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ANALYSIS OF EFFICIENCY OF OIL AND GAS COMPANIES: EVIDENCE FROM RUSSIA

Master's Thesis by the 2nd year student
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Аннотация

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Описание цели, задач и основных результатов	То, как фирмы используют свои ресурсы оказывает большое влияние на их прибыльность, устойчивое развитие, конкурентоспособность. В настоящее время деятельность российских нефтегазовых компаний подвержена воздействию таких внешних факторов как санкции и низкие цены на нефть, а также локальных тенденций, включая износ основной ресурсной базы. Повышение эффективности даст возможность оптимизировать количество факторов производства и приведет к оптимизации затрат и более точному анализу инвестиционных решений. Главная цель работы заключается в определении факторов, оказывающих влияние на эффективность добычи российских нефтегазовых компаний. Так же рассматривается взаимосвязь эффективности и доли собственности в компании, принадлежащей государству. Чтобы достичь поставленной цели был проведен анализ научной литературы по теме эффективности и особенностям ее измерения в нефтегазовом секторе, также был сделан аналитический обзор нефтегазового рынка РФ. В работе было построено и оценено несколько моделей: две эконометрические, шесть моделей линейного программирования для каждой компании за период 2013-2018, также было проведено шесть глубинных интервью с экспертами нефтегазовой индустрии. Результаты, полученные методами эконометрического моделирования, линейного программирования и глубинных интервью были использованы для получения управленческих рекомендаций. Результаты исследования показали, что эффективное использование трудовых ресурсов и геологических запасов имеют положительное влияние на добычу нефтегазовых компаний. Коэффициент доли государственной собственности в компании был найден незначительным. Эксперты также считают важными для роста эффективности следующие факторы: диджитализация, диверсификация неуглеводородные сектора и более высокая скорость принятия решений. Работа имеет значительный теоретический и практический вклад в тему эффективности нефтегазового рынка.
Ключевые слова	нефтегазовая индустрия, эффективность, стохастическая производственная граница,оболочечный анализ данных

Abstract

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Description of the goal, tasks, and main results	The way how a firm uses its resources has a strong impact on its financial profitability, sustainable development, competitiveness on the market. Currently the performance of Russian oil and gas companies is affected by both external factors: sanctions and low oil prices and local trends, including the increasing depletion of major oil producing fields. Improved efficiency may give Russian industry players an opportunity to optimize the quantities of production factors and lead to cost optimization and more precise assessment of investment decisions. The main research goal of this paper is to identify the factors that have an impact on production efficiency of Russian petroleum companies. The relationship between share of state ownership and efficiency of Russian oil and gas companies is also studied. In order to reach the research goal, a literature review and market overview were conducted to study the concept of efficiency and specifics of its measurement in oil and gas industry. Moreover, several models were built and estimated: two econometric models, six linear programming models for each company in 2013-2018 and in-depth interviews with six industry experts were conducted as well. The results of econometric and linear programming methods, as well as insights from in-depth interviews were used to formulate theoretical and managerial implications. The research results show that the efficient utilization of resources and employees is positively related to production. The share of state ownership that was mentioned by previous researches as one of the key factors affecting efficiency of petroleum companies was proved insignificant for Russian market. Experts emphasize that digitalization of both upstream and downstream sectors, diversification to non-hydrocarbons businesses and higher speed of decision making are also critical for efficiency improvement. The research has significant theoretical and practical contribution to the topic of efficiency of oil and gas sector.
Ключевые слова	oil and gas industry, efficiency, stochastic frontier analysis, data envelopment analysis

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Introduction

Efficient performance and performance measurement remain a widely discussed issues in academic literature. Neely and Andy (2007) argue that performance is the ability of a firm to achieve its goals effectively by efficiently using its resources. Indeed, how a firm uses its resources has an ultimate impact on its profitability, competitive position and even potential for survival (Barney 1991). While measuring performance by using financial ratios remain one of the popular techniques, while ratios may point on major performance gaps, they seldom answer the question why this underperformance has occurred (Brealey and Myers 2000). Eccles (1991) claimed that financial perspective should not be perceived as a foundation of performance rather it should be one of the components of a broader set of perspectives and measures.

First the notion of efficiency was described in the article of Farrell (1957): in order to be efficient, largest possible result or output should be produced from the given set of production factors or inputs. Currently modern studies also consider the firm efficient if optimal amount of resources is used to achieve target production (Kumbhakar et al. 2005; Hawdon 2003). By minimizing resources involved in production and using them efficiently, lean manufacturing and cost optimization can be achieved, for illustration, as in the case of Toyota production system.

The researchers emphasize that the main factor that affects efficiency in oil and gas industry is the share of state ownership (Wolf 2009; Eller et al. 2013). Previous studies claim that national oil companies, which control about 80 percent of the world's proven oil reserves, are less efficient in comparison to their private competitors, while the results of previous studies for Russian companies contradict this conclusion. Thus, it appears to be a research gap regarding this issue. Furthermore, in the era of sanctions and low oil prices it is important to find out key factors affecting the efficiency of Russian companies in order to provide potential of reducing the quantities of certain production factors, which, in its turn will lead to cost optimization. Moreover, these new metrics may be used in taking investment decisions regarding new projects or projects expansion, since, according to EY, oil and gas projects carry a high risk involved and not comprehensive assessment of investment decision usually leads to large overspending, the delay of deadlines or even the project abandonment.

The most common measures of efficiency are Stochastic Frontier Analysis (SFA), based on econometric modelling, and Data Envelopment Analysis (DEA) based on linear programming. These methods are widely applied to measure efficiency in oil and gas industry (Eller et al. 2007; Kapustina and Krylov 2008; Basil and Lee 2014); **therefore, were chosen to be used in this paper**. Previous studies examined the relationship between the level of production and quantities of such production factors as labor and capital, commonly represented by reserves, involved with the sole focus to maximize production. **The relationship between oil and gas production and amount of reserves and number of labor force involved** is studied in this paper. No studies previously were concentrated on minimizing the production factors involved which presents a great potential for a company to optimize its costs. Furthermore, the paper also examines the link between the share of state ownership and company's depletion policy on production efficiency. The depletion policy mentioned as one of the key factors by previous studies was also never examined before.

The main research goal of this paper is to identify the factors that affect production efficiency of Russian petroleum companies. Furthermore, the relationship between share of state ownership and efficiency of Russian oil and gas companies will be also examined. **The main research question to be addressed is** whether the share of state ownership affects the efficiency of Russian oil and gas companies and what the key factors affection production efficiency of Russian petroleum companies are.

The research objectives are as follows:

- To conduct a literature review of research papers on the topic of efficiency and methods to measure it
- To study the specifics of efficiency measurement in oil and gas industry
- To conduct an empirical study of factors that may have a relationship with the efficiency of oil and gas company
- To conduct in-depth interviews with industry experts to determine the practices of efficiency measurement in oil and gas industry
- To discuss the results of empirical study and in-depth interviews and derive theoretical and management implications.

The methodology of the study is econometric modeling (SFA) and regression models construction, linear programming modelling (DEA) and in-depth interview. In both SFA and DEA models the dependent variable is oil and gas production, independent variables are labor and oil and gas reserves. Furthermore, a regression model with dependent variable of company's inefficiency and independent variables of share of government ownership and reserves to production rate, which is a proxy for depletion policy, was constructed.

This thesis has both theoretical and practical contributions. Theoretical contributions include the proof that the general conclusion regarding inefficiency of national companies in comparison to private ones does not hold in Russian realities. Thus, the similar studies may be concluded to check this hypothesis on other emerging markets. Secondly, in-depth interviews conducted revealed that there are more possible dimensions to look at when assessing efficiency in oil and gas industry, such as corporate governance, including CEO market orientation, degree of business diversification, research and development activities and many other. As for practical implications, the results of this study may be used by managers to analyze the efficiency of existing projects and take efficiency metric in consideration while making investment decisions regarding project expansion or new project development.

This research paper consists from an introduction, followed by two chapters that include the literature review of research topic, presentation of research methodology, obtained empirical results and discussion, possible theoretical and managerial implications, conclusions, and research limitations.

The first chapter examines the definition of efficiency as a method of performance measurement, identifies types of efficiency. The main methods of efficiency measurement, precisely, the methods of Stochastic Frontier Analysis (SFA) and data envelopment analysis (DEA) were covered, their advantages and limitations were discussed. Finally, a comprehensive analysis of Russian oil and gas market was conducted with regards to both global and local factors that influence the market.

