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Modeling and Estimating the Impact of the OPEC Agreement on Oil Production in Russia

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Abstract: The shale revolution in the United States dramatically changed the situation on the global oil market. The response to the shale boom of 2013-2014 was the OPEC + agreement, which aims to regulate the market in order to stabilize oil prices. The article analyzes the impact of the OPEC+ agreement on the global oil market, taking into account the dynamics of US oil shale production. A simulation dynamic game model is proposed, which describes the relationship between the oil demand, the strategy of oil supplying by the players and the dynamics of oil price. The model allows, by setting different strategies for the behavior of players, to simulate the movement of oil prices, which in turn affect the choice of players in their decisions on oil production and its supply to the market. The model includes three players: US shale companies, OPEC+ countries (including Russia), and non-OPEC countries (including conventional US oil production). The research methodology is based on scenario modeling and analysis of OPEC+ strategies for managing the supply and demand balance (decrease or increase in production) for targeting oil prices at specified target levels. We tried in this study to answer the question: is the OPEC agreement favorable for Russia? Calculations show that for Russia, in terms of maintaining market share, the option of targeting oil prices at lower levels is the most profitable, but at the same time, gross oil revenues of Russia are noticeably reduced.

Keywords: OPEC agreement, Oil market models, supply and demand balance.

1. INTRODUCTION

The emergence of fracking shale oil production technology in the United States has changed the outlook for the global petroleum industry in recent years. It was the US shale industry that became the main reason for the sharp increase in oil supply in the market in 2013-2015, which led to a sharp drop in oil prices to 30 USD/bbl in mid-2014.

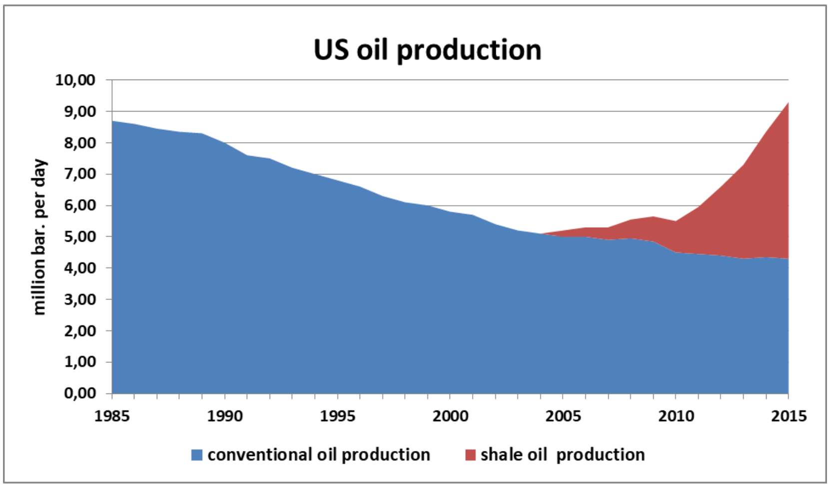

Fig. 1. US Oil Production Dynamics.

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Figure 1 plots the dynamics of the US crude oil production, for 1985-2015 (in million barrels per day). Source: U.S. Energy Information Administration (EIA), 2015. The explosive growth of shale oil production in the United States in 2013-2015 came as a surprise to the market. In 2015, the volume of shale oil produced in the United States almost reached the level of traditionally produced oil - more than 4.5 million barrels per day. For reference, it is almost half of the volume of oil production in Saudi Arabia or Russia.

If in the period up to 2013, the increase in oil supply on the market was offset by an increase in demand, in 2014 oil consumption grew at a lower rate, and the difference between supply and demand reached 1.5-2.0 million barrels per day. Such an imbalance of supply and demand led to a shock reduction in the price of oil.

OPEC could reduce the level of oil production and thus eliminate the excess supply, which would help the price to return to a higher level. However, in 2014, OPEC abandoned the use of such a strategy. This decision is aimed at maintaining its share by lowering oil prices. Shale oil producers reacted to the decline in oil prices by lowering drilling volumes at the least profitable fields: the number of active drilling rigs almost halved by 2016.

But by 2016, the world oil market has moved from the phase of competition and the price war of 2014–2015 to market regulation aimed at stabilizing prices at the desired levels. Therefore, in November 2016, OPEC agreed to reduce oil production by 1.2 million barrels per day. In December, another 11 non-OPEC countries, including Russia, joined the agreement. The parties to the agreement agreed to reduce production by 1.75 million barrels per day compared with the level of October 2016.

