhelming majority of the world nations. These actions will definitely impact fossil fuel use in some fashion. The nations that depend on fossil-fuel exports are looking for diversification strategies (e.g., Saudi Arabia's national transformation program "Vision 2030" with the goals of reduce its dependence on oil, diversify its economy and develop service sectors such as health, education, infrastructure, and tourism).

There is no easy or universal recipe for diversification for energy-exporting countries. IMF (2016) stresses the need to develop non-fossil sectors, but notes that country specific circumstances will determine the strategies for diversification. Economic researchers usually call for an asset diversification with investment in human capital (education, health, better-functioning government and other regulatory institutions, etc.) which leads to an increased productivity of the entire economy. More productive labor has a higher value that is reflected in higher compensation leading to higher consumption. Higher productivity affects economic growth and leads to higher GDP. As a result, economic diversification helps to achieve a higher level of welfare. However, even in theory, allocating higher percentage of assets to human capital and research and development does not lead to immediate changes in labor productivity and higher economic growth. Determining a long-term strategy and staying the course when no instant results can be provided to gain a broader political and popular support is a challenging task.

5. Major risks for the Russian economy in the post-Paris world

The shift of global economy towards low-carbon development declared in Paris may jeopardize the Russian model of economic development based on fossil fuels production and exports. Energy sector and various carbon-intensive industries (metallurgy, fertilizers production, chemical and petrochemical industries) amount to a large share in GDP, exports, budget incomes and employment that makes Russia vulnerable to a number of significant risks.

5.1 Risks for Russian energy exports

It is highly unlikely that Russia will be able to substantially expand its exports of fossil fuels that were the major driver of the country's economic development in 2000-s. Restraints to exports that were previously observed on the supply side would shift to the demand side as the leading national economies tend to limit their consumption of fossil fuels. The intensity of this trend differs across scenarios. In the *ParisForever* scenario, Russia would have opportunities to increase the exports of natural gas relative to the current levels, primarily to Asian markets. In the *Paris2C* scenarios Russian fossil fuels exports would decrease dramatically for all categories of fossil fuels except oil products.

In all the scenarios, coal is the most vulnerable sector. 2°C target declared in Paris Agreement suggests that coal should gradually vanish from the energy mix worldwide. Our analysis concludes that by 2050 coal use in Europe and Asia will be about 75% lower than in 2015. Even in the *ParisForever* scenario, coal consumption is expected to decrease both in Europe and in Asia where it will be intensively substituted by natural gas and renewables. The role of coal industry in the Russian economy and its political influence remain very high, as most of production is concentrated in a small number of regions with the non-diversified economy and long history of social tensions with participation of coal miners. Employment and social stability in these regions depend heavily on coal exports revenues. Their reduction would require special efforts to restructure regional economies which have been neither made nor planned yet. At the same time, the Russian energy strategy for the period up to 2035 (the last edition was published in February 2017) still suggests to maintain the current amount of coal exports even in conservative scenario with possibilities to expand exports 1.5 times in optimistic scenario (Ministry of Energy, 2017). Our estimates for coal exports by their Europe and Asia destinations show quite different trajectory (**Figure 7**).