The second chapter describes methodology of the study and the models used. After the descriptive analysis of variables is provided, followed by empirical results that were obtained. Then the results are discussed, their theoretical and practical implications are stated, limitations are drawn, and the conclusion is made.

Chapter 1. Literature review and overview of Russian oil and gas market

1.1 Efficiency as an indicator in performance measurement and methods to measure efficiency

1.1.1 Efficiency as an indicator in performance measurement

In order to achieve sustainable performance each organization should have a set of five processes in place that go beyond the organization's boundaries: setting objectives; assigning responsibility; measuring performance; feedback of information to decision making; and external accountability (Pollitt 1999).

Smith and Goddard (2002) define four broad categories of actions company should undertake to manage its performance:

- formulation of strategy with to determine what constitutes performance;
- development of performance measurement instruments;
- application of analytic techniques to interpret such measures;
- development of instruments designed to encourage appropriate organizational responses to performance information.

Out of these four categories, performance management turned out to be one of the most broadly discussed topics. For instance, Neely and Waggoner (1998) estimated that in the US alone a new book on performance measurement appears every week since 1994. According to Folan and Browne (2005), the concept of performance measurement was formed in late eighties-early nineties and all the most popular techniques of performance measurement are dated the same period. It must be said that in terms of performance measurement, each discipline, for illustration financial management, strategic management and operational management, has its own language, traditions, preoccupations and prejudices and; therefore, different methods of measuring performance (Smith and Goddard 2002).

Brealey and Myers (2000) claim that in order to understand the firm’s overall performance, its financial statements must be reviewed, and key financial ratios must be calculated to find out potential problem areas. Van Horne and Wachowicz (2008) limited the usage of key indicators, such as profitability, liquidity, leverage, capital adequacy, and solvency to measure only financial performance, the company's financial condition over a certain period. However, while ratios may point on major performance gaps, they seldom answer the question why this underperformance has occurred (Brealey and Myers 2000). Nevertheless, financial ratios allow to analyze large volumes of financial data and compare the performance of different companies. Efficiency, according to Brealey and Myers (2000) can be measured by asset turnover, inventory turnover and turnover of the receivables: the authors understand the concept of firm's efficiency as how well a firm uses its various assets.

However, most researches argue that applying solely financial criteria to measure the performance is not enough (Kaplan 1987; Hronec 1993). Furthermore, Eccles (1991) criticized the dominant role of financial measures and claimed that financial perspective should not be perceived as a foundation of performance rather it should be included as a component of a broader set of perspectives and measures. By applying wider scope of indicators, it becomes possible to reflect changes in modern firm's strategies and in the competitive landscape and detect more factors that are crucial for future success. While maximizing profit remains one of the major company's goals, applying this measure alone is insufficient, since modern measures should also show what aspects companies have to manage in order to be profitable.

In his article regarding performance measurement Eccles (1991) argued that the performance measures should be regularly evaluated and modified to adapt to the constantly changing business environment and increasing competitiveness of rivals. Aracioglu et al. (2013) cite the famous saying of Peter Drucker "if you cannot measure it, you cannot manage it" in order to support their claim that a firm should measure the success of its strategies and make corrections if needed to get the outcome desired. Porter (1996) defines strategy as a vital tool for a firm that serves two purposes: differentiation from competitors and creation of sustainable advantage for the firm.

Measurement of performance from strategic point of view should start from the definition of strategic management, which is an organized development of company's resources of all functional areas, including financial, manufacturing, marketing, technological, etc. in order to pursuit the firm's objectives (Ritson 2011). Therefore, in order to measure the performance of all these areas and evaluate how well they contribute to organizational objectives, a balanced set of measures should be adopted.

Kaplan and Norton (1992) argue that strategic approach of performance measurement aims to answer the following fundamental questions:

- How do we look to our shareholders (financial perspective)?
- What must we excel at (internal business perspective)?
- How do our customers see us (the customer perspective)?
- How can we continue to improve and create value (innovation and learning perspective)?

Overall, strategic performance measurement is viewed as a mean to set key objectives and corporate priorities, provide strategic alignment, implement and change strategy if needed and encourage innovation and process improvement (Bisbea and Malagueno 2012; Gimbert et al. 2010).

As Porter (1996) claimed, strategic performance of a firm and its operational effectiveness are not the same; therefore, performance from the operational point of view should be measured differently. Majority of researches studying the topic of operational performance measurement agree on the main dimensions that should be measured: time, quality and flexibility (Kaplan 1983; Neely et al. 1995).

In their turn, these four dimensions also divided into several components. In terms of quality, researchers recommend measuring such parameters as product performance, innovation, reliability of delivery and waste. Time dimension encompasses such direct time measures as lead time, process time, speed of delivery, cycle time and some indirect parameters which also affect time such as labor efficiency and productivity, efficient resource utilization. Efficient resource utilization is also important in the flexibility dimension, combined with volume flexibility, effectiveness of processes in place, digitalization and innovation and future growth. Customer service is typically measured by service quality, market share, corporate image, competitiveness of the offerings and innovation of increasing customer satisfaction methods.

Hauser and Katz (1998) argue that a key idea of performance measurement is the ability of performance indicators to provide information for decision making. According to Aracioglu et al. (2013), these measures should include both measures of outcomes as well as performance drivers. As there are different methods to define, measure and analyze the performance, this variety may create confusion for managers interested in applying performance indicators to practical scenarios (Melnyk et al. 2004; Perrin 1998).

Bendickson and Chandler (2019) argue that operational performance of a firm is one of the microfoundations of its strategy and that measuring operational performance, especially in a labor-intensive industry will improve firm's financial performance as well. Operational performance also provides a competitive advantage in terms of employee productivity, product quality, time and flexibly to adapt (Bendickson and Chandler 2019). Neely and Andy (2007) state that the ability of a firm to achieve its goals effectively by efficiently using its resources defines its performance. Indeed, how firms use their resources affects not only its operational performance but also strategy overall because it has an ultimate impact on their profitability, competitiveness and even potential for survival (Barney 1991).

The first definition of efficiency was described in the article of Farrell (1957), where he described it as producing the largest possible result, which is called output, from the given set of factors of production or inputs. This terminology can be illustrated by the example of classic

Cobb-Douglas production function, where dependent variable that represents total production will be viewed as output, while independent variables such as capital and labor will be viewed as factors or inputs used in production.

Farrell (1957) further decomposed efficiency into technical efficiency and price or allocative efficiency. Technical efficiency means producing the maximum amount of output from the given amount of inputs; whereas, the allocative efficiency indicates the ability of the firm to use optimal proportions of inputs regarding their relative prices and production technology. Technical and allocative efficiencies combined represent overall or economic efficiency (Figure 1)

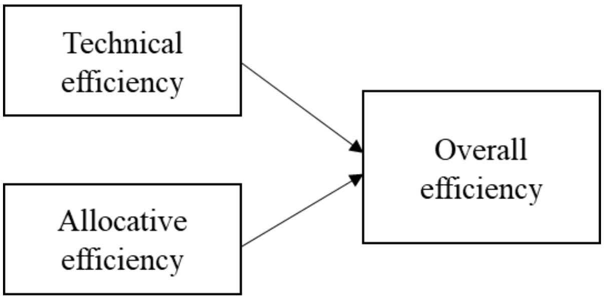


Figure 1: Types of Efficiency

Source: made by the author

Farrell also introduced a concept of efficient production function that shows the output which can be obtained from any set of inputs by the fully efficient firm. For production function the concepts of maximality and minimality are important. Since the function sets a limit to the range of possible observations, the researches meaningfully apply the word production frontier. Therefore, some points can be below the production frontier if the firms produce less than possible maximum output, but no points can be situated above the production frontier. Hence, the inefficiency of a firm can be measured by the amount by which it lies below the production frontier (Forsund et al. 1980). Forsund et al. (1980) also claim that the attempts to measure inefficiency was the main motivation of researches to study the frontiers. In their article the authors state that it is more possible to measure average level of inefficiency within one industry than to measure inefficiency of an individual firm since the latter fundamentally depends on the assumptions of a researcher.