A similar decision was made in December 2018. According to it, the OPEC + countries, including Russia, decided to reduce oil production by 1.2 million barrels per day. The target for the oil price set by the agreement was 70 + USD/bbl. Saudi Arabia and other OPEC members in the current situation are counting on cooperation with oil-producing countries led by Russia, which will help reduce the negative effects of the American shale revolution on the world oil market. OPEC + solutions aimed at restoring the balance of supply and demand in the oil market can be quite effective. The reduction in production of OPEC + leads to an increase in reserve production capacity, which reduces price volatility.

Nevertheless, thanks to the implementation of the OPEC + strategy to regulate the market, shale oil companies can develop and increase production at high rates. According to the OPEC forecast, the annual growth of shale oil production is expected on average by 1.4 million barrels per day in 2019-2020 [10]. Then, after 2023, a slowdown in the growth of shale oil production in the United States is predicted. In the period 2027-2028 peak shale oil production is projected at 14.3 million barrels per day (or approximately 13.5% of the market share). Then, by 2040, production will drop to 12.1 million barrels per day (approximately 10.5% of the market share). For comparison, in 2018, shale oil production in the United States reached 7.5 million barrels per day, which accounted for about 7.5% of the market share [10].

OPEC also expects growth in global oil demand in the medium term by 1.2 million barrels per day - to 104.5 million barrels per day by 2023. Then, a “gradual slowdown in growth rates” of demand is projected, which will reach a maximum in 2040 at the level of 110.0–111.5 million barrels per day. This forecast is consistent with the IEA forecast, which also implies a slower growth in global oil demand after 2040. Leading global oil companies, such as Royal Dutch Shell and BP, expect a peak in global demand in the years 3035–2040 at 110.3–110.5 million barrels per day.

The important question is - how profitable is the OPEC + agreement for Russia? The OPEC forecast was made on the condition that oil prices remain at 70 USD/bbl. In this situation, the share of shale oil in 7-9 years can almost double. At the same time, the share of the remaining producing countries, including Russia, will decrease. It is clear that it is desirable for Russia to maintain its share in the global market, which in 2018 was 11.8%. But, clearly, this possibility occurs at lower price levels.

It should be noted that the growth rate of shale oil production largely depends on the price of oil on the global market. Of practical interest is the study of scenarios in which OPEC + will support other price ranges, for example, (60-70), (50-60), (40-50) USD/bbl. Everywhere else, if it is not specifically stated, the price of oil refers to the Brent price. What is oil price Russia needs to fulfill budget commitments and economic development, as well as to save its share in the global oil market? The article is devoted to the discussion of these important issues.

2. MODEL OF BEHAVIOR OF U. S. SHALE PRODUCERS

The US shale revolution has changed the parameters of the global oil market model: the supply of oil by producers has become more elastic. US shale companies increase oil production in response to price increases, and, conversely, reduce production if oil becomes cheaper. A quick response from the US shale industry to the changing situation in the oil market is capable of keeping prices within a narrow range, which also depends on the oil production strategy of other of other producers. Before the US shale revolution, oil price shocks were common due to the inelastic supply of conventional oil.

An important question arises - how can we describe the behavior of US shale companies depending on the dynamics of world oil prices?

Currently, the shale oil companies are drilling and producing at five shale plays, which differ significantly among themselves, including production profiles, well productivity, well flow rate growth dynamics, transport costs and selling price. The main indicator that affects the profitability of investments in shale projects and their ability to generate positive cash flow is the breakeven price. Figure 2 shows the distribution of WTI breakeven prices for all 2Q 2018 horizontal oil completions for the major U.S. liquids plays (source: Rystad Energy Shale Well Cube, August 2018). The breakeven price calculation is based on the traditional DCF model, which includes all investments, operating and fiscal costs (excluding land value) plus a 5% yield.

Fig. 2. Breakeven oil prices distribution for main shale plays

It should be borne in mind that due to the exploitation of shale basins, companies will have to move from areas with a lower break-even price to areas with a higher break-even price. For this reason, in the future, the average break-even price for the main US shale basins will rise, despite improvements in production technology and lower costs for some of the cost items.

Another important factor that can influence the rate of U.S. shale oil production is also the size of the proven reserves. According to the latest data provided by the SEC, reserves in the Permian basin (the most promising in terms of development) can reach only 3.8 billion barrels. The Eagle Ford and Bakken pools can hold 5 billion barrels each.

