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Estimating the Effect of Taxing CO2 Emissions on Russian Oil Industry[1]

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Abstract

The impact of hypothetical restrictions on fossil fuel consumption, implemented through the introduction of a tax on CO2 emissions in the global economy and certain regions, on oil production by Russia, Organization of the Petroleum Exporting Countries (OPEC), and eight other major oil producers is assessed in this article.

The first part of this study reviews the current literature on taxation of emissions in the global economy. Approaches to modelling such a policy and the problem of choosing the trajectory of the tax rate are analyzed, as are the main conclusions, consequences, and recommendations for the economic policy of oil exporting countries. Approaches to modelling pricing in the oil market are considered separately. The analysis shows that the premise of oligopolistic strategic interaction of oil exporters plays an important role in modelling the oil market.

Subsequently, a model of strategic interaction between countries in the oil market is built according to the Cournot model. This model is calibrated using data on the parameter of demand as well as supply, including the production costs of individual exporting countries according to Rystad. Twelve scenarios for taxation of the industry through the introduction of a tax on CO2 emissions in the amount of $25, $50, and $75 dollars per ton of emissions are built. It is assumed that this tax is converted into a tax on the purchase of oil in proportion to the amount of emissions that are produced when using each barrel of oil. For each initial value of the rate of tax on emissions, cases are considered when the rate remains unchanged or increases at a constant rate of 1.5% per year. Further, the same options for taxation when applied only by developed countries are also considered.

The analysis in this article shows that a gradual increase in the tax rate leads to accelerated oil production. It also reveals the significant role of the spillover effect between markets in the case of the introduction of a tax only in some countries. Thus, with the introduction of a tax of $50 per ton of emissions with an annual growth of 1.5% worldwide, the peak oil price is lower by $29.6 per barrel. With the introduction of such a tax only in developed countries, the fall in oil prices at its peak compared to the baseline scenario without taxation is $18.4 per barrel in the market where a tax was introduced and $7.8 per barrel in a market that did not impose a tax. It is also indicated that, due to the introduction of the tax, Russia has one of the largest losses in revenue among all oil exporters.

Keywords: oil, emissions tax, OPEC, oligopoly, cartel, pricing

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Introduction

The global oil market has faced uncertainty recently due, in part, to the risks associated with the pandemic and a temporary drop in energy demand, the risks of an oil embargo against Russia, as well the policy of reducing CO2 emissions and switching to green energy undertaken primarily by developed countries and likely to spread to the entire world economy in the future.

In December 2015, the Paris Accord was ratified, according to which countries should strive to pass the peak of global greenhouse gas emissions as soon as possible. In addition, in 2021, the European Union (EU) announced the introduction of a border carbon tax on goods imported into the EU (CBAM). The tax is applied to goods requiring substantial emissions in production, such as cement, electricity, fertilizers, and aluminum. Oil and gas were not included in the list, which significantly reduces the potential effect on Russian producers. To mitigate the consequences of taxation, it was decided to introduce it gradually over several years, but the list of taxed carbon-intensive goods may extend toward oil and petroleum products. In any case, it is obvious that the tax will significantly reduce the competitiveness of Russian goods in the European market. Consequently, all these trends may significantly reduce the future global demand for oil.

The model constructed in this article makes it possible to estimate the effect of taxation on the global oil price and revenues of the key producers considering their strategic interaction in the context of various options for taxation of CO2 emissions. The first section contains a review of the research on modelling global oil demand and supply, various pricing structures in the world oil market, and game-theoretic approaches to cartel formation. The next section discusses the model's structure and the calibration of its parameters. The following section presents simulations of taxation and discusses the results. In addition, due to the events of February 2022, the world community is very likely to seek to reduce dependence on hydrocarbons due to an assessed increase in geopolitical risks. These intentions can be implemented under the auspices of the fight against global warming. All these trends may significantly reduce the global demand for oil in the future.

The purpose of this study is to quantify the impact of hypothetical restrictions on fossil fuel consumption implemented by introducing a tax on CO2 emissions in the global economy, or in certain regions, on oil production in Russia, the Organization of the Petroleum Exporting Countries (OPEC) and eight other major oil producers. Calculations are based on the Cournot model of oligopolistic competition for the global oil market. The model proposed in the study is an extension of R.S. Pindyck's work [1978] regarding the choice of functions for oil exporters and Z. Yang's work [2008], which also relies on Cournot interpretation of strategic interaction, as well as an iterative algorithm for numerical solution of the model. In this study, interaction of a larger number of players compared to the mentioned works is modelled. To calibrate the model, we use current data and results of econometric studies on the oil market. The key element of novelty is the numerical simulation analysis and the estimates of the impact of restrictions on oil consumption within the framework of the Cournot oligopoly model on the world oil market. As far as we know, no such calculations have been carried out before.

The model remains quite stylized; however, the calculations carried out may contribute to the discussion about the consequences for the Russian economy of the green changes in global economic policy, as well as induce further research of more complex models.

Literature Review

There are many studies devoted to the problem of taxation of CO2 emissions. W. Nordhaus [2015] analyzed sustainability of coalitions of countries committing to reduce CO2 emissions following the example of the Kyoto Protocol. The simulation results showed that for coalition stability, small fines are needed for countries that violate the agreement. He considered emission tax rates of $12.5, $25, $50, and $100 per ton as realistic values. W. Nordhaus [2017] estimated the optimal tax in 2015 at the level of $31 per ton of CO2 (in 2010 prices) with an average growth rate of 3% per year until 2050. This value of the optimal tax can be described as very moderate among the estimates found in the literature.

S. Paltsev [2014] studied the effect of the EU emissions tax on the Russian economy. He concluded that a decrease in demand for natural gas corresponding to the planned EU emissions reduction of 80% would lead to a drop in Russian gas exports to the EU by 75%. S. Paltsev and E. Kalinina [2014] showed that the introduction of an increasing emissions tax in the global market at the level of $160 per ton by 2050 would cause a reduction in Russia's gross domestic product (GDP) by 10–20%. Similar calculations [Orlov, Aaheim, 2017] indicate a loss of welfare of Russians by 1.8% due to the global fight against emissions. I. Makarov, H. Chen, and S. Paltsev [2020] also showed that the Paris Accord will lead to a significant reduction in Russian exports of fossil fuels, as well as energy-intensive goods. From this point of view, diversification of production and investment in green energy will play a decisive role in the development of the Russian economy.

Pricing in this market is crucial for estimating the effect of taxation on the energy market. The world oil market has gone through numerous stages, which are characterized by changes in the pricing mechanisms used. At the present stage, the volatility and instability of world oil prices has an impact on the economies of oil-producing countries. Above all, it is critical to identify the type of strategic interaction.