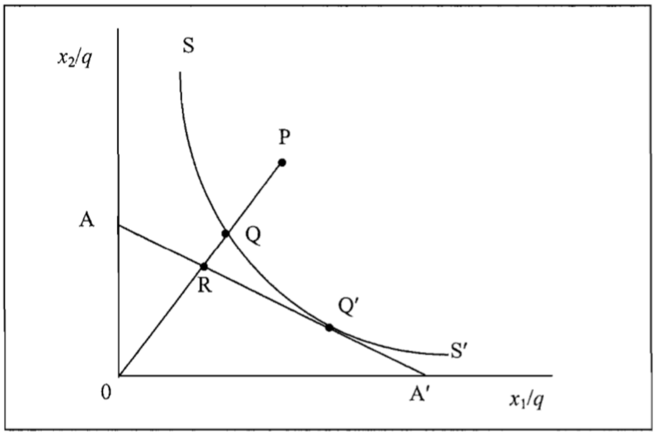


Figure 2: Graphical representation of efficiency

Source: Farrell (1957)

In the graphic representation of his idea Farrell provides a simple example with two inputs (x1 and x2) used to produce single output (q), constant returns to scale technology is assumed (Figure 2). Constant returns to scale mean that increase in inputs, for example, capital and labor will cause the same proportional increase in output.

The assumption of constant returns allows technology be illustrated by the isoquant SS' of the fully efficient firms, or, in other words, the efficiency frontier. If to produce a unit of output a firm uses quantities of the first input (x1) and of the second input (x2) described by point P, the technical inefficiency of the firm is visually represented by the distance QP. This distance shows an amount by which the firm can proportionally reduce all its inputs without decreasing its output. This percentage by which all inputs are reduced in order for the firm to demonstrate technically efficient production is expressed by the ratio QP/0P.

Consequently, the technical efficiency of a firm can be measured by

TE= 0Q/0P = 1-QP/0P

Technical efficiency lies between zero and one, where the value of one means full technical efficiency. For instance, on the graph the Point Q is considered fully efficient since it is situated on the efficient frontier.

The major limitation of the Farrell's work is that the efficiency can be calculated in the proposed way if and only of the production function is known which is not always the case in practice, where the frontier is usually estimated from the sample data.

The book of Coelli et al. (2005) contains another example of the technical efficiency measurement. While the Farrell's example answers a question by how much the inputs can be reduced without changing the quantities of produced output, the Coelli et al. (2005) example also answers the question by how much can the output quantities be proportionally increased without changing the quantity of inputs utilized in production process. Hence, Coelli et al. (2005) example also deals with output-oriented measures of efficiency.

To illustrate, in the figure below, one input (x) and one output (q) is used. The decreasing returns to scale technology f(x) are assumed, so that increase in inputs result in a proportionally smaller increase in output.

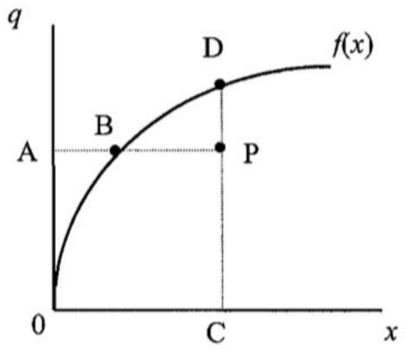


Figure 3 Graphical representation of input- and output-oriented types of efficiency

Source: Coelli et al. (2005)

Point P indicates an inefficient point of operation of a firm. In this case the Farrell's input-oriented method of measuring technical efficiency will be expressed as

TE = AB/AP

Thus, in order to be efficient from input-oriented point of view a firm should operate in point B instead of point P. Meanwhile, the output-oriented measure of technical efficiency is calculated as

TE=CP/CD

This means that in order to be efficient from the output point of view, a firm should now operate in point D, which is also situated on the frontier.

Overall, it should be noticed that, according to Fare and Lovell (1978) the technical efficiency measured by input- and output- oriented measures will be the same when and only when constant returns to scale (CRS) are assumed. Kumbhakar et al. (2005) present the definition of technical efficiency that accounts for both measures: a firm is technically efficient if for the given inputs a higher quantity of output cannot be technically attained (output-oriented measure), or fewer inputs cannot be utilized to reach the observed level of output (input-oriented measure). Hawdon (2003) states that the firm can be considered as technically efficient if it achieves maximum output from the given inputs or utilizes minimum inputs to achieve the given. On the other hand, allocative efficiency compares different combinations of inputs or outputs in terms of their prices.

1.1.2 Parametric methods to measure efficiency

Aigner and Chu (1968) took the Farrell's work as a foundation for their parametric approach to the estimation of the production function. Schmidt (1976) claims that parametric approach outperforms non-parametric in two main ways: it enables to describe a frontier in a non-complex mathematical form as well as to allow non-constant returns to scale which cannot be done using Farrell's approach.

Aigner and Chu (1968) assume production process to be deterministic and use one-output, two-input Cobb-Douglas production frontier to estimate US industry production function. Aigner and Chu allowed all the observations to be on or beneath the frontier and suggested that technical efficiency can be computed from the vector of residuals, though it was not done in their paper.

The model of Aigner and Chu (1968) may be written as:

$$\ln y = \ln f(x) - u \quad \text{or:}$$

$$\ln y_i = a_o + \sum_{i=1}^{n} a_i \ln x_i - u$$

$$u \geq 0$$

$$y \leq f(x)$$

Where

y_i is a vector of outputs

$x_i$is a vector of inputs

a_o and a_i are coefficients to be estimated

U is a vector of residuals

This model of deterministic parameter frontier can be estimated either by quadratic programming (minimizing the sum of squared residuals, under condition that each residual must be non-positive) or by linear programming (the sum of the absolute values of residuals is minimized under the same constraint)

However, this mathematical interpretation of the frontier may be too simple or unjustified. Schmidt (1976) argues that since model contains no assumptions about the disturbance term and regressors, the frontier is not statistical, and the estimates obtained cannot have any statistical properties and come without t- ratios, standard errors and other attributes. Furthermore, in linear programming estimation usually there is a limitation imposed on a number of firms that can be technically efficient. Finally, Schmidt and Aigner and Chu note that the established frontier is extremely sensitive to outliers. One way of coping with this problem is to neglect a few observations if it helps to achieve a desired impact on the estimates (Aigner and Chu 1968).

Schmidt (1976) was the first who attempted to give the model of Aigner and Chu a statistical basis and added one-sided disturbance term to their model. The disturbance term is either negative or zero because it is assumed to account for the firm's technical inefficiency. Since no observations can lie above the production frontier which shows the maximum possible output that can be obtained from the given of factors, the disturbance term cannot be positive. Because of the Schmidt's (1976) modification of the model, an opportunity to estimate it with maximum likelihood method, given the distributional assumption of the disturbance term, arose. In his paper Schmidt suggest to use either exponential or half-normal distribution for the disturbance term and argues that the estimation of the model using maximum-likelihood techniques will be the same as Aigner and Chu linear programming technic in case of exponential distribution and as quadratic programming technic in case of half-normal distribution. The function will be maximized by minimizing the sum of absolute residuals subject to the constraint of the negativity of residuals. Finally, in his article Schmidt describes the efficiency of the firm as the closeness to the production frontier.

The main drawback of deterministic frontier models is that they do not account for any exogenous shocks. Aigner and Chu acknowledge that one of the possible reasons why output of some firms lie below the frontier is random shocks in production process. Schmidt (1976) elaborates on this claim and gives examples of these shocks such as machine malfunctioning, bad weather conditions and so on. Furthermore, in deterministic frontier the statistical noise that is represented in every empirical relationship is omitted. The statistical noise accounts for any error in measurement of variables as well as for the fact that the equation may lack any individually important regressors that affect the dependent variable. In deterministic frontier this noise is not distinguished from the inefficiency, measured by the disturbance term. Therefore, these observations question the possibility of a single one-sided error term to reflect "inefficiency" because in fact it accounts for not also the inefficiency of a firm, but also random shocks, as well as the measurement error.

This issue caused the creation of the stochastic frontier model, which was simultaneously developed by Aigner et al. (1977) and Meeusen and Van den Broeck (1977). The main difference of the stochastic frontier model from other frontiers is that the disturbance term is divided in two components: the first, one-sided one accounts for the inefficiency and another component is responsible for the random shocks and variation of the frontier across companies, as well as for the effects of measurement error and other statistical noise.