A number of publications are devoted to the problem of forecasting US shale oil production [6, 8, 9]. The most popular is the approach associated with the use of various modifications of the autoregressive models. In [6], to estimate future supplies of shale oil (using the example of the Bakken Basin), it is proposed to use a non-linear and linear forecasting model based on the Auto Regressive Integrated Moving Average method

(ARIMA). In [8], a new hybrid model NMGM-ARIMA was proposed to forecast U.S. shale oil production, in which the ARIMA method was supplemented with a non-linear model to correct the residual term of the sequence. Empirical results show that the NMGM-ARIMA method can improve forecast efficiency [8]. These methods are designed to forecast the horizon for several quarters. Another approach is to use models in which the relationships between a large numbers of factors are modeled and expert information is widely used. These methods allow you to make forecasts with a horizon of several years. Note that in these methods, the market price of oil is also exogenous and is set in the form of several scenarios.

In [9], the results of studies obtained using the medium-term model of the US shale industry are presented. The model generates forecasts for 6 key indicators for each of the five shale basins (Bakken, Eagle Ford, Anadarko, Niobrara and Perm). The model allows building forecasts of production dynamics depending on the WTI oil prices, possible growth of drilling equipment productivity and other technological and resource constraints. The Simulation results show that, if the WTI oil price is at the level of USD 70 per barrel and higher, then annual production growth in the next two to three years may reach 2.0-2.5 million barrels per day [9]. If the price of WTI oil is in the range of 60-70 US dollars per barrel, then production growth is projected at the level of global demand growth, that is, at the level of 1.2-1.4 million barrels per day. When the price of WTI crude oil is about $ 50 per barrel, production growth will be negligible or even zero. With prices below $ 50 a barrel, shale projects will no longer be attractive to investors. It should be borne in mind that the price of WTI crude oil is on average 10% lower than the price of Brent crude oil. We will use these results and the results of other analysts when building a model for the behavior of US shale producers.

To implement the proposed approach, it is necessary to build the dependence of U.S. shale oil production on two parameters: the market price of oil and the forecast period. The solution to this problem depends on a large number of factors, many of which can only be evaluated expertly. When constructing these dependencies in Fig. 3, the author used the results obtained in [9], as well as research results and forecasts from other sources.

Let G^t_{shale} - the increase in shale oil production in period t. G^t_{shale} - depends on the dynamics of oil prices and the time elapsed from the beginning of the forecast period. Then $G^t_{shale} = \Psi(P^{t-1}, t)$, where P^t is the price of oil on the market. This dependence can be defined as a series of graphs depending on the period of time and the dynamics of production growth in previous periods. The averaged dependences of the increase in U.S. shale oil production on the WTI oil price for the periods (2019-2020), (2023-2024) and (2026-2027) are shown in Figure 3.

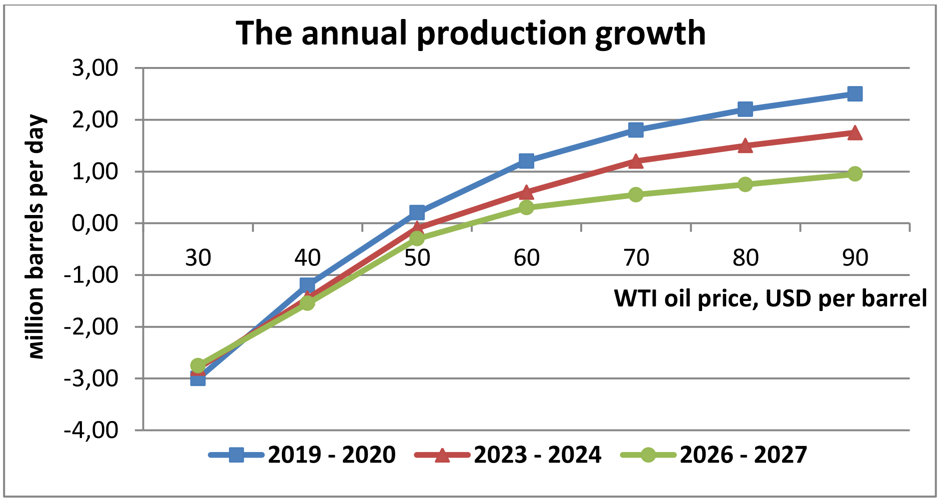

Fig. 3. The dependence of U.S. shale oil production growth on the WTI oil price

Then the production of shale oil is given by the following recurrent formula:

$$S^{t}_{shale} = S^{t-1}_{shale} + \Psi(P^{t-1}, t) \quad (1)$$

Please note that the price of oil (P^t) is not known in advance and is determined based on the market pricing mechanism, depending on the ratio of supply and demand. We will discuss this relationship in detail in the next section.