Researchers identify the type of pricing in the global oil market, considering OPEC policy from different angles and using various methods to obtain their results: dynamic models, optimization problems with discrete and continuous time, numerical methods and differential equations, as well as broad economic theory (game-theoretic approaches of Nash, Cournot, Stackelberg models, price leader, perfect competition and pure monopoly). In a study by A.F. Alhajji and D. Huettner [2000], the hypothesis of dominant producer for OPEC, OPEC core countries, and Saudi Arabia was tested, when non-OPEC oil producers are considered as a competitive fringe. They found evidence that neither OPEC nor the core of OPEC can be considered to be a leader. S. Böckem [2004] confirmed that OPEC is the price leader, while all non-OPEC countries are price followers. Estimation of a system of simultaneous equations in P.A. Almoguera, C.C. Douglas, and A.M. Herrera [2011] answered two questions: which market structure characterized best the global oil market in 1974–2004 and whether there were transitions from collusion to non-cooperative behaviour during this period. The results showed that during the period OPEC's behaviour is best described by the Cournot model, when faced with competitive non-OPEC producers, and despite periods of collusion, the organization was unable to consistently keep prices above the level of quantitative competition. The null hypothesis that there was no switching of OPEC policy from collusion to non-cooperative behaviour was rejected in favour of the alternative, according to which both cooperative and non-cooperative behaviour was observed in the period 1974–2004. In D.P.T. Young [1994] two key aspects of price behaviour were combined: presence of OPEC monopoly power in pricing and importance of interaction and investment behaviour of its participants. It was found that although OPEC does not match the general theory of monopoly, there is clearly a certain degree of monopolism in the behaviour of prices. J.M. Griffin and W. Xiong [1997] developed the topic of the gains from various strategies of OPEC members. Their study calculated price trajectories and profits in cases of perfect competition, Cournot, and maximizing the joint profit of all members. It was found that actual oil prices are higher than Cournot price, but lower than prices that maximize total profits, which indicates that the cartel has at least partially succeeded in achieving higher profits. Second, unlike non-resource industries with rapidly growing production, the presence of short-term capacity and resource constraints in the oil industry significantly weakens the incentive of participants to fraud. It is also shown that the biased system of market quotas inherent in the organization in favour of small producers weakens but does not eliminate their incentive to deviate from collusion.

Quantitative methods and iterative algorithms used in Z. Yang [2008; 2013] are of particular interest for oil market analysis. Yang [2008] investigated the impact of exploration of new Arctic National Wildlife Refuge (ANWR) deposits on strategic behaviour of OPEC members using a dynamic Cournot model. Numerical simulation of the game (using an iterative algorithm to obtain optimal price and production trajectories in the case of an oligopoly and in the case of an OPEC collusion) yielded the following result: even though ANWR exploration could increase U.S. domestic production, its scale cannot change the fact that the country will continue to depend on foreign oil; OPEC strategic decisions have a much stronger impact on the U.S. oil market than ANWR exploration. In a subsequent article, Yang [2013] explored oil production profiles in the Stackelberg equilibrium scenario. After calibration according to real data of the world oil market, the problems in the case of Stackelberg and Cournot-Nash were solved numerically to study some properties of the Stackelberg equilibrium in the market of exhaustible resources. In a calibrated model of the depleted resources sector, simulating the international oil market, an oligopolistic market structure is established, where OPEC is the leader in production volumes according to Stackelberg, and other major producers are followers who strategically interact with each other. The results of applying the numerical modeling approach were as follows. Compared to the Cournot-Nash equilibrium, Stackelberg's leader retains a moderate advantage over its followers. However, the advantage decreases as the size of the followers increases. The leader slightly delays its mining profile, and followers slightly accelerate their mining profiles while they are functioning in the market. In general, the differences between the Cournot-Nash and Stackelberg equilibria turned out to be small.

There are also studies indicating a weakening of the role of OPEC in its ability to have a significant impact on world oil prices, for example that by B. Fattouh [2007], which additionally states that the price of OPEC is not constant and varies depending on oil market conditions. At the same time, the so-called shale revolution and the increase in crude oil production in the United States caused by technological advances in hydraulic fracturing and horizontal drilling, have brought long-term changes to the global oil market. Therefore, the impact of the development of alternative energy sources on world oil prices is actively discussed in foreign literature, for example, in H.C. Bjørnland, F.M. Nordvik, and M. Rohrer [2019], N.S. Balke, X. Jin, and M. Yücel [2020], H. Benchekroun, G. van der Meijden, and C. Withagen [2020], G. Bornstein, P. Krusell, and S. Rebelo [2017]. Balke, Jin, and Yücel [2020], constructed and evaluated a dynamic structural model of the global oil market in order to quantify the impact of the shale revolution, which is modelled as a sharp reduction in shale production costs, and investigated how the growth of shale production affects the level and volatility of oil prices and conventional oil production. They found that oil prices in 2018 would have been about 36% higher if the shale revolution had not occurred and that the shale revolution implies a decrease in current oil price volatility by about 25% and a decrease in long-term volatility by more than 50%. The authors also noted that, despite the sharp increase in the market share of shale oil, OPEC's market share did not change in this period, which indicates that the growing share of shale in world oil production is mainly due to other producers of conventional oil.

In Benchekroun, van der Meijden, and Withagen [2020] it was found that the OPEC market power leads to inefficient use of oil reserves. Because of this inefficiency, the authors noted the detrimental impact on the overall well-being of the U.S. shale revolution. By decomposing the effects of imperfect competition on welfare and climate into the "conservation effect" and the "consistency effect," the authors showed that the first of these really slows down climate change by increasing the initial oil price. On the other hand, imperfect competition causes an excessively high supply of polluting unconventional oil, which exacerbates climate change. In their model of imperfect competition, the recent shale revolution not only increases climate damage, but also reduces well-being, as shale oil displaces OPEC oil produced with less damage to the environment. However, despite the detrimental impact on the ecology of shale oil and oil produced by non-OPEC exporters noted in Benchekroun, van der Meijden and Withagen [Ibid.], the study by Bornstein, Krusell, and Rebelo [2017] found that one of the consequences of the shale revolution was a decrease in oil price volatility. The authors used a data set covering all oil fields in the world to evaluate a stochastic equilibrium model of the oil industry with two alternative market structures. In the first, all manufacturers are perfect competitors. In the second, OPEC acts as a cartel and non-OPEC producers are a competitive periphery. With their model specification, it was confirmed that the demand for oil is relatively inelastic in price and that supply is elastic in the long term, since firms can invest in the discovery of new oil fields, but inelastic in the short term.

Thus, the problem of pricing at the world markets of exhaustible resources has been studied extensively. However, though many economic studies have been conducted in relation to the oil market, there is no generally accepted description of this market. The articles tested various hypotheses about the structure of the global oil market, internal structure of cartels, and the scheme of cooperation between their participants, as well as the external actions of cartels in relation to competitive countries. Using various methods and assumptions, the researchers identified optimal pricing strategies and the division of production and production between cartel members.