The benchmark formula of stochastic frontier model (SFM) is:

$$y_i = m(x_i;\beta) + \varepsilon_i = m(x_i;\beta) - u_i + v_i$$

Where

$m(x_i;\beta)$ is a production frontier of DMU (decision-making unit)

y_i is a vector of outputs

x_i is a vector of inputs

β is a parameter that is going to be estimated

u_i is an inefficiency term, or a shortfall from the maximum input

v_i is a stochastic shock

For SFA model to be estimated several assumptions must be introduced. Firstly, it is assumed that production inputs are independent of u and v and, secondly, u and v are assumed not to be mutually dependent. Furthermore, since the inefficiency term indicates a shortfall in output, the term is assumed to be one-sided. The SFA method has numerous advantages, especially over basic linear regression models as well as over deterministic frontier models. The advantage of SFA over the deterministic frontier is basically an inclusion of disturbance term in the model that allows to estimate the model using traditional statistical methods. As for ordinary regression models, to filter out the effect of statistical noise they estimate average relationships that depend on various factors. All deviations are assumed to be caused by statistical error; hence all the dependent units are usually characterized as fully efficient. Therefore, these models ignore some possible sources of inefficiency, such as asymmetric information (Stiglitz and Greenwald 1986), different practices of management and even different cultural peculiarities such as traditions and beliefs.

Though SFA also estimates production relationships as a conditional average, it allows to decompose the total deviation from the frontier in two terms - statistical noise and inefficiency. Though these terms are not observable, they can be estimated for a sample or for each individual dependent unit by using specific assumptions and approaches of SFA. Furthermore, sometimes SFA can present statistical evidence of fully efficient case if the inefficiency term turns out to be statistically insignificant, so the assumption of full efficiency can also be tested. Besides that, some SFA models can also distinguish the sources of inefficiency when the inefficiency term is regressed over some variables that are assumed to be a cause this inefficiency.

1.1.3 Non-parametric methods to measure efficiency

The most popular non-parametric method of measuring efficiency is Data Envelopment Analysis (DEA), which is based on linear programming. In attempt to generalize the Farrell's method of technical efficiency, Charnes, Cooper and Rhodes proposed DEA in 1978. DEA measures the efficiency of decision-making units (DMUs) relative to the best practice frontier, or the frontier of excellence and can take into account several inputs and outputs. A DMU is considered efficient if no other DMU can use fewer inputs to produce the same or higher amount of outputs (input-oriented measure). A DMU is also supposed to be efficient if no other firm can produce higher outputs by utilizing the same or smaller quantity of inputs (output-oriented measure). Consequently, if these terms are not followed, the DMU turns out to be inefficient.

The model of Charnes et al. (1978) is called CCR by first letters of the authors surnames or constant returns to scale (CRS) model. It assumes constant returns to scale, hence, can be used only if all firms conduct operations at the optimal scale. Charnes et al. (1978) define technical efficiency as the maximum of a ratio of weighted outputs to weighted inputs subject that the similar ratios for every DMU be less or equal to unity. Their notation was adopted further now is usually written as (Jones 2004):

$$TE_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i \, x_{ik}}$$

Where:

- $\mathrm{TE_k}$ stands for the technical efficiency of firm k ;
- $\mathrm{y_{rk}}$ is the quantity of output r produced by firm k ;
- $\mathrm{x_{ik}}$ shows the quantity of input i employed by firm k ;
- $\mathrm{v_i}$ is the weight of input i ;
- $\mathrm{u_r}$ is the weight of output r ;
- n represents the number of firms to be evaluated ;
- m shows the number of inputs ;
- s shows the number of outputs.

When evaluating each firm of the data set, the maximum efficiency score that can be generated by the weights of inputs and outputs is one. Furthermore, the weights of inputs and outputs are assumed to be strictly positive.

The use of the CRS specification when not all firms are operating at the optimal scale, results in measures (Coelli et al. 2005). This can be caused by government regulations, imperfect competition and many other factors. In order to modify the CRS model, assumptions of the constant returns to scale had to be relaxed. It was done by Banker et al. (1984), who proposed a model assuming variable returns to scale, VRS or BCC model. This model, with an added return to scale measure is more suitable when optimal scale is not achieved by all firms. Banker et al. claim that apart from calculating efficiency this model specification allows to check whether there is a presence of increasing, constant or decreasing returns to scale for a particular DMU. In VRS model only same scale DMUs are compared while calculating the efficiency ratio (Banker et al., 1984).

In both CRS and VRS models, the DMUs are efficient, if the technical efficiency ratio is equal to one and inefficient otherwise. In order to reach the frontier, the outputs or inputs of inefficient DMUs will be changed in the same proportions. In their article Charnes et al. (1978) provide how to evaluate the potential of inefficient DMUs or their target quantities of inputs and outputs they can reach if managed efficiently. However, there are sometimes situations when a DMU is on the best-practice frontier; however, if there is an input-oriented model one of its inputs can still be reduced or one of its outputs can still be increased in case of output-oriented measure and this DMU will still be on the frontier.

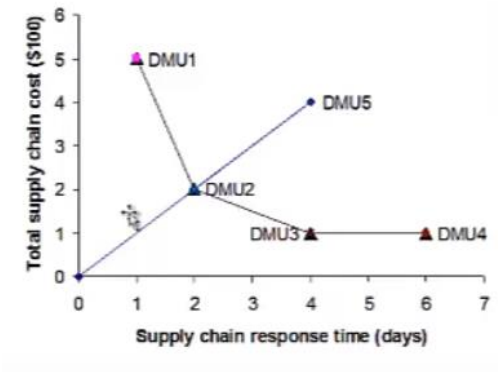


Figure 4 Pareto-Koopmans concept of efficiency

Source: Koopmans (1951)

As it can be seen, even though DMU4 is already on the frontier and, hence, is efficient, it can still reduce its Input 2 further by two units. Not only DMU4 will reduce the quantity of its input 2 but also stay on the frontier and have the same quantity of inputs as DMU3. After such operations, DMU 4 will be considered efficient according to Pareto-Koopmans concept. Koopmans (1951) argues that a DMU is fully efficient if and only if it is not possible to improve any input or output without worsening some other input or output. Therefore, the researchers agree that if the efficiency score is equal to 1 and DMU is on the frontier it is considered to be efficient according to Farrell's concept, which is used in one-stage DEA models.

Between Farrell's and Pareto-Koopman's definitions of efficiency there is a gap regarding slacks. In order to check for Pareto-Koopman's efficiency, two stage DEA is usually calculated where the second stage refers to slack calculation. However, sometimes slacks can arise because of certain specification of the frontier construction and because of the use of finite samples as well; therefore, it is better to check different frontier specifications before making any conclusions regarding slacks (Coelli 1998).

In the extension case of their DEA model, Charnes, Cooper and Rhodes (1978) argue that the DMU is considered to be efficient if and only if the two conditions are met. Firstly, the score of its technical efficiency ratio must be equal to one. Secondly, there must be no slacks. Zhu (2014) argues that if only the first condition is met, the DMU is known to be weakly efficient.

Another issue of DEA relates to the number of decision-making units, their inputs and outputs. The number of technically efficient firms always grows when the number of DMUs decreases or when more variables are used. Overall, if a ratio of number of DMUs to the sum of the number of inputs and outputs is too small, DEA model loses its discriminative power and puts more firms on the best-practice frontier (Pedraja-Chaparro et al. 1999). Hence, there should be enough numbers of DMUs in relation to the number of factors. Three groups of researchers, precisely, Cooper et al. (2007), Friedman and Sinuany-Stern (1998) and Banker et al. (1989) recommended that the number of DMUs should be three times as great as the sum of the number of inputs and outputs. However, no agreement is reached yet. Dyson (2001) suggested that the number of DMUs should be twice the product of the number of inputs and outputs. Another rule of thumb suggests that there should be twice as many DMUs as the number of inputs and outputs (Golany and Roll 1989).