3. THE MODEL OF THE OIL MARKET BASED ON THE SUPPLY AND DEMAND BALANCE

In [1, 4, 5, 7], the problem of modeling the oil market and forecasting oil prices was considered, taking into account the dynamics of U.S. shale oil production. In [4], a game approach was proposed for analyzing the strategies of OPEC +, taking into account the dynamics of U.S. shale oil production. Various Cournot equilibrium models were used, in which the pricing model in the market is defined as a function of linear demand. It is assumed that the oil demand on the part of consumers depends linearly on its market price. This approach does not take into account the low elasticity of oil demand from its price. Based on calculations and comparison of the obtained results with historical data for the period 2014–2016, the authors concluded that the proposed approach does not explain the real data and needs to be improved.

In [5], using the structural vector auto regression (VAR) model, factors affecting the appearance of oil market shocks is analyzed. The study made it possible to draw a number of interesting conclusions regarding the importance of the demand and supply balance factor in explaining fluctuations in the oil market, as well as the effect of various assumptions regarding the elasticity indicators of the oil market. The relationship between oil prices and macroeconomic indicators is analyzed in [7] based on the general equilibrium model, which takes into account technological shocks depending on the development of new technologies, oil supply shocks and forecasts for future oil supplies. In [1] the problem of choosing the investment strategies of oil companies with production of conventional and shale oil is considered. A mathematical model is proposed that describes the relationship between the investment strategies of companies and the price of oil, which depends on the ratio of supply and demand on the world oil market. The solution is reduced to the analysis of the bimatrix game, in which the payoff matrix is formed as a result of numerical simulation.

We present a simulation dynamic game model, which is shown in Figure 4. The model describes the relationship between oil demand, the strategy of oil supply by producers and the dynamics of changes in the price of oil. The model allows, by setting various strategies of producers 'behavior, to calculate the movement of oil prices, which, in turn, affects the choice of producers' decisions regarding the oil supply. The model includes three producers (let's call them players): US shale companies, OPEC+ countries (including Russia) and non-OPEC countries (including conventional US oil producers)

The research methodology is based on scenario modeling and analysis of the OPEC + management strategies to maintain the supply and demand balance (decrease or increase in production) for targeting oil prices at specified target levels. When modeling each scenario, two criteria are assessed: gross oil revenues for a period and the dynamics of changes in market share.