Russia, a state with a significant share of production and exports in the raw materials market, cannot ignore the policy of OPEC. Nevertheless, studies of the interaction between OPEC and Russia are practically absent from the literature. Although many economists confirm that OPEC benefits from cartelization, Russia is in no hurry to join the cartel. But, the formation of a stable oil price is a common task for both.

The Model

The dynamics of the global oil market are set with simultaneous demand and supply equations (1)–(3):

$$Q_t = \alpha_1 (p_t + \tau(1+\gamma)^t)^{\beta_1} {Q_{t-1}}^{\rho_1} g_1^t, \tag{1}$$

$$Sdirty_t = \alpha_2 \, {p_t}^{\beta_2} \, g_2^t, \tag{2}$$

$$Sclean_t = \alpha_3 \, (p_t + \tau(1+\gamma)^t)^{\beta_2} \, g_3^t, \tag{3}$$

Q_t—global demand for oil in year t, million BBL;

p_t—world oil price in year t, \$ per BBL;

τ—emissions tax rate, \$ per BBL;

γ—emissions tax rate growth rate;

$Sdirty_t$, $Sclean_t$—oil supply of competitive fringe in year t, million BBL;

g^t_1, g^t_2 и g^t_3—parameters of demand and supply in year ;

$\alpha_1, \alpha_2, \alpha_3, \beta_1, \beta_2, \beta_3, \varrho_1, \varrho_2$—coefficients.

We study the Cournot competition among 10 oil exporting players. These are OPEC (Algeria, Angola, Venezuela, Gabon, Iran, Iraq, Congo, Kuwait, Libya, UAE, Nigeria, Saudi Arabia, Equatorial Guinea—taken together as one player) and another nine of the largest oil producers, according to the Energy Information Administration (EIA): Russia, U.S., China, Canada, Brazil, Mexico, Kazakhstan, Norway, and Qatar. We consider all oil exporters of the rest of the world as the competitive environment, as described by equation (2) and biofuel is equation (3). As biofuel is not subject to carbon taxation, its consumer's and supplier's prices both equal .

The goal of each oil producer is to maximize the present value of its profit. Therefore, the value function of each exporter is (4) under constraint (5):

$$\sum_{t=1}^{T} \frac{1}{(1+\delta_i)^t} \left(p_t q_{it} - c_i(r_{it}, q_{it})\right) \to max\{q_{it}, r_{it}\} \quad i = 1, \dots N, \tag{4}$$

q_{it}—exporter's *i* oil production in year *t*, million BBL;
p_t—oil price in year *t*, \$ per BBL;
r_{it}—exporter's *i* oil reserves in year *t* , million BBL;
$c_i(r_{it}, q_{it})$—exporter's *i* cost in year *t*;
δ_i—exporter *i* discount rate;
N—number of producers;
T—number of periods.

Various cost functions can be found in the literature (for example, depending on oil production and reserves, see Pindyck [1978] or quadratically dependent on production, see Yang [2008, 2013]). It is crucial that the cost function implies higher average cost for larger output. We use the same specification as Pindyck [1978]:

$$c_i(r_{it}, q_{it}) = \frac{m_i}{r_{it}} q_{it}, \tag{6}$$

where m_i is initial reserves of exporter *i* multiplied by its initial cost.

We employ an iterative algorithm to determine the optimal choice of output in Cournot oligopoly. Solving the dynamic problem of maximizing a nonlinear function with constraints gives optimal trajectories for output, reserves, and equilibrium prices. We maximize function (4) under constraints (5), taking into account that the world oil supply is given by equation (7):

$$Q_t = q_t^o + S_t = q_{it} + \sum_{j \neq i} \overline{q_{jt}} + Sdirty_t + Sclean_t, \tag{7}$$

where $\sum_{j \neq i} \overline{q_{jt}}$ is exogenous production of other exporters except for *i*.

The algorithm is as follows:

1) We determine present value function for exporter *i* profit;
2) We exogenously introduce other exporters' output treated as given by *i*;
3) We maximize (4) under constraints (5), (7) and system (1)—(3) that gives optimal output, price, and reserves for *i*;
4) We proceed for $i = 1, \dots N$;
5) We update the exogenous output of other (non-*i*) players on every iteration;
6) We continue until convergence.

Calibration

We need to specify the model's parameters that generate the oil market's dynamics: oil demand, shale oil and biofuel supply, and oil production cost functions. There is much literature estimating elasticity of demand (both for individual regions and global) by price and income. The estimates vary substantially depending on the data and methods used.

J.C.B. Cooper [2003] estimated a regression model for 23 countries (non-OPEC members). The estimates confirmed that demand for crude oil on a global scale is insensitive to price changes. The average estimate of short-term elasticity across countries is –0.05 and long-term is –0.21. As expected, all long-term elasticities exceed the short-term values.

In P.K. Narayan and R. Smyth [2007] the main conclusion from panel data analysis of the Middle East countries was that the demand for oil is slightly elastic in terms of income and extremely inelastic in terms of price in the long run. This is consistent with the observation that oil demand in the Middle East is largely driven by strong economic growth, while consumers are largely insensitive to price changes. The long-term elasticity of oil demand by price for the entire data panel is –0.015 and by income is –1.014; the short-term elasticity by price is slightly different from zero. In L. Kilian [2017] it was mentioned that the traditional estimate of the long-term elasticity of oil demand at a price is –0.8.

An article by J.D. Hamilton [2009] presented a review of studies in which it was concluded that the average estimate of the short-term price elasticity of demand is –0.06. However, more recent studies have presented higher estimates: for example, L. Kilian and D. P. Murphy [2014] obtained a short-term elasticity value of –0.26 based on structural vector autoregression. The authors noted that common estimates of short-term elasticity presented in studies such as by Cooper [2003] and C. Dahl [1993] are not trustworthy, pointing out that the methods they used lead to a bias. They provided a superior model taking into account the role of reserves in the global oil market. In addition, they used a global model of the world oil market instead of regressions for individual countries.

Hence, we specify price elasticities as –0.25 for short-term and –0.8 for long-term. As for the long-term elasticity of demand by income, its estimate is assumed to be 0.55, obtained in N. Krichene [2002] and D. Gately and H.G. Huntington [2002]. An estimation of the short-term elasticity of oil supply is given in F.M. Nordvik [2019]. Using panel data, the authors concluded that there is a low positive elasticity of oil supply at a price, the resulting value of which is 0.71. We use this value for both competitive sectors $Sdirty_t$ and $Sclean_t$.