The DEA method of measuring efficiency has some considerable advantages in comparison to parametric methods, it supplies researchers a number of new insights about the activities that were previously studied by another methods (Seiford and Thrall 1990; Cooper, Seiford and Tone 2000). For illustration, DEA serves as a powerful tool of benchmarking and allows to identify some sources of inefficiency even in the most profitable firms that were taken as benchmarks due to profitability criteria. The DEA method facilitates the search of better benchmarks in numerous industries and encourages many applied studies. Furthermore, the model does not require any production function specification or explicitly formulated assumptions, the measurement of whether one DMU is efficient in comparison to others is done by DEA in a straightforward way. Finally, there is a flexibility of dealing with multiple inputs and outputs and the resulting efficiency measure is easy and comprehensive (Bozec et al. 2010). Not only the best-practice firms are identified, but also it is possible to calculate the efficient target estimates for inefficient DMUs (Charnes et al. 1978).

Overall, both parametric and non-parametric methods are widely used in measuring efficiency of different companies and industries, for illustration, railway (Kumbhakar 1998), manufacturing (Peresetskiy 2013), airports (Barrows at el. 2012), hospitals (Nyman et al. 1990), agriculture (Bojnec 2014) and many others. According to Eller et al. (2013), the number of studies regarding efficiency in oil and gas sector is extremely low.

Overall, efficiency can be measured either using parametric or non-parametric methods. In case of stochastic frontier analysis, a production function, in its base specification most similar to Cobb-Douglas function in estimated. Though the disturbance term in contrast to ordinary regression models is further divided in two parts: one of them represents inefficiency and another account for external shocks. By looking at p-value associated with inefficiency term, it is possible to conclude whether inefficiency is presented in the industry and then calculate individual efficiency scores. In SFA the frontier of best practice firms is specified mathematically by maximizing the function it states the targets what maximum output can be produced using a certain amount or resources in place and then compares these mathematically obtained targets with the real results of companies. The companies which are on frontier will have zero inefficiency or, in other words, be fully efficient with a score of 1.

The main difference of DEA method is that the frontier of best practice firms to which individual results are compared later are not specified mathematically but rather taken from best practice firms in the industry after assessing linear programming model. This model can be assessed in two ways: either it is possible to produce more, given the resources in place (output-oriented efficiency), meaning that the current production results are not optimal. The model compares the results of individual firm with the results of other firms in the industry. At the same time, it is also possible to analyze whether it is possible to produce the same amount of production by using less resources (input-oriented efficiency) and if so, the current input quantities are not optimal. The main drawback of DEA method is that it does not account for external shocks that may cause the deviation from best practice frontier and assumes that all deviations are caused by firm internal inefficiency.

1.2 Oil and gas industry value chain and application of efficiency measuring methods

According to Munira et al. (2020), measures, attributable to operational performance, capture the performance of specific value chain activities within the firm. Thus, to fully examine the operational efficiency of oil and gas companies and the main factors that influence it, the mechanism of oil and gas business and its value chain needs to be understood first.

Any oil and gas project starts with search of potential field to start exploration. This follows by the stages of project appraisal, and, finally, development and production part with a number of substantial services such as geophysical and geological analysis, supply of equipment, drilling of rigs. All the mentioned operations belong to so-called exploration and production

(E&P) activities and comprise the upstream business, which is often argued to have the highest risk but generate the most value (Tordo et al. 2015).

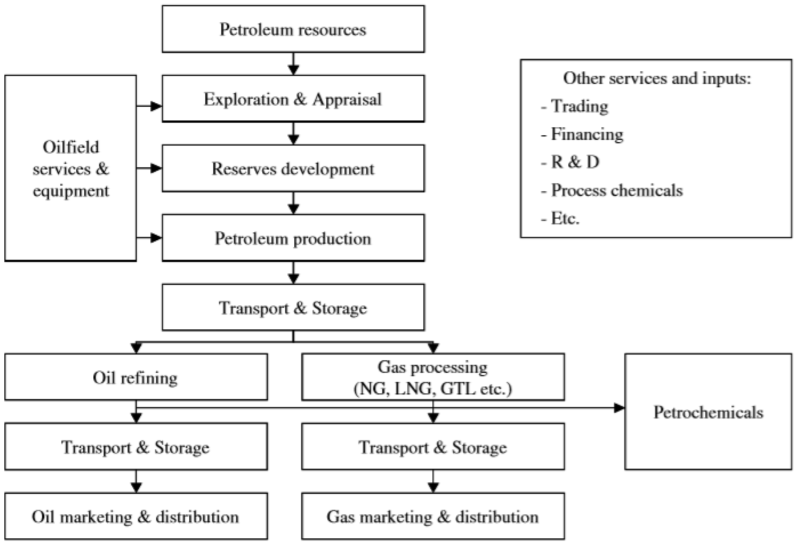


Figure 5 Oil and gas value chain

Source: (Wolf 2009)

The midstream operations include organization of essential infrastructure such as pipelines, connections with roads, ports and rails and storage to support the main business processes. The downstream activities comprise two main branches: refining, that transforms hydrocarbons into other usable products, and marketing, that ensures realization of the company's products to its final clients (Wolf 2009).

Strong links between the value chain establish faster and sustainable operations and bring additional value. That is why companies often perform more than one key activity and; therefore, imply a certain degree of vertical integration. Operational vertical integration involves exchange of hydrocarbons between subsequent different stages of the value chain (Bindemann 1999). The most common case is to combine E&P and refining and marketing (R&M) operations. The horizontal integration occurs when a company seeks business scale and expands within its key operations to achieve diversification of geological risks, enhancement of technological and operating expertise, and building a solid competitive advantage (Stevens 2008).

Tordo et al. (2015) claims that the performance of oil and gas company is significantly affected by sector organization and governance, which, in their turn, are impacted by state policy decisions. The four most important decisions are industry participation, resource depletion policy, licensing and petroleum contracts and taxation (Tordo et al. 2015). These four factors are expected to have the most material impact on value created by oil and gas companies, especially the national ones.

On the Figure 4 policy options are described with regards to the level of participation and competition in the oil and gas sector. On the one hand there is a complete state-owned monopoly that does not allow any outside players, on the other hand there is no any direct state influence or regulation, there is perfect competition on the market.

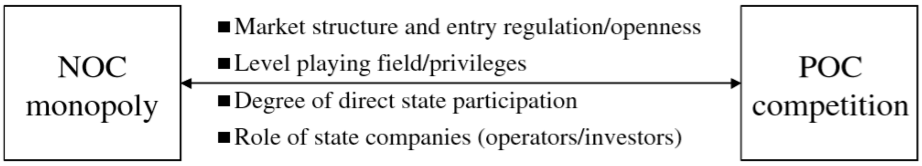


Figure 6 Options for the level of competition and participation in the petroleum sector

Source: Wolf (2009)

In real world the options of NOC monopoly and POC competition are not met in its pure condition, a company often implies a certain degree of one or another options. Even in the US where all oil and gas companies are private, some auction pre-qualification conditions are set by the government, therefore the market competition is not completely perfect.

If government ownership accounts for more than half, most researches regard this company as national, if there is less the company is defined as private (Tordo et al. 2015; Victor 2007). Such giants of oil and gas industry as ExxonMobil, BP, Chevron, Total and Royal Dutch Shell are usually noted as “Big 5” of private international companies. It must be stated that though national and international petroleum companies typically operate not only in oil sector, Ledesma (2009) states that most researchers still call them National Oil Companies (NOCs) and International Oil Companies (IOCs), as normal industry acronyms.

Overall, the company’s location to either of the two extreme points determines its willingness and ability to create social value and what extend it is affected by local content policies (Tordo et al. 2015). According to Tordo et al. (2015) local content policies first came into place in the early 1970s in the North Sea and covered topics from import limits to the establishment of NOCs. The local content policies usually include the employment of local labor, development of infrastructure, transfer of knowledge or technology, control from the local authorities, etc. Some authors (Hartley and Medlock III 2008; Tordo et al. 2015) claim that since the degree of state intervention is higher for national companies, they are more impacted by local content policies. These policies can implemented by the government via different means: contract terms to use local goods and services; protectionist measures such as different taxation schemes or subsidies to home companies, local content criteria used in determining the winning bid (E&P) license or contract, investment in education or infrastructure and so on.