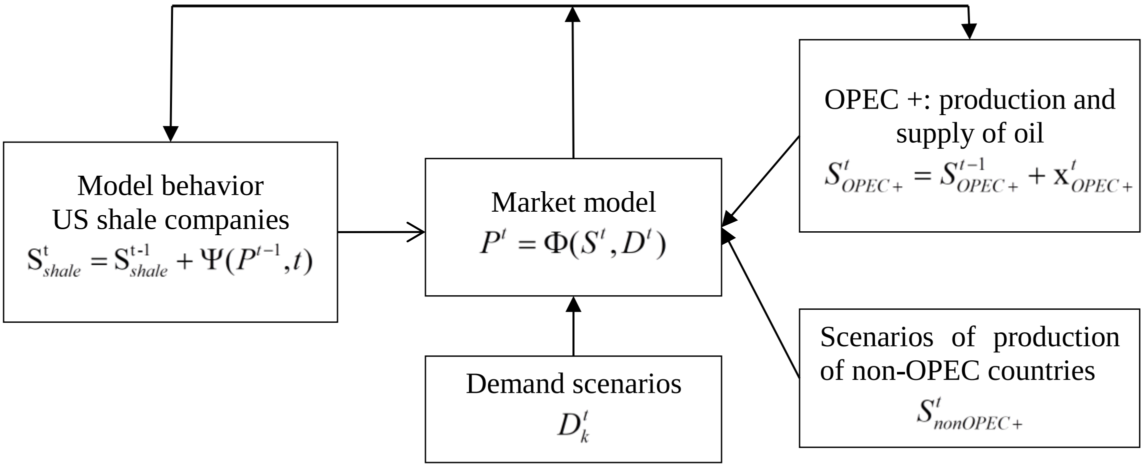

Fig. 4. Integrated model

Let x^t_{OPEC+} - control by OPEC + in the form of a decrease or increase oil production in period t. The value x^t_{OPEC+} is determined depending on the ratio of market oil prices in the previous period t-1 and the boundaries of a given interval. The choice mechanism is denoted by ω, $x^t_{OPEC+} = \omega(P^t, P_н, P_в)$, where $P_н$ and $P_в$ are the boundaries of the target range. For example, this mechanism may be as follows: $x^t_{OPEC+} = (D^{t-1} - S^{t-1}) \cdot k^t$, where the coefficient k^t, which depends on the degree of deviation P^{t-1} from the target level $(0 \le k^t \le 1)$.

D^t_k - the scenarios of global oil demand. It is assumed that the demand D^t_k is unknown in advance to market participants. The pricing model on the market is given by the recurrence formula [2]:

$$P^t = P^*(t) \cdot (1 + \gamma(t) \cdot (\frac{\sum_{t-2}^{t} D^t_k - \sum_{t-2}^{t} S^t}{\sum_{t-2}^{t} D^t_k}) \quad (2)$$

Here S^t is the total oil supply on the market, $S^t = S^t_{shale} + S^t_{OPEC+} + S^t_{nonOPEC+}$. In accordance with [2], the coefficient of price elasticity in the model $\gamma(t) = \gamma^+$, if $D^t_k - S^t \ge 0$ and $\gamma(t) = \gamma^-$ otherwise. The medium value γ^+ is equal to 9.75 and, accordingly, γ^- is equal to 28.7. The model uses the information on the dynamics of supply and demand for the two previous periods to calculate the forecast price.

The value $P^*(t)$ is calculated as follows: $P^*(t) = P^*(0)$, where $P^*(0)$ is the oil price in the initial period. If at some time $t^{''}$ $D(t) = S(t)$, then $P^*(t) = P^{t^{''}}$ for all $t \ge t^{''}$. The model takes into account the "hysteresis" property when calculating the price. The new equilibrium value of the price can be determined at a level different from the initial one.

In [2], it was shown that the coefficient of elasticity in the zone of oil deficiency is less than the coefficient of elasticity in the zone of surplus. This is due to the fact that in a period of high oil prices even with a shortage of oil (demand exceeds supply), it is more profitable for oil companies to increase production and not raise prices too high, since this may lead to an irreversible decrease in demand due to market adaptation to new conditions.

During the period of oil surplus on the market (supply exceeds demand), it is more profitable for oil companies to reduce the oil price and thereby stimulate oil demand. Moreover, companies with a low break-even point have the advantage of reducing the oil price without losing a positive profitability. As a result, some players leave the market and, accordingly, the oil supplies are reduced [3].

Figures 5 and 6 show the results of testing the proposed model on historical data on demand, supply and oil price in the period 2Q 2013 - 4Q 2018. Source: International Energy Agency (https://www.iea.org/oilmarketreport/omrpublic).