We also assume that the autonomous demand for oil will grow in the future at a rate of 1.5% per year, the autonomous supply of the competitive oil producers will decline at a rate of 1% per year, and biofuel supply will grow at the rate of 4% per year as a consequence of technology growth. The values of constants in the total demand function and the supply function of producers in the competitive environment were calibrated based on data on crude oil prices and data on the volume of oil produced by all producers with the exception of the 10 exporters considered in the model. τ and γ are equal to 0 in the basic scenario.

The costs of type (6) are calibrated in accordance with the data on the reserves of the oil exporting countries under consideration and the average costs of oil production. The volumes of reserves come from the EIA, and the cost data are from the Wall Street Journal reports (which published the results of calculations by Rystad Energy [2016]), as well as from the report of the Saudi oil company Saudi Aramco [2019], which published calculated data on the total cost of oil in different countries with included taxes.

The data used by Rystad Energy to estimate cost curves includes information on 62920 fields for 1970–2014, obtained from reports of government agencies in countries such as the U.S. and Norway, including financial and environmental regulators, reports of large private companies, as well as interviews with representatives of major oil and transport companies. Such a time-consuming complex approach is explained by the fact that the oil industry is quite information-closed both for commercial and political reasons, primarily in the Middle East. For example, for closed countries such as Syria, tanker traffic is used to approximate macro data on production, and micro data is estimated using engineering models. Engineering and geographical factors are taken into account, such as capital costs for exploration, drilling, maintenance of the facility, operational costs of production, transportation, sale and administration, tax costs and other payments to the state, and licensing. These data are used in a number of academic papers modelling the global oil market [Asker Collard-Wexler, de Loecker, 2019; Bartik et al., 2019; Bornstein, Krusell, Rebelo, 2017]. Alternative estimates were made by the World Bank [2011] by aggregating all the costs of a country's oil industry and dividing the amount by the volume of production. Despite the five-year gap in the evaluation time, the results of the World Bank and Rystad Energy analyses show a correlation of 0.84 for a sample of 340 observations.

Incorporating newer data for extraction costs in Russia allows us to account for significant increase in the cost of Russian oil, also noted in Rosstat data showing, for example, that in 2018–22 production costs in rubles increased 2.6 times. To calculate the ratio of oil prices of various oil grades, the current quotes of Brent, OPEC basket, Mexican, Canadian and Chinese oil, Urals, WTI, Lula, CPC, and Qatar land are used.

The profit discount rates for each player are calibrated so that the model correctly reproduces oil production by exporters in the base year. Indeed, the current production rates in some countries are very high relative to reserves, which indicates a significant discounting of profits. In the real world, there are significant differences between countries in production rates relative to reserves. Thus, the low production rates relative to the opportunities in the Persian Gulf countries are explained by the high propensity to save in these countries and are confirmed in E. Hnyilicza and R.S. Pindyck [1976]. High production rates and, thus, discount rates in politically unstable countries are explained, among other things, by expropriation risks [Mabro, 1987] and, in the case of state ownership of oil production, by the acute need of the state for money in the short term [Hartley, Medlock, 2008]. These values are shown in Table 1.

Table 1. Official Data for Extraction, Costs, Relative Prices and Reserves of Major Oil Exporters and Calibrated Discount Rates

Country	Extraction, Billion BBL, 2021	Reserves, Billion BBL, 2021	Price, % of Brent	Costs, $ per BBL	Discount Rate
OPEC	11.5	1226.5	98	30	0.045
Russia	3.9	80.0	97	43	0.160
U.S.	2.3	31.0	89	46	0.145
China	1.7	26.0	105	57	0.145
Canada	2.0	170.3	66	50	0.148
Brazil	1.3	12.7	96	52	0.165
Mexico	0.7	5.8	87	47	0.150
Kazakhstan	0.7	30.0	95	48	0.042
Norway	0.7	8.1	100	44	0.080
Qatar	0.7	25.2	98	19	0.017

Source: Extraction and reserves—EAI, costs—Saudi Aramco и Rystad.

Simulations

Cournot Oligopoly Baseline

Before considering the impact of emissions taxation on production of exporters and the world price of oil, we analyze the baseline scenario of Cournot oligopoly. Figure 1 shows the equilibrium trajectories for this case. The year 0 corresponds to 2022. In the baseline global oil production and consumption decline from 26.8 billion BBL per year to zero in 95 years. For instance, Russia's production contracts from almost 3.8 billion BBL yearly to zero in 70 years.

To facilitate comparison between policy scenarios, we breakdown global oil consumption to two markets: the U.S., EU, Canada, UK, Switzerland, and Japan (western market) and the rest of the world (eastern market). We assume the ratio of consumption in these two regions to be constant, which according to the EIA is 40 and 60%. Due to supply cuts by major exporters, the price of oil rises until about 2100, then the effect of shrinking supply is offset by alternative energy sources ($Sclean_t$). OPEC remains the largest oil exporter throughout the period under review, followed by Canada (CND), the United States (US), China (CHI), Qatar (QAT), and Russia (RUS). Kazakhstan (KAZ), Brazil (BRA), Mexico (MEX), and Norway (NOR) have smaller market shares.