Apart of the industry participation another important factor that affects oil and gas companies' value creation is licensing and petroleum contracts. All countries except the US either have a complete state ownership on the subsoil or retain a veto on its use (Mommer 2002). In the case of state-ownership of subsoil, the right to explore the field can be either granted to one party and be a monopoly right or a special licensing system that accounts for multiple agents' participation can be developed. Usually the exploration rights are granted via award or auction with solicited or unsolicited proposals from the interested parties. The bids are usually assessed taking into account different forms of company's commitments, such infrastructure offered to be built, the ability of a company to train the labor, the use of local contractors, minimum money spent on exploration or minimum number of wells drilled, etc. (Tordo et al. 2015). Waelde (1995) argues that often the form of the contract being granted is much less important than its "actual content, i.e. how the major functions and issues (management and control; risk assignment; revenue sharing) are being regulated".

Taxation regime is another aspect to consider since oil and gas sector has one of the highest tax rates and these rates around the world are different as a result of historical or regional preferences (Tordo 2008). For instance, in upstream sector, the total government take of the cash flow of the petroleum project usually composes 40-90% around the world (Johnston, 2007). Apart from having a strong financial impact, high tax rates also influence the company's incentives, asset allocation and contractual relationships. Tordo et al. (2015) argue that distortive tax regime does not support the efficient behavior of the firm, since it may discourage cost savings or encourage excessive investment.

Depletion management can involve not only individual petroleum reservoirs but also connected areas of production of the company or the total aggregated national depletion level. The depletion policies are either imposed by the government via licensing and contract mechanism or certain legal frameworks or set bottom-up by the operators of the certain project (Tordo 2008). The production rate that measures the pattern of using up reserves is a key element of depletion policy, which can be also significantly affected by the government. Therefore, the production rates may vary significantly around the world (Victor 2007; Wolf 2009). The depletion policy can be also affected by firm's price and cost expectations. For example, if oil price is low, it will be unprofitable to extract hard-to-recover reserves due to their high costs of extraction. As for cost expectations, Stiglitz (2007) states that is the costs of extraction are expected to be lower over time because of technological advances, the return to waiting will be higher; therefore, it becomes more profitable to postpone the extraction.

The article of Al-Obaidan and Scully (1991) is the first study that examines technical efficiency in petroleum industry Using the sample of 44 international oil and gas companies, the authors construct a production frontier applying different parametric methods. Authors suppose that state-owned companies' managers often serve to more principles and control mechanisms of management performance are often vaguer. Thus, Al-Obaidan and Scully (1991) state that apart from maximizing profit, managers of state-owned companies are required to fulfill other goals that result in less efficiency of public companies in comparison to that of private ones. This hypothesis is supported by the results of the study: private companies demonstrate higher labor and capital productivity results and that (NOCs) account only for 61-65% of their efficiency. Authors also argue that a state company can satisfy the demand with less than half of its current resources employed through converting to a private company.

Kim et al. (1999) applies DEA to find out the determinants of efficiency in natural gas industry. Their sample included 28 international firms and cover the period of 1987-1995. The findings partly support the results of Al-Obaidan and Scully, since according to efficiency scores, two out of three top performers among 28 international firms turned out to be private companies: Transwestern corp. in the US and Ruhrgas company in Germany. However, the Italian national gas company Snam also turned out to have high efficiency scores regardless of the estimation method used. Therefore, the hypothesis of link between government ownership and firm's efficiency is not fully proven.

The more up-to-date and comprehensive article, examining efficiency in oil and gas industry was written by Eller et al. (2007). The study of Eller et al. (2007) is considered to be more comprehensive, since it includes companies from the OPEC countries that represent around 40% of global oil production. Al-Obaidan and Scully (1991) claim that OPEC countries should not be included since their efficiency is mostly a result of geographical location than the rational allocation of resources. However, if some firms are considered to be more efficient due to their ability to produce higher result from the same quantities of factors used, their geographical location should not be considered as a primary explanation of this phenomenon.

Eller et al. (2007) used both non-parametric and parametric methods: data envelopment analysis and stochastic frontier and studied 80 petroleum companies in 2002-2004. The focus of their study was technical efficiency in revenue generation from firm's reserves and employees. Hence, total revenue was chosen as a dependent variable and reserves and employment as independent variables, both of which proved to be highly significant in all DEA and SFA model specifications. The authors oppose the decision of Al-Obaidan and Scully (1991) to include total assets as an input, claiming that their book value may be over or understated in comparison to their economic value that must be used as an input to production and that their depreciation is correlated with the age but not always with assets productive capability.

Meanwhile, Eller et al. (2007) confirm the findings of Al-Obaidan and Scully (1991) that a degree of vertical integration and a share of government ownership have a considerable impact on the firm's efficiency. A positive coefficient of vertical integration shows enhanced firm's ability to generate revenue when it is vertically integrated. Regarding the degree of government ownership, the negative coefficient indicated lower efficiency to produce revenue if the firms has higher share of government ownership. Authors explain this tendency by subsidies NOCs usually provide on the national market, selling their production below the market prices. The degree of government ownership may also result in overemployment (Hartley and Medlock III 2008). Thus, Eller et al. (2007) added the interaction term between government share and employment and found it to be strongly negative and highly statistically significant. This means that when employment is increased, the higher the share of government ownership is, the lower the marginal revenue product is. Overall, the results of all models proved that private oil and gas companies appear to be closer to the production frontier and; therefore, more efficient than the national ones: the average efficiency score for the largest private companies turned out to be 73% while the average result for national companies was only 27%.

In his article Wolf (2009) studied two types of efficiency of oil and gas companies: efficiency to generate production and efficiency to generate revenue. The author provides additional support that private oil and gas companies are more efficient and demonstrate higher performance in case of generating physical output; however, if revenue is taken as a dependent variable the findings do not demonstrate any solid advantage of each form of ownership. Looking from the short-term perspective, Wolf insists that political preference of national oil is usually accompanied by economic cost, since national companies underperform the private ones by about 21-30%.

Reserves as an independent variable was proved to be highly significant in explaining production. Furthermore, Wolf (2009) argues that accounting for reserves allows to capture the effect of different depletion policies of oil and gas companies, which is important if production is taken as a dependent variable. Though in case of modelling revenue generation, Wolf (2009) takes total production instead of reserves that were taken by Eller et al. (2007), and this specification may be more justifiable since revenue is production multiplied by price. Wolf (2009) finds total employment to be insignificant in explaining production, but not revenue generation. In case of revenue, the increase in employment has a positive impact on revenue generation, which strengthens the finding of Eller et al. (2007).

Basil & Lee (2014) used DEA to measure differences in efficiency of 38 petroleum companies in the period of 2003–2010. The authors argue that the only similar research was done by Eller et al. (2007), who also used DEA as one of the approaches to measure efficiency of petroleum companies for 3-year period of 2002–2004. Therefore, the study of Basil & Lee (2014) can be considered as a follow-up study, covering the next years up to 2010. Nevertheless, the difference of this study is that Basil & Lee (2014) divided companies into 3 groups: OPEC NOCs, non-OPEC NOCs and international private oil companies and Eller et al. (2007) did not distinguish OPEC NOCs as a separate group.

Furthermore, the main focus of the study of Basil & Lee (2014) was to investigate the efficiency of oil and gas companies to convert their input resources into maximum output results achieved, thus the authors decided not to account for such external social effects as subsidies that may impact revenue of NOCs (Eller et al. 2007) and to use physical output, precisely, total production instead. The number of employees was chosen to account for labor factor of production, consistent to other studies (Eller et al. 2007; Wolf 2009). Whereas, the amount of reserves was chosen a proxy for capital factor of production, since the authors support the claim of Eller et al. (2007) that reserves comprise a substantial part of total assets and serve a more reliable measure to take because book value of assets do not necessarily match their economic value, which should be used in production function.

By studying OPEC NOCs separately Basil & Lee conclude that higher government ownership breeds higher inefficiency. Furthermore, by partial privatization of 50% of its shares fully state-owned NOC will be able to increase its efficiency by 0.175 points. A second important finding regrading vertical integration turned out to contradict the previous studies, since Basil & Lee (2014) found out that higher degree of vertical integration results in decrease of a firm's production efficiency, possibly because of such factors as overemployment and difficulties of the transformational process. According to the authors, increasing vertical integration by one unit leads to a drop of a company's efficiency by 2,54%. Thirdly, according to the results of regression that Basil & Lee (2014) conducted to estimate which factors explain the variation of DEA efficiency score, that was taken as a dependent variable, the employment variable turned out to be insignificant in explaining variation of production which aligns with the findings of Wolf (2009). However, according to another article of Wolf and Pollitt (2008), the excessive employment, that results primarily because of the high degree of state influence, is one of the main inefficiency characteristics of national oil companies. This finding is supported in the work of Hartley and Medlock III (2008) who argue that political pressure force national oil companies (NOCs) to employ more labor than needed to obey the wide-spread requirement of hiring more locals. Furthermore, the results of parametric method of Eller et al. (2013) also revealed that the government ownership tends to cause a reduced productivity of labor or, in other.