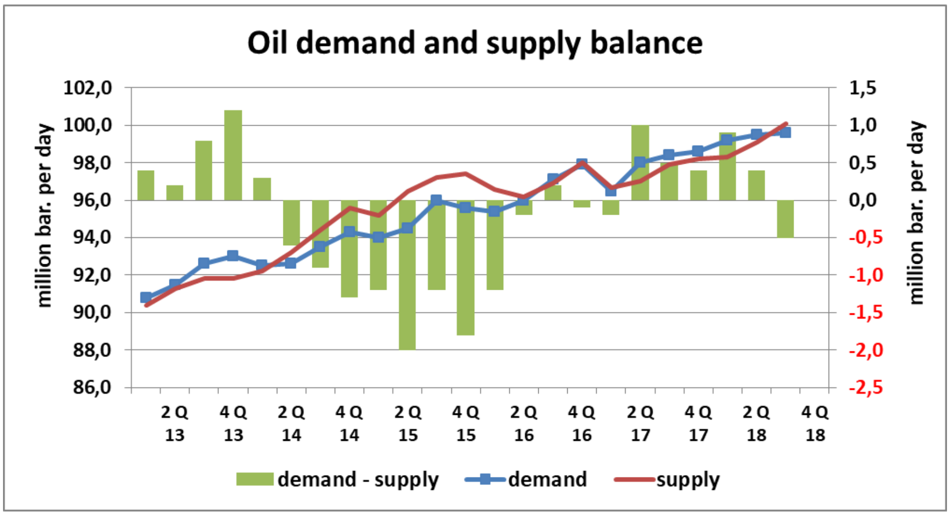

Fig. 5. Oil demand and supply balance

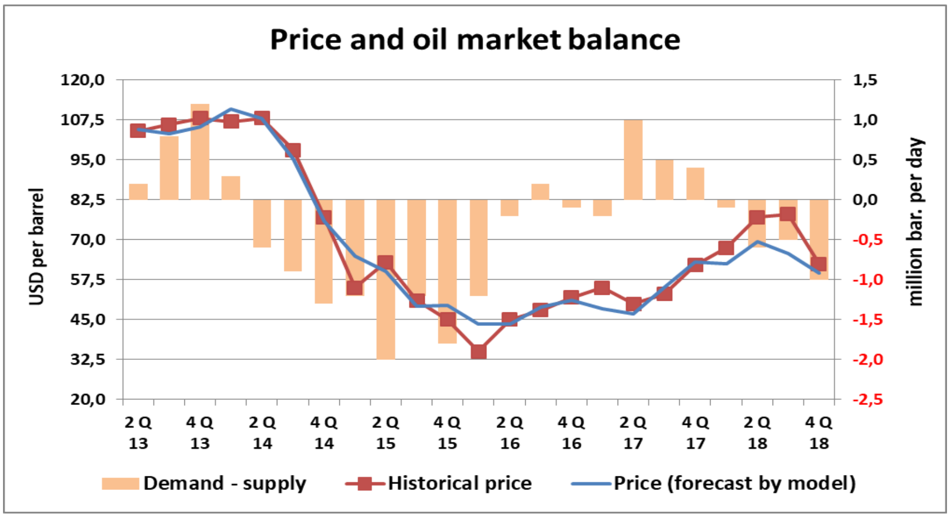

Fig. 6. Price and balance on the oil market

The results show that the oil price obtained using the model is quite consistent with historical data. The deviation of the forecast price from the historical one in some periods can be explained by the increasing role of factors unrelated to the balance of supply and demand in the market. For example, in the period 2Q 2013 - 4Q 2018, the oil price was also influenced by foreign factors, mainly related to the events in Venezuela and the US sanctions against Iran.

The model described in this section makes it possible, using data on demand options, production scenarios of non- OPEC countries, the OPEC quota formation mechanism, to calculate the oil price dynamics based on model (2). The problem is to choose x^{t}_{OPEC+} in each period t the value at which the oil price will remain in a given target range. The software simulation model (Fig. 4) and the optimization and parameter selection methods are implemented using MS EXCEL.

4. ANALYSIS OF THE RESULTS

The oil demand is not elastic, that is, it does not depend on changes in the market price and is set exogenously in the model in the form of a set of scenarios. The main scenario for modeling is the OPEC forecast of global demand in the period 2019 - 2028 [10]. Table 1 presents the results of calculations of the dynamics of oil production and market share for major producers. It also presents the results of the calculation of the decrease / increase in oil production by OPEC countries to maintain the price at the target level of USD 65 per barrel.

Table 1. Forecast of the dynamics of oil production and market share in the period 2019 - 2028

1	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
2	101,2	102,2	103,2	104,1	105,0	105,9	106,7	107,6	108,4	109,2
3	7,40	9,20	10,64	11,79	12,71	13,45	14,04	14,51	14,89	15,08
4	7,3%	9,0%	10,3%	11,3%	12,1%	12,7%	13,2%	13,5%	13,7%	**13,8%**
5	48,4	47,6	47,1	46,9	46,9	47,0	47,3	47,7	48,1	48,7
6	47,8%	46,6%	45,7%	45,1%	44,6%	44,4%	44,3%	44,3%	44,4%	**44,6%**
7	0,0	-0,8	-0,5	-0,2	0,0	0,2	0,3	0,4	0,4	0,6
8	45,4	45,4	45,4	45,4	45,4	45,4	45,4	45,4	45,4	45,4