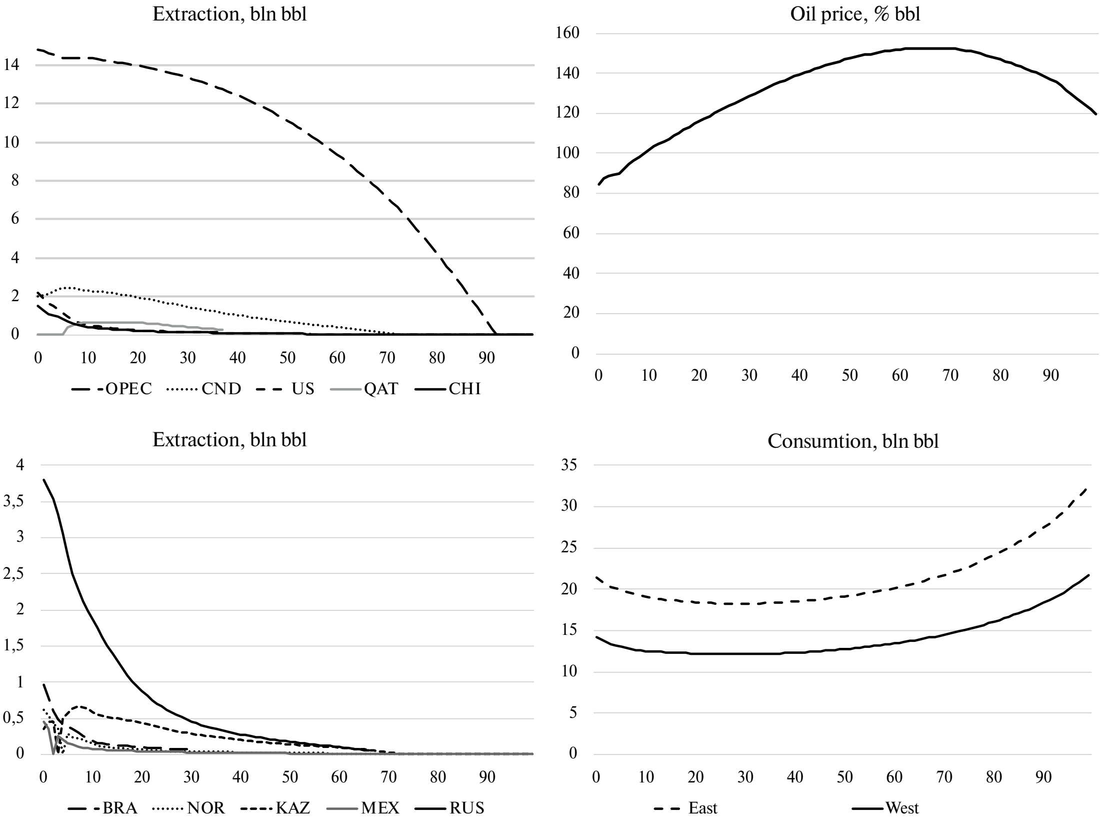

Fig. 1. Oil Price and Consumption in the Baseline

Source: Authors' calculations based on EAI, Rystad, Saudi Aramco.

A Worldwide Emissions Tax Scenario

Now assume that all oil consumers impose a tax on CO2 emissions. As a basic option, we consider a tax of $50 per ton of emissions. Since 1 million British thermal units (Btu) account for 72.6 kg of emissions, and one barrel of oil gives 5.7 million Btu, consumption of one barrel of oil releases an average of 0.414 tons of CO2. Accordingly, in the model, a $50 emissions tax is equivalent to a tax of $20.1/BBL. Also assume that the tax is growing at a rate of 3% per year throughout the period under review.

As can be seen in Fig. 2, this leads to a reduction in oil production and consumption. Since the tax rate is gradually increasing, the optimal production trajectories approach the zero level more sharply. The price increase is not limited to $152.6/BBL, as in the baseline scenario, but at the level of $123.0/BBL. The Russian oil supply is reduced from 3.2 billion BBL to zero in 60 years.

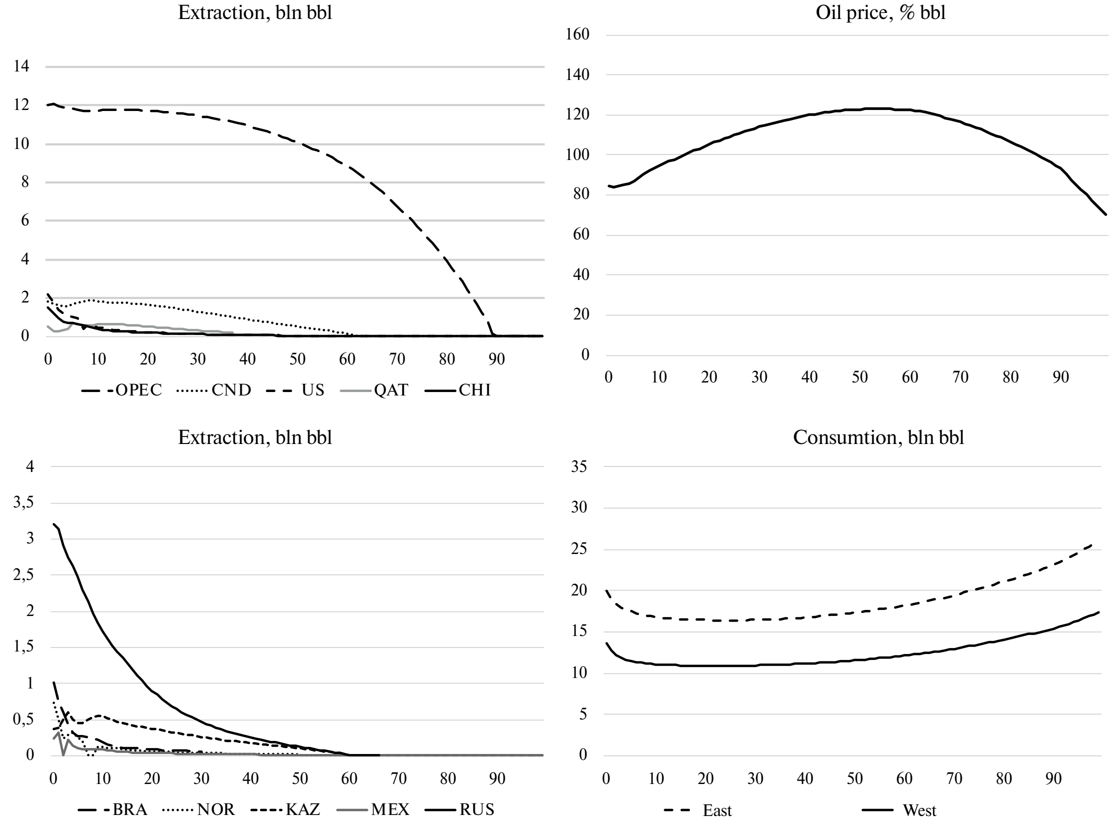

Fig. 2. Oil Price and Consumption Under a Global Emissions Tax Scenario

Source: Authors' calculations based on EAI, Rystad, Saudi Aramco.

A Regional Emissions Tax Scenario

Since developed countries are more active regarding taxation of emissions, consider a scenario where the tax is imposed only in parts of the regions: the U.S., EU, Canada, Great Britain, Switzerland, and Japan. We also assume that Russia's access to these markets is limited.

Thus, we introduce two separate markets (western and eastern) into the model, and we believe that Russian oil is sold only on the eastern market.

In this scenario, if a similar tax is introduced only in the western market, there will be a significant reduction in the volume of the western market. In the base year, it will be equal to 13.1 billion BBL instead of 14.2 billion BBL. The left over oil will be sold on the eastern market, as a result of which its volumes in the base year will increase compared to the base scenario. Oil supply from Russia would be 3.7 billion BBL in the starting year and would last 72 years.

Due to differences in taxation, prices in the two markets will differ markedly. The price on the western market will noticeably decrease in comparison with the baseline scenario, its peak will be $134.2/BBL, instead of $152.6/BBL in the basic scenario. The price in the eastern market will also decrease due to the overflow effect, but to a lesser extent, from $144.8/BBL in the peak. However, these price levels turn out to be higher than in the case of the introduction of a tax on the entire world oil market.