Considering the main findings above, it can be concluded that one of the main factors that determine efficiency in oil and gas sector is the share of government ownership. Thus, this link should be researched further. In the study of performance of national petroleum companies Victor (2007) investigates the production of oil and gas, as well as revenue generation on the sample of 100 oil companies from all over the world in 2004. The author claims that more than half of global gas reserves are "dead" because owned by national oil companies. Victor (2007) argues that increasing the gas reserves base by the same amount leads to about 43% increase for both major and private companies, but only about 21.5% for national companies.

The major companies: BP, Chevron, ExxonMobil, Total, Shell also turn out to be the most efficient in terms of use of oil reserves: doubling reserves leads to a 50% increase in oil production compared to a 38% increase for least efficient NOCs. The author concludes that NOCs are characterized by a much slower pace of resource development and less efficient revenue generation because of the tight government ownership, government-required slower depletion rates, and subsidies for employment and delivered products.

Nevertheless, Kapustina and Krylov (2008) claim that there is a tendency of national companies to increase their efficiency scores, with the pace even higher than that of private companies, that may indicate the change of best practice firms in the future. The authors used non-parametric DEA method to examine 18 national and private petroleum companies from different countries and compare their DEA efficiency scores in 2004 and in 2007. Consistently to previous studies, Kapustina and Krylov (2008) take number of employees and total reserves as independent variables and explores how efficiently oil and gas use their reserves and labor to generate revenue. The authors support the finding of Victor (2007) that BP, Chevron, ExxonMobil, Total and Shell normally have one of the highest efficiency scores. Moreover, their results also demonstrate that another US company ConocoPhillips together with Shell demonstrated the highest efficiency in the sample both for 2004 and 2007 studied years. On average companies with more than 25% of the government ownership showed only 69% of efficiency of the private companies.

Kapustina and Krylov (2008) also argue that technology and financial resources are becoming the major competitive advantage of private oil companies. At the same time, private companies are less able to increase their oil production because of political and geological factors. Wolf (2009) agrees that in future it can more difficult for private companies to get access to new reserves, especially if national oil companies find more comfortable to work with their foreign national partners. Thus, Wolf (2009) admits that the possible threat that can affect the higher efficiency and performance of private companies is NOC-to-NOC collaborations on developments of new fields. Furthermore, the author states that there is much more analysis to be done in the field since current analysis is not full due to the lack of data on some OPEC NOCs.

The study of Eller et al. (2013) complements their previous paper written in 2007 by extending the time period and examining how the efficiency of 61 NOCs and private companies has changed over a decade. Though the overall result reaffirms the gap between the higher efficiency scores of private companies and lower results of NOCS, there is a new finding of the faster rate of efficiency improvement for national companies over the last decade, which supports the claim made by Kapustina and Krylov (2008). Moreover, both parametric and nonparametric methods used by the authors state that retail subsidies were a primary source of decreased efficiency to generate revenue by many national companies.

1.3 Russian oil and gas market overview

1.3.1 Global trends: supply, demand and price dynamics

In 2018 global oil production increased by 2,4% and amounted 94 718 thousand barrels per day (b/d). The increase of global supply was majorly driven by production increase in the US (2,2 million b/d), Canada (410 000 b/d) and Saudi Arabia (390 000 b/d). As it can be seen on the Graph in 2018 there was a stable oversupply since June, which had only increased by the end of the year. Production of OPEC countries decreased by 330,000 b/d because of the OPEC agreement, which was prolonged to mitigate the threat of market oversupply in 2018. US, together with China was also one of drivers of oil consumption which increased by 1.4 million b/d mostly because of increased oil usage in energy-intensive industries (BP 2019).

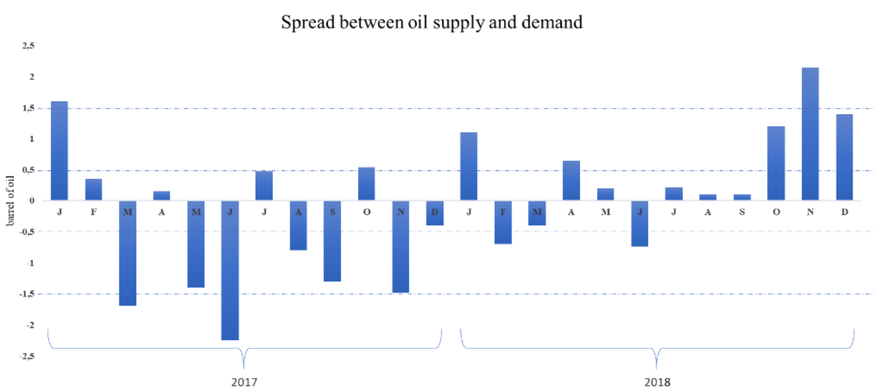


Figure 7 Spread between oil supply and demand

Source: McKinsey (2019)

Russian production of oil totaled 11 438 thousand of b/d and demonstrated a 1,6 % increase from the previous year amount due to the growth of oil sector revenues as well as the development of new fields. Russia's share in global oil production in 2018 amounted 12,1%, in comparison, the share of Saudi Arabia totaled 13% and the largest share was attributed to the US – 16,2% with an annual production growth of 16,6%.

The global natural gas market is divided into 2 segments: pipeline gas and liquified natural gas (LNG). It must be stated that the share of LNG market, which is now at 45.7% of the total trade, keeps increasing each year and is projected to outnumber the pipeline segment in 2020. In 2018, the natural gas market experienced one of the highest increases in production over the last 30 years which amounted to 3,867.9 billion cubic metres (bcm) (BP 2019).

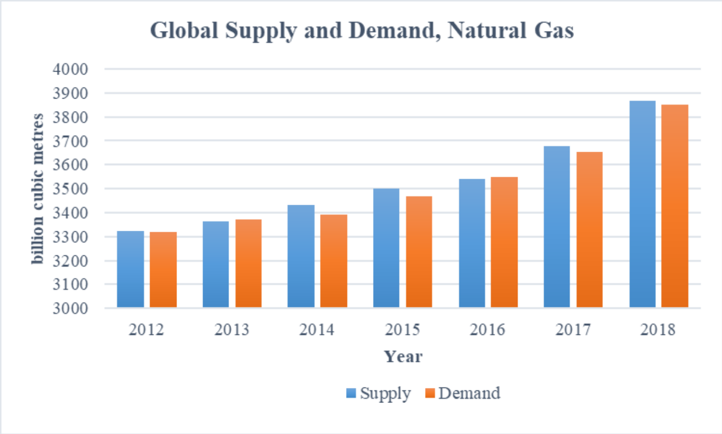


Figure 8 Global supply and demand of natural gas

Source: made by the author

The spike in production in 2018 was mainly driven by the US who contributed to 45% of the total growth of global production primarily because of increased demand for US LNG (BP 2019). Other countries that caused the supply growth were Russia (by 34 bcm), Iran (by 19 bcm), and Australia (by 17 bcm) (BP 2019). The global supply of LNG also grew almost 10%, due to the ramping up of new gas liquefaction plants in the US, Australia, and Russia (BP 2019).

The global increase in natural gas demand in 2018 was one of the highest during the last decade at 5.3% and comprised 3848.9 bcm (BP 2019). The major driver was the US, who contributed 40% of the total increase in global demand (BP 2019). In the US natural gas usage was primarily driven by weather-related factors that increased demand for space heating during winter and for air conditioning during summer.

Overall, the data indicates a global market oversupply of 19 bcm (production of 3867.9. vs consumption of 3848.9 bcm). The Asia Pacific region came in second place in terms of overall consumption with growth rates of 7.4% overall, with Chinese demand increasing 17.7% and South Korean demand increasing 12.4% (BP 2019). Chinese consumption primarily increased due to the government initiative of clear energy policy that implies graduate switching from coal to gas. A fall in demand of 2,1% was registered in Europe because of the milder than usual temperature during the first months of the heating season and drop in gas demand for energy intensive industries (BP 2019).