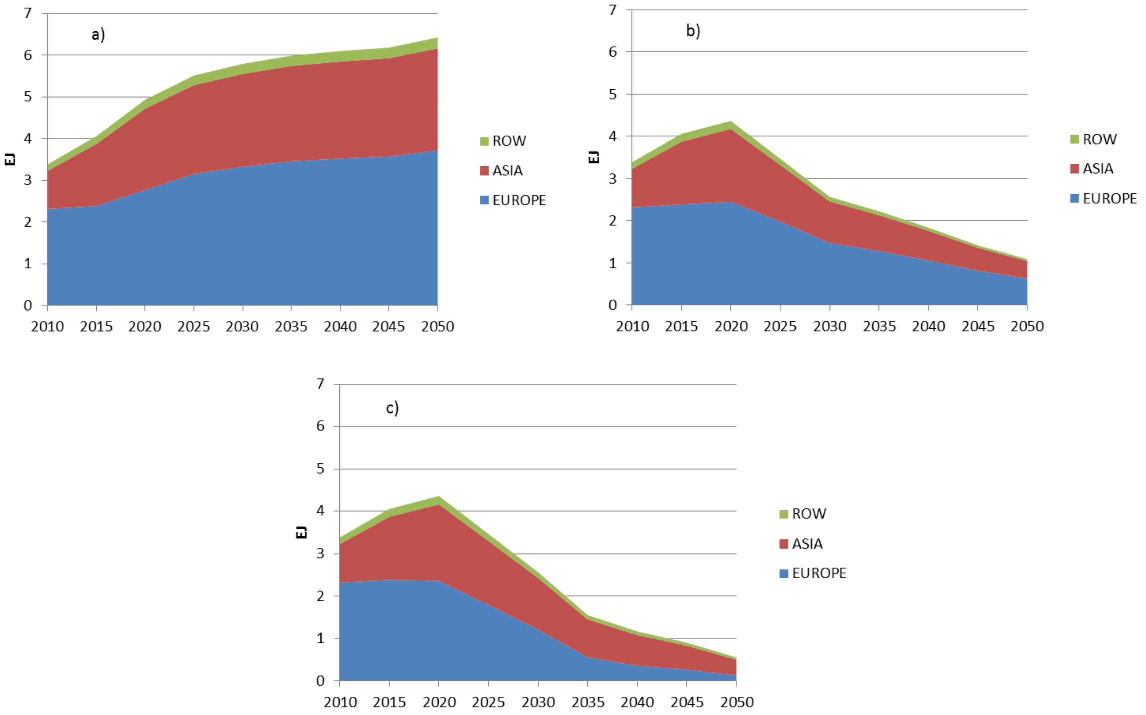

Figure 7. Russia's coal exports in: a) the *Reference* scenario; b) the *ParisForever* scenario; c) the *Paris2C_RussiaPolicy* scenario (Exajoules).

The dynamics of Russian oil exports will depend on the evolution of the transport system in both developed and emerging economies. The Paris Agreement would strengthen the trend towards tightening vehicle and fuel standards, development of public transportation and further progress in electric vehicles, especially in developed countries, which would reduce their demand for crude oil and oil products. At the same time, in Asia the growing number of cars would stimulate the demand for oil products that will allow Russia increase its oil products exports even in the *Paris2C* scenarios. However, the progress in electric vehicles remains the factor of high uncertainty and may result in additional risks for Russian oil exporters.

The world consumption of natural gas in the *ParisForever* scenario is increasing. In particular, Europe's 2050 gas consumption is 25% higher than the 2015 levels and Asia's 2050 gas consumption is 60% higher than the current (2015) levels. However, the previous expectations of 'the golden age of gas' as a transition fuel on the way from fossil fuels to renewables (IEA, 2011) also make way to the more conservative views on gas demand (Mitchell and Mitchell, 2016). In the *Paris2C* scenarios, natural gas consumption in Europe and Asia are declining giving the way to a wide expansion of renewables. The largest niches for natural gas are in the countries where coal is still dominant in energy mix, primarily in China and India. A number of existing projects under construction (Power of Siberia, Yamal LNG) or those in the process of negotiations (Power of Siberia 2, expansion of Sakhalin projects) would increase Russia's share in Asian markets (**Figure 8**). However, in the *Paris2C* scenario, Russian rising exports to Asia would not be sufficient to compensate the drop of gas exports to Europe where active climate policy aimed to achieve 2°C target would lead to rapid substitution of Russian gas by renewables. In this case, Russia will face not only the challenge of reducing coal exports but gas exports as well.