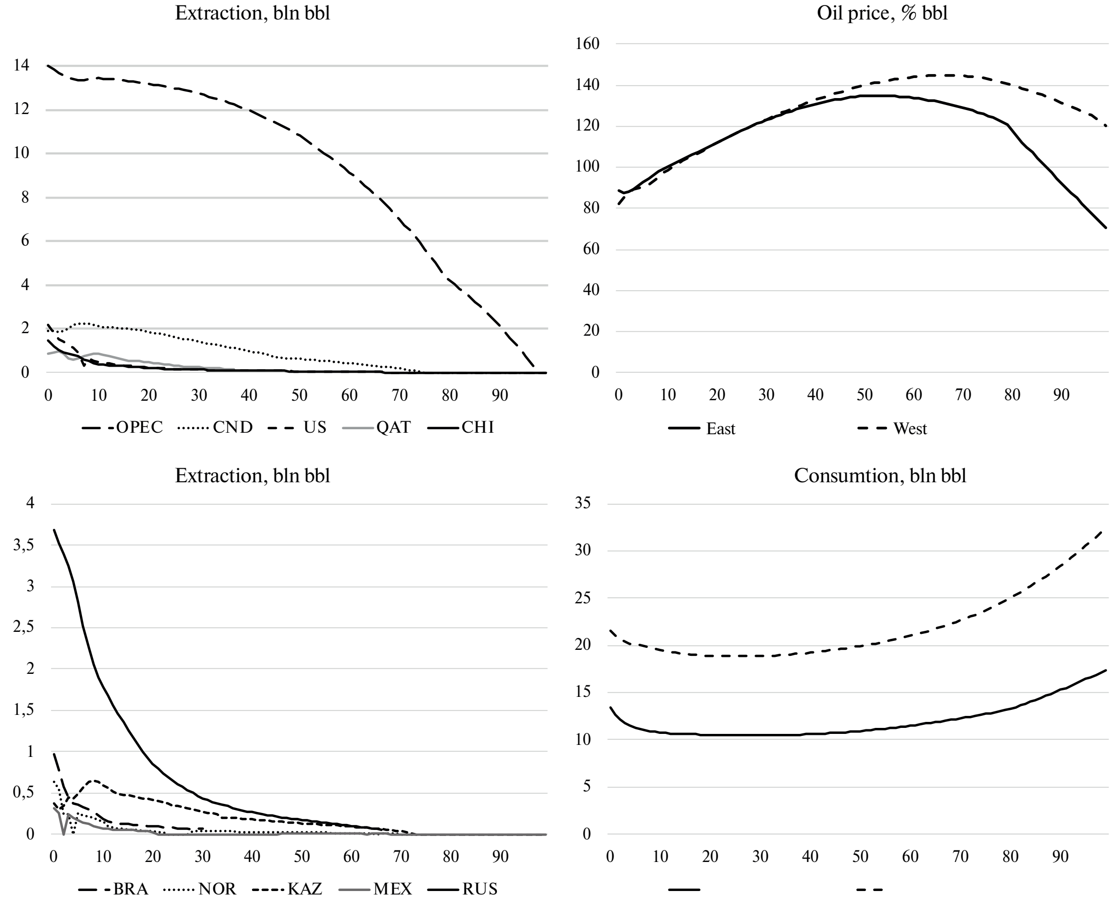

Fig. 3. Oil Price and Consumption Under a Regional Emissions Tax Scenario

Source: Authors' calculations based on EAI, Rystad, Saudi Aramco.

Tables 2 and 3 present other options for an emissions tax imposed on the entire world market and only on the western market, respectively. Prices, production volumes, and revenue of each exporter are given as a percentage of the baseline scenario. Output and revenues are calculated as totals for the specified periods and prices are calculated as averages for these periods. Each table shows 12 scenarios involving the introduction of an emission tax in the amount of $25, $50, or $75 per ton of CO2 emissions and an increase in the rate of 1.5% or staying constant.

A monotonous negative dependence of the oil price on the tax rate and its growth rate is revealed. Also, the introduction of a tax that increases over time stimulates an even greater acceleration of oil production by major exporters. Revenue changes proportionally to prices and production. For example, in the case of a constant initial tax rate of $50 per ton for Russia, Russia will lose 14.3% of revenue on average for the period up to 2030 and 9.1% of revenue for the period 2031–40, whole a gradual increase in the tax rate by 1.5% per year will cost from 5.7% to 12.6% of revenue depending on the period, and under a 3% tax increase, losses will range from 17.0% to 11.8% over the selected periods. Thus, with the selected tax values, a twofold acceleration of the rate leads to a commensurate reduction in revenue for Russia, which is one of the largest percentage drops among the 10 allocated by the exporter. This is the implementation of the spillover effect: the introduction of a tax in one market will displace producers to another market, where they will compete with Russia.

For a permanent tax of $25 per ton of emissions, the reduction in Russian oil revenue will be about 8.7% for the period up to 2030 with a further reduction in the effect. However, for a tax growing at a rate of 1.5%, the losses of the Russian Federation will increase to 9.7%. If the tax is imposed only on markets from which Russia is isolated, then the losses amount to about 2–3% over the entire horizon, both with a growing and with a constant tax rate.

For the tax rate of $75 per ton of emissions, the revenue received by the Russian Federation in the initial periods is 20.9% for the constant rate and 23.3% for the growing one, and, for example, for the period 2041–50, it will be 3.3% and 10.5%, respectively. If the tax is imposed only on the western market, taking into account the oil embargo, losses for Russia will vary from 3.6% to 6.1% for a constant tax rate and from 6.2% to 7.6% for an increasing one.

Conclusion

We constructed a model of Cournot oligopoly for the global oil market represented by OPEC, Russia, Canada, the U.S., China, Qatar, Kazakhstan, Brazil, Mexico, and Norway with demand and cost parameters calibrated to current data. We produced 24 scenarios of taxation of CO2 emissions from oil consumption and analyzed their impact on demand for oil. The global oil market is quite a complex object to model. Different types of participants operate within it: completely competitive agents, large oligopolists and national monopolists, state-owned companies, and state regulators, which can be controlled by managers pursuing their own political goals. In addition to the complex structure of the market, the researcher also inevitably faces the problem of limited and closed data on the industry. Despite this, the proposed model of the oil market, in our opinion, considers the main factors, and gives fairly accurate quantitative estimates. The calculations carried out can contribute to the discussion on this topical topic. In particular, the model considers the possibility of restricting access of Russian oil to the markets of several developed countries.

Twelve scenarios of possible options for taxation of CO2 emissions from oil consumption and their impact on oil demand were analyzed. We assumed the initial tax rate equaling $25, $50, or $75 per ton of emissions constant or with a yearly increase of 1.5%. We distinguish global and regional emissions taxation, that is, taxation in developed countries only: the U.S., the EU, Canada, the UK, Switzerland, and Japan. The restriction of access to these markets for Russia is also considered.