In the first column of table 1, the following notation is used: 1 - periods, 2 - demand, million barrels per day (OPEC forecast), 3 - US shale oil production, million barrels per day, 4 - the US shale market share, 5 - OPEC + oil production, million barrels per day, 6 - OPEC + market share, 7 - the decrease / increase in oil production by OPEC (year-over-year), 8 - non-OPEC + production, million barrels per day. In addition, two more scenarios were considered: the OPEC forecast for growth global oil demand plus 15% and the OPEC forecast for growth global oil demand minus 15%. The results of the analysis of the market share and currency income of Russia from the sale of oil, depending on the target level of the price are presented in Table. 2

Table 2. Market share of Russia depending on the target oil price level

The target oil price level	40 - 50	50 - 60	60 - 70	70+
OPEC forecast of growth in world oil demand in 2019-2028				
Market share by 2028, %	12,0%	11,1%	10,5%	10,1%
Gross oil revenues of Russia, trillion USD	13,338	15,280	17,334	19,443
OPEC forecast of growth in world oil demand in 2019 - 2028 plus 15%				
Market share by 2028, %	12,1%	11,2%	10,7%	10,3%
Gross oil revenues of Russia, trillion USD	13,596	15,595	17,706	19,873
OPEC forecast of growth in world oil demand in 2019 - 2028 minus 15%				
Market share by 2028, %	11,8%	10,9%	10,4%	10,0%

Gross oil revenues of Russia, trillion USD	13,083	14,968	16,965	19,017

CONCLUSION

The calculations (table 1) confirm that OPEC +, by reducing production in order to maintain the oil price at a high target level, creates a free niche in the market. This niche is occupied by producers outside the agreement, mainly shale oil producers, who can continue to increase production. With lower target oil prices set by OPEC +, oil production growth by shale companies will be limited and, under certain growth scenarios for global demand, OPEC + quotas can be set to increase production, which will help maintain their market share.

However, with the current strategy of OPEC + (the target price level of oil in the range of 60- 70 USD per barrel), the United States will remain the leader in production growth. Calculations carried out on the model show that by 2028, US shale oil production compared to 2018 could almost double and reach 15.1 million barrels per day. US shale oil will occupy 13.8% of the market, while the market share of Russian oil will drop to 10.5%.

Calculations show that for Russia, in terms of maintaining market share, the option of targeting oil prices at lower levels is the most profitable, but at the same time, gross oil revenues of Russia are noticeably reduced. On the whole, it can be concluded that Russia's participation in the OPEC agreement, as well as the participation of other countries in it, under current conditions is a reasonable strategy.

REFERENCES

[1] Akinfiev, V. (2017) A model of competition between oil companies with conventional and unconventional oil production. *Large-scale Systems Control. Issue 67. Moscow: ICS RAS.* 52-80, [in Russian].

[2] Akinfiev, V. (2018) An Analysis and Forecasting Volatility of Crude Oil Market. *Proceedings of the 11th International Conference "Management of Large-Scale System Development" (MLSD). Moscow*: IEEE, https://doi.org/10.1109/MLSD.2018.8551767

[3] Akinfiev, V. (2018). Modeling competition in the oil market. *Herald of computer and information technologies. № 2.* 18-27, [in Russian], https://doi.org/10.14489/vkit.2018.02.

[4] Ansari, D. (2017). OPEC, Saudi Arabia, and the shale revolution: Insights from equilibrium modeling and oil politics. *Energy Policy, Volume 111, December*, 166-178.

[5] Caldara, D., Cavallo, M., & Iacoviello, M. (2019). Oil price elasticities and oil price fluctuations. *Journal of Monetary Economics*, 103, 1-20.

[6] Smith, JL. (2018) Estimating the future supply of shale oil: A Bakken case study - *Energy Economics, Elsevier Energy Economics 69*, 395–403.

[7] Olovsson, C. (2019). Oil prices in a general equilibrium model with precautionary demand for oil. *Review of Economic Dynamics, Volume 32, April*, 1-17.

[8] Wang, Q., Song, X. & Li, R. (2018) A novel hybridization of nonlinear grey model and linear ARIMA residual correction for forecasting U.S. shale oil production. *Energy 165*, 1320-1331.

[9] Salikhov, M. & Kurilov, V. (2018) New wave of growth of shale oil production in the USA: scenario forecasts. *Institute of Energy and Finance, Analytics, October*. [in Russian]. [Online]. Available https://fief.ru/img/files/Slanceva__otrasl__20181031.pdf

[10] World oil outlook 2018. (2018). *The annual OPEC forecast*. [Online]. Available https://woo.opec.org/.