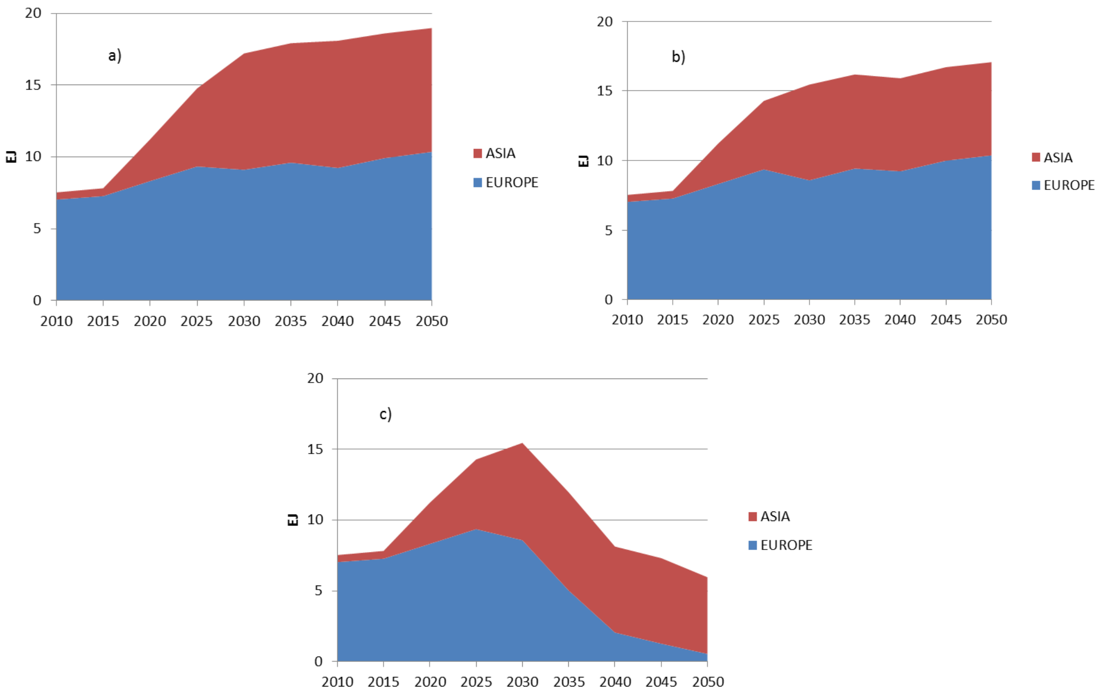

Figure 8. Russia's natural gas exports in: a) the *Reference* scenario; b) the *ParisForever* scenario; c) the *Paris2C_RussiaPolicy* scenario (Exajoules).

5.2 Risks for Russian energy-intensive exports

According to the EPPA model results, in *Paris2C_RussiaBAU* scenario Russia may partially benefit from carbon leakage from developed economies where carbon pricing will put additional pressure on carbon-intensive industries. This situation, when most of the countries reduce emissions to achieve 2°C target and Russia follows the BAU scenario is an example of the "prisoner's dilemma", where the non-cooperative strategy that is not able to sustain collectivebest outcome is however individually preferential. In the absence of additional enforcement mechanisms it would become the first-choice option for Russian policy-makers among the *Paris2C* scenarios.

However, following such a strategy is hardly feasible because companies and governments from the cooperating countries possess sufficient enforcement mechanisms. The development of data and analytical instruments makes it possible to monitor emissions along the whole value chain (Plambeck, 2012; Acquaye et al., 2014). The growing number of companies demands from their partners to meet basic environmental standards. Industrial codes of conduct and even carbon regulation schemes appear in some sectors, with aviation as the most illustrative example. Many companies introduce corporate carbon prices (Weiss et al., 2015) and now they are interested in expanding them to the whole market. In general, being 'green' becomes an important competitive advantage for any business (Porter and Kramer, 2011), and many Russian companies lack it, which makes them less competitive.

Market access barriers may not only be introduced by business but also by governments. One possible instrument which is widely debated both in academic literature and public politics is border carbon adjustment (BCA), which assumes imposing an additional tax on imported carbon intensive products (Condon and Ignaciuk, 2013; Sakai and Barrett, 2016). In theory, the volume of this tax should be calculated as a difference in carbon footprints of imported product and its domestic analogue, multiplied by the carbon price (for example, defined by national emissions trading scheme). In practice, it is often suggested to impose carbon taxes on products imported from countries without carbon pricing system.

For Russia, these actual and potential barriers for carbon-intensive goods are an additional source of risk associated with implementation of the Paris Agreement. This risk is especially high given that Russia is the second largest country in terms of emissions embodied in exports (after China) and has the highest carbon-intensity of exports among all the large economies (Makarov, Sokolova, 2015). One reason for this is Russian trade specialization and structure of Russian exports. 32% of Russian emissions are released for production of exported goods. They include emissions related to extraction and transportation of fossil fuels but as well as emissions generated for production of different energy-intensive goods including metals, chemicals, fertilizers or agricultural products. The other reason is in the use of the relatively outdated technology compared to many developed countries (Makarov and Sokolova, 2015).

Regardless of the reasons, large carbon-intensity of exports and the lack of domestic carbon regulation make Russia vulnerable to any carbon-related market access barriers introduced abroad. The closer Russian policy is to BAU scenario and the closer the policy of rest of the world is to *Paris2C* scenario, the higher are the risks of additional barriers to Russian exporters of energy-intensive goods.