The major results are as follows. A monotonous negative relationship is revealed between the emissions tax rate, as well as its growth rate and oil prices, both under the tax introduced worldwide and regionally. For Russia, the lost oil revenue due to the introduction of an unchanged tax rate of $50 per ton of emissions will amount to 14.3% on average for the period up to 2030 and 9.1% of revenue for the period 2031–40, and in the case of an increase in the tax rate at a rate of 1.5% per year, the losses will amount to significantly more: 17% and 11.8% for the corresponding time periods.

If such a tax is imposed by developed countries that do not buy Russian oil, Russia will also face revenue losses. They will be from 2.8% to 4.0% and from 3.3% to 6.0%, respectively, for permanent and growing taxes. Thus, in the world oil market, strong effects of overflow between local markets are revealed in the case of the introduction of a tax in parts of countries that are transmitted through oil prices. Thus, with the introduction of a tax of $50 per ton of emissions with an annual growth of 1.5% worldwide, the peak price of oil is lower by $29.6/BBL. With the introduction of such a tax only in developed countries, the drop in oil prices at the peak compared to the baseline scenario without taxation is $18.4/BBL in the market where the tax was introduced and $7.8/BBL in the market where the tax was not introduced.

The article also shows that in the short term, with an increasing tax, production is higher than with an unchanged tax rate, since players, expecting higher taxes and, accordingly, declining profitability in the future, increase production in the current time periods—world oil consumption in later periods (2030–40) falls the most. At the same time, it is precisely for 2030–40 that fuel production in the baseline scenario falls. Thus, with increasing taxes on emissions, the profile of oil production becomes more uneven.

In addition, due to the introduction of an emissions tax, Russia is experiencing one of the most significant reductions in oil revenue compared to other oil-producing countries, which indicates relatively high risks of reducing oil demand for Russia.

Table 2. Oil Price, Production and Revenue of Major Oil Exporting Countries Under a Worldwide Emissions Tax (% from the baseline)[2]

Scenarios	Price	Consump	Extraction										Revenue									
25–0%			OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT	OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT
2023–2030	–2,3	–5,4	–10,3	–6,6	–2,5	–2,8	–10,8	–2,6	–16,0	12,5	1,0	90,2	–11,8	–8,7	–4,2	–5,1	–12,7	–5,2	–19,1	9,7	0,2	85,6
2031–2040	–3,0	–5,5	–8,5	–0,7	–3,9	–5,9	–8,9	–5,5	–22,3	–10,8	–10,6	–5,2	–11,3	–3,4	–6,8	–8,7	–11,6	–8,5	–24,2	–13,6	–13,5	–8,3
2041–2050	–3,9	–4,0	–6,3	3,5	–1,8	–2,4	–4,0	–3,5	–6,0	–6,4	–2,7	–11,2	–9,8	–0,5	–5,6	–6,2	–7,7	–7,2	–9,6	–10,0	–6,3	–14,7
25–1,5%			OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT	OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT
2023–2030	–2,9	–5,3	–9,8	–7,1	–3,0	–3,4	–12,7	–3,4	–16,9	13,9	0,6	113,1	–11,9	–9,7	–5,3	–6,3	–15,1	–6,5	–20,5	10,4	–0,9	105,9
2031–2040	–3,8	–6,2	–9,2	–2,0	–5,1	–7,2	–11,0	–6,6	–23,5	–10,2	–8,6	–0,8	–12,7	–5,4	–8,6	–10,7	–14,4	–10,3	–26,0	–13,8	–12,3	–5,0
2041–2050	–5,2	–5,5	–8,0	2,2	–3,8	–4,3	–6,6	–5,8	–8,3	–7,1	–4,3	–13,0	–12,7	–3,0	–8,7	–9,2	–11,4	–10,6	–12,9	–11,9	–9,0	–17,5
50–0%			OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT	OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT
2023–2030	–3,1	–10,3	–18,2	–11,9	–6,2	–7,9	–21,5	–7,8	–5,8	8,3	–1,9	143,0	–20,8	–14,3	–8,7	–10,6	–24,2	–10,7	–8,8	3,2	–5,3	126,1
2031–2040	–6,2	–10,3	–16,4	–3,2	–5,6	–6,5	–16,1	–4,6	–1,5	–11,4	–7,3	–7,9	–21,5	–9,1	–11,4	–12,3	–21,2	–10,5	–7,7	–16,7	–12,7	–13,6
2041–2050	–7,5	–7,8	–12,3	6,3	–2,9	–4,2	–9,0	–6,3	–7,6	–10,6	–4,3	–17,9	–18,8	–1,6	–10,1	–11,3	–15,8	–13,1	–14,3	–17,2	–11,2	–24,0
50–1,5%			OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT	OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT
2023–2030	–4,4	–10,6	–18,2	–13,5	–7,5	–9,4	–24,9	–9,0	–7,6	11,7	–0,9	194,9	–21,8	–17,0	–11,1	–13,1	–28,4	–12,5	–10,9	5,6	–5,1	170,7
2031–2040	–7,6	–11,6	–17,7	–4,8	–6,9	–8,6	–20,2	–7,2	–4,4	–11,1	–12,8	–4,6	–23,9	–11,8	–13,8	–15,5	–26,1	–14,1	–11,6	–17,7	–18,8	–11,9
2041–2050	–9,8	–10,5	–15,6	3,9	–6,5	–8,2	–14,4	–10,3	–12,1	–11,8	–6,4	–20,8	–23,8	–6,2	–15,6	–17,1	–22,7	–18,9	–20,5	–20,3	–15,3	–28,5
75–0%			OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT	OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT
2023–2030	–4,6	–14,4	–25,4	–17,4	–9,5	–11,8	–30,2	–10,5	–8,3	13,3	–2,1	202,6	–28,9	–20,9	–13,3	–15,6	–33,7	–14,5	–12,3	6,2	–6,8	176,3
2031–2040	–9,0	–14,8	–23,3	–5,2	–7,0	–9,2	–24,1	–9,0	–6,7	–18,0	–13,8	–12,5	–30,0	–13,5	–15,3	–17,3	–30,8	–16,9	–15,0	–25,1	–20,9	–20,3
2041–2050	–10,9	–11,5	–18,0	8,4	–4,9	–7,4	–14,5	–9,7	–12,1	–15,2	–7,3	–24,4	–26,9	–3,3	–15,1	–17,2	–23,6	–19,2	–21,3	–24,2	–16,9	–32,6

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[2] *W* and *E* are prices in western and eastern markets.

Scenarios	**Price**	**Consump**	**Extraction**										**Revenue**									
75–1,5%			OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT	OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT
2023–2030	–5,9	–14,5	–24,8	–18,8	–11,0	–13,7	–34,2	–12,4	–10,3	17,9	–2,9	260,7	–29,2	–23,3	–15,7	–18,5	–38,4	–17,4	–15,3	9,0	–8,7	224,6
2031–2040	–10,9	–16,6	–25,3	–8,2	–9,4	–11,9	–29,4	–11,7	–9,2	–16,8	–14,8	–6,3	–33,3	–18,0	–19,1	–21,4	–36,9	–20,9	–18,9	–25,5	–23,4	–16,6
2041–2050	–13,9	–15,4	–22,8	3,7	–11,5	–14,3	–22,7	–17,8	–19,9	–17,3	–11,9	–28,6	–33,5	–10,5	–23,6	–26,0	–33,3	–28,9	–30,7	–28,6	–23,7	–38,4

Source:

Table 3. Oil Price, Production and Revenue of Major Oil Exporting Countries Under Emissions Tax in the Western Market (% from the baseline)[3]

Scenarios	**Price**		**Consump**	**Extraction**										**Revenue**									
25–0%	E	W		OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT	OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT
2023–2030	0,1	–1,4	–1,9	–4,3	–1,0	–1,6	–1,6	–4,9	0,4	–3,7	10,0	4,2	49,8	–5,1	–2,4	–2,7	–3,3	–6,0	–1,2	–5,6	9,4	–4,2	0,8
2031–2040	–1,3	–1,1	–2,2	–3,0	–0,9	0,2	–1,0	–3,2	–6,1	–40,8	–7,8	–13,5	–4,3	–4,2	–1,9	–0,7	–2,0	–4,4	–7,6	–40,3	–9,0	159,7	–2,0
2041–2050	–1,6	–1,5	–1,5	–9,0	–0,4	–0,7	–0,8	–1,0	–1,0	–6,0	–2,5	2,5	–5,5	–3,8	–1,9	–2,2	–2,4	–2,5	–2,6	–7,5	–3,9	–	63,0
25–1,5%	E	W		OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT	OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT
2023–2030	–0,2	–1,6	–1,9	–4,0	–1,1	–1,8	–1,8	–5,5	0,3	–3,8	10,9	4,2	57,2	–5,1	–2,8	–3,1	–3,7	–6,9	–1,6	–5,9	10,0	–5,1	1,8
2031–2040	–1,6	–1,4	–2,4	–3,2	–1,3	–0,4	–1,7	–4,1	–6,8	–41,5	–7,9	–12,5	–2,2	–4,7	–2,5	–1,5	–2,9	–5,5	–8,4	–41,2	–9,4	171,8	–1,5
2041–2050	–2,1	–1,9	–2,1	–11,9	–0,9	–1,4	–1,5	–2,0	–1,9	–7,1	–2,9	1,6	–6,3	–4,9	–2,8	–3,4	–3,5	–3,9	–4,0	–8,9	–4,9	–	67,2
50–0%	E	W		OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT	OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT
2023–2030	–1,1	–1,6	–3,8	–6,9	–1,3	–2,3	–2,9	–8,9	–10,2	–6,4	–2,8	–5,0	11,9	–8,4	–2,8	–3,5	–4,1	–10,3	–11,4	–7,6	–4,5	–6,1	8,0
2031–2040	–2,4	–2,3	–3,8	–5,9	–2,5	–2,6	–3,2	–6,1	–9,6	–35,0	–2,8	–9,4	–3,0	–8,2	–4,8	–4,9	–5,6	–8,3	–12,0	–35,7	–5,2	–12,0	–5,2
2041–2050	–3,1	–2,8	–2,8	–16,8	–1,2	–0,3	–0,7	–2,6	–0,9	–14,6	–3,0	–5,3	–6,1	–7,2	–4,0	–3,3	–3,7	–5,5	–3,9	–17,0	–5,9	–7,9	–8,9

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[3] *W* and *E* are prices in western and eastern markets.

Scenarios	**Price**		**Consump**	**Extraction**										**Revenue**									
50–1,5%	E	W		OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT	OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT
2023–2030	–1,6	–1,9	–3,8	–6,6	–1,6	–2,6	–3,4	–10,2	–3,9	–0,8	0,5	–1,9	50,7	–8,4	–3,3	–4,0	–4,7	–11,9	–5,3	–1,9	–1,9	–5,2	0,7
2031–2040	–2,8	–3,0	–4,2	–6,3	–3,1	–3,4	–4,1	–7,4	–1,9	–10,0	–2,5	–8,1	2,6	–9,1	–6,0	–6,2	–7,0	–10,2	–5,0	–12,6	–5,5	210,3	–1,9
2041–2050	–4,0	–3,6	–3,8	–21,7	–1,9	–1,5	–1,8	–4,3	–2,6	–19,1	–4,0	–8,5	–7,7	–9,0	–5,4	–5,3	–5,6	–7,9	–6,5	–22,1	–7,7	–	69,9
75–0%	E	W		OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT	OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT
2023–2030	–2,0	–2,3	–5,3	–9,5	–1,6	–2,7	–3,3	–11,9	–4,3	–0,6	–1,3	–3,2	43,6	–11,6	–3,6	–4,4	–4,9	–13,9	–5,9	–1,7	–4,0	–6,3	1,7
2031–2040	–3,2	–3,3	–5,3	–7,9	–4,5	–6,7	–10,0	–10,7	–8,3	–45,9	–5,4	–19,2	2,9	–10,9	–7,5	–9,7	–13,2	–13,7	–12,1	–48,4	–8,9	218,8	–2,0
2041–2050	–4,6	–4,2	–4,0	–23,6	–1,8	2,7	4,7	–2,9	7,1	–12,0	–2,9	5,9	–10,1	–10,3	–6,1	–2,4	–0,8	–7,3	1,3	–17,0	–7,1	–	70,2
75–1,5%	E	W		OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT	OPEC	RUS	US	CHI	CND	BRA	MEX	KAZ	NOR	QAT
2023–2030	–1,4	–2,9	–5,0	–8,6	–3,5	–4,1	–4,7	–12,9	–4,0	–9,7	4,5	–2,4	77,8	–11,0	–6,2	–6,1	–6,7	–15,1	–5,8	–10,6	1,8	–7,4	2,6
2031–2040	–4,0	–3,9	–5,5	–8,2	–2,5	–2,9	–4,9	–10,5	–6,0	–37,1	–6,9	–12,5	–0,1	–11,9	–6,3	–6,7	–8,7	–14,1	–9,9	–39,8	–10,7	224,0	–2,7
2041–2050	–5,4	–4,8	–5,0	–28,2	–2,9	–2,8	–3,3	–5,9	–3,8	–53,8	–5,8	–12,4	–11,1	–11,8	–7,6	–7,7	–8,2	–10,6	–8,8	–55,2	–10,5	–	67,3

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