5.3 Risks of relying on outdated technology and the need for diversification

The targets declared in the Paris Agreement are impossible to achieve without a rapid energy technology transformation. Consensus that was achieved in Paris boosted a momentum for accelerating innovations related to low-carbon developments in different sectors: energy production and transportation, automobiles, construction, and urban planning (IEA, 2017). Carbon pricing and other climate policy instruments that have been introduced in many countries would further incentivize energy-related technical change. Governments in many countries tend to support R&D in green technologies or directly subsidize their implementation. They consider such measures as win-win policies aimed at both climate change mitigation and gaining first-mover advantage at the prospective markets.

In Russia, energy technologies have always been declared as one of the major directions in the national system of support of innovations (Proskuryakova, 2017). However, most of innovations have been focused on the technologies of extraction of fossil fuels. “Green” technological trends (such as the expansion of renewables, progress in electrical vehicles, and development of smart grids) have no reflection in the evolution of the Russian energy sector. For example, the target for the share of renewable electricity production at the level of 4.5% by 2020 introduced in 2009 is much more modest than in most of developed economies, but even this target has been revised as unachievable. Despite some positive trends in the development of renewables in 2016-2017, there is still no guarantee that even the new target at the level of 2.5% will be achieved (Porfiriev, Roginko, 2016).

The potential for development of green technologies in Russia has been affected by sanctions imposed on the country. A number of international institutions including the European Bank of Reconstruction and Development and the International Financial Corporation have already stopped financing clean projects in Russia. Moreover, sanctions on Russian financial institutions have undermined their opportunity to finance any long-term projects. The government hopes to build the new system of clean project finance through the emission of green bonds and to attract green investment from new development institutions. One clean project – small hydropower stations in Karelia region – has been already financed by BRICS New Development Bank. Asian Bank of Infrastructure Investment may also become a new source of project finance (Makarov, 2016). However, these efforts are unlikely to keep Russia in line with international trends of “green” technologies development. Remaining on the sidelines of these trends and following *Paris2C_RussiaBAU* scenario, Russia risks to remain reliant on technology that will become outdated.

One potentially positive example of Russian low-carbon technology development is nuclear power. While nuclear generation has its own issues and faces difficulties in Europe and USA, in many regions of the world (such as China, India, The Middle East, Africa) nuclear power can offer a competitive solution for the low-carbon economy. Advancing the economic competitiveness of Russian nuclear power export projects offers an example of an industry that can be globally competitive (Minin and Vlcek, 2017). Investments and potential innovations in other low-carbon technologies that Russian industry can advance would help with diversification efforts.

Russia might decide to continue to rely on fossil fuels for its own production, but the loss of export revenue might be substantial regardless of whether Russia participates in a climate policy or not. If there were carbon border adjustments against energy intensive products imposed on the countries with inadequate climate policies, the situation could be worse. The technologies to extract and use fossil fuels might be quite advanced, but if the world decides to eliminate them, not embracing the “right” technology might be impactful for the economy.

How can Russia use carbon mitigation to advance economic growth and diversify away from reliance on exports of fossil fuel? For illustrative purposes, we create additional scenarios, where we impose charges on fossil fuel production (oil, natural gas, coal) to finance investments in education to increase labor productivity. For the *ParisForever* scenario, we impose taxes on fossil fuel production outputs at the level of 1%, 2%, or 3% of the value of production. We estimate the impacts of education investment in the following way. First, from the collected tax revenue we calculate the number of students it can support (using OECD (2013) to estimate the annual expenditure per student in Russia). Second, we use the education rate of return of 12% (based on Arabsheibani and Staneva, 2012) to calculate the increased average labor productivity of new workers.

Figure 9 shows the changes in sectoral output in the scenario with a 3% tax on the value of fossil-fuel production. Relative to the *ParisForever* scenario, in the long-term most of the sectors’ output levels increase. This reorientation of assets from the fossil-fuel sector to the services sector leads to an initial relatively small decrease in GDP in 2020 by 0.11%, 0.24%, and 0.39% relative 2020 level without such policy (the impacts are corresponding to the level of output tax), but to a long-term robust increase in GDP in the consecutive periods. By 2050 the GDP increases are 1.3%, 2.7%, and 3.95% relative to the GDP level in 2050 without a diversification policy. While there are many practical challenges to implementation of this policy, these diversification scenarios provide an illustration for the magnitude of potential changes.

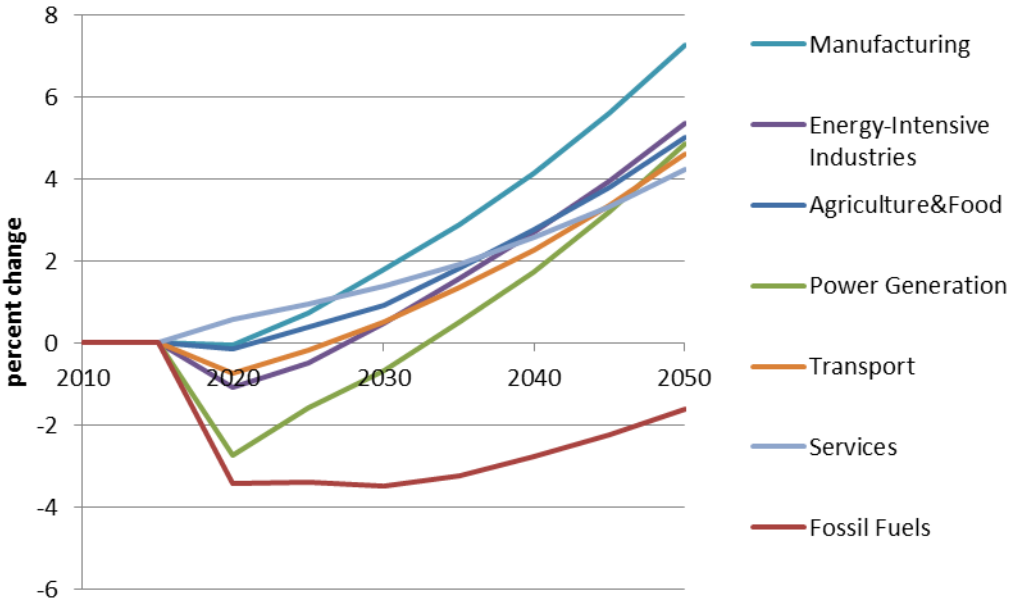

Figure 9. Change in Russia's sectoral output in the scenario with a 3% tax on the value of fossil-fuel production, relative to the *ParisForever* scenario.

6. Conclusions and policy recommendations

The Paris Agreement not only writes the rules of the international climate regime for coming decades but also reflects the consensus of the world community regarding future evolution of global energy landscape towards low-carbon development. This paper shows a number of scenarios of how this future landscape would affect the Russian economy, one that is highly dependent on the production and export of fossil fuels. Even relatively modest national targets declared by the parties of the Agreement by 2030 within their NDCs bring some risks for the Russian economy, for example, those associated with the decreasing demand for Russian coal or potential additional market barriers for Russian exporters of energy-intensive products. However, these risks concern primarily specific sectors, are manageable, and are unlikely to dramatically affect Russia's general economic performance. At the same time, any tightening of NDCs beyond 2030 would become a significant obstacle to Russian economic growth.

Risks associated with the Paris Agreement slightly depend on Russia's formal participation in the international climate regime. A potential non-ratification of the Agreement would not improve Russia's position and probably would lead to additional risks for Russian exporters. For

Russia, it is critically important to get ready to mitigate the risks associated with the Paris Agreement by adjusting itself to the new energy landscape. Diversification of the economy is the major response. This paper simulates three simple diversification scenarios showing that redistribution of incomes from energy sector to the development of human capital would help avoid the worst possible outcomes. We show that the magnitude of GDP increase can be in the order of 1-4% relative to the no-diversification scenario. While the development of a full-scale strategy of adaptation of the Russian economy to a low-carbon future is beyond the scope of any academic paper, we advocate for the acceleration of this process by Russian industrial, academic, and government experts. Our results provide the initial exploration of the major areas to focus on for such a strategy.

We argue that the objective for this strategy should be broader than just the planning of low-carbon development. In addition to the plans to support low-carbon technologies that are most relevant to the Russian market and to introduce new regulations and legislative incentives to promote low-carbon development (including emissions disclosure requirements and carbon pricing scheme), the strategy should find ways to address three types of risks: risks of reducing energy exports, risks of additional market barriers to Russian exporters of energy-intensive goods, and risks of relying on outdated energy technologies. The post-Paris energy landscape poses a challenge for Russia to gradually change the model of its economic development, launch the process of diversification of the economy, and elaborate the new comprehensive development strategy identifying its new position in the world economy. The current way of fossil export based development will be difficult to sustain in the coming decades, regardless of Russia's own climate policy choices.

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