In Russia increased its gas output by 5,3% due to the export increase, especially of LNG that rose by 70% (BP 2019). Its annual production of 669,5 bcm gives Russia the second place in the global production with a share of 17,3%. The leader of production is the US with 21,5% market share.

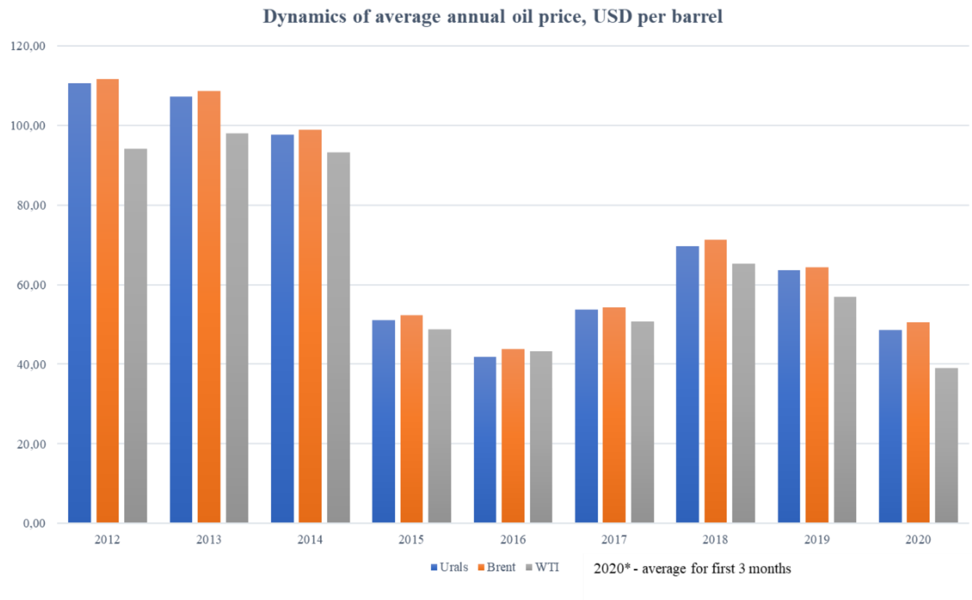


Figure 9 Average oil prices in 2012-2020

Source: Made by the author

As it can be seen from the graph, starting from the first fall of oil price in 2014, while having considerably increased in 2018, currently oil prices demonstrate downward trend because of the global market oversupply. Urals represent the Russian oil brand, and Brent and WTI represent two global price benchmarks of purchasing the oil across the globe.

OPEC agreement currently is only one implemented option to stabilize the market. Most recently the Urals average price for the first three months of the year amounted 48,52 USD/barrel, average Brent price was a bit higher with 50,45 USD/barrel and average US WTI dropped to 39,03 USD/barrel. The main factors that caused the surge of prices were coronavirus pandemic and the temporary termination of OPEC agreement in March 2020, when Russia did not agree on the additional cut of 1.5 mb/d.

Japan's Cost, Insurance and Freight (CIF) LNG is one of the most popular indexes used to determine the price of long-term LNG contracts in Japan, Korea, and Taiwan (BP 2019). Japan/Korea Marker (JKM) is an indicator for assessment of LNG price for spot physical cargoes, mainly delivered using Delivered Ex Ship (DES) into Japan, China, South Korea, and Taiwan (S&P Global Platts). It is also used for medium and long-term contracts. The other indexes represent average price of contracts for pipeline natural gas. National Balancing Point (NBP) is a trading virtual platform for the sale, purchase, or exchange of British natural gas (Reuters, 2017). The price of NBP is often used as a benchmark for the wholesale natural gas market in Europe. Another indicator of gas prices in Europe is the Title Transfer Facility (TTF), a virtual trading facility in the Netherlands. It is considered more liquid than NBP due to its larger total volume of trade (Reuters, 2017).

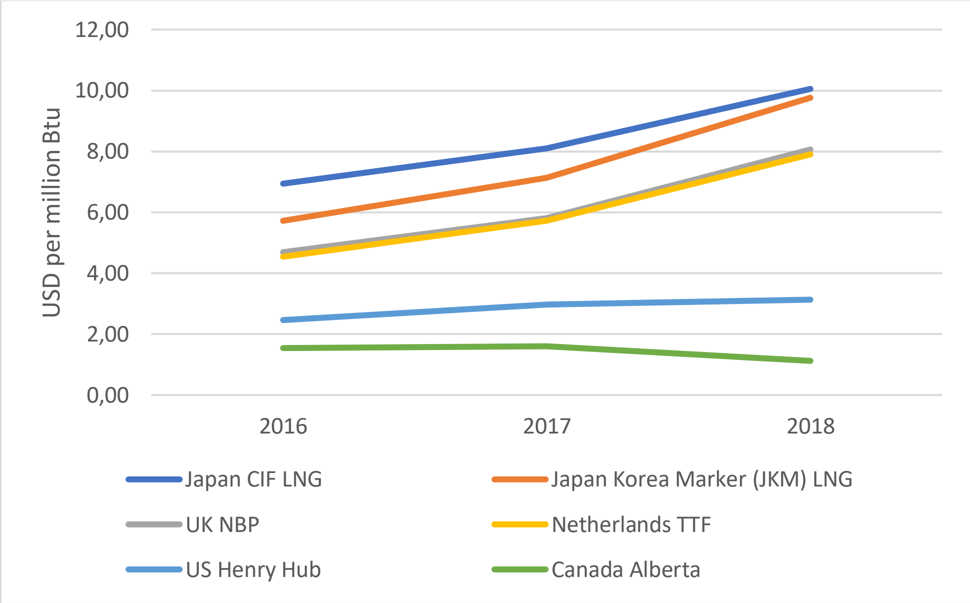
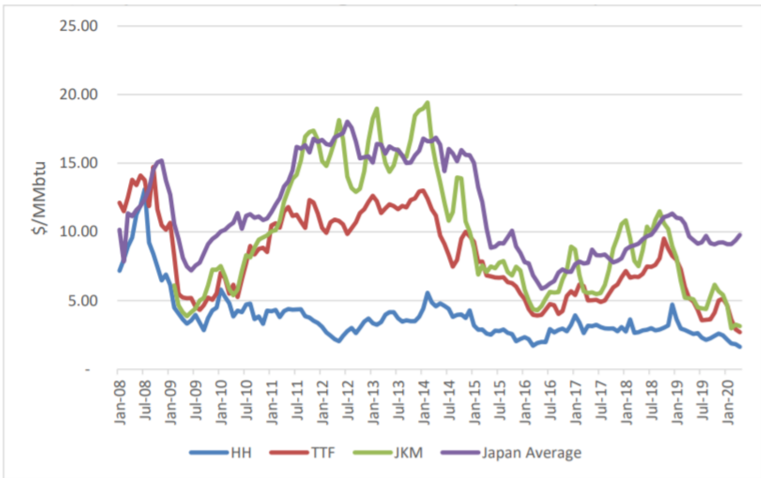


Figure 10 Average prices of natural gas in 2016-2018

Source: made by the author

As can be seen from the graph, in 2016-2018 the prices of Japan's CIF LNG showed a strong upward trend, starting the period at 6.94 USD per million Btu (British thermal unit) and growing to 10.05 USD/MMBtu by 2018. Likewise, the JKM began 2016 at 5.72 USD/MMBtu in 2016 and grew to 9.76 USD/MMBtu 2018 (BP 2019). The major driver was the rising Chinese demand for LNG that was caused by transition to clear energy policy (Chinese sustainable future report). The prices of NBP and TTF also increased and demonstrated similar dynamics, since both represent the price of natural gas in Europe. The NBP began at 4.69 USD/MMBtu and grew to 8.06 USD/MMBtu by 2018 while the TTF started at 4.54 USD/MMBtu in 2016 and grew to 7.9 USD/MMBtu in 2018 (BP 2019).

The price of Henry Hub, gas benchmark of the US, increased from $2.46 USD/MMBtu to $3.13 USD/MMBtu over the studied period, whereas the price of Canadian gas was much more volatile. In 2017, the price started off at $1.55 per million Btu, rose to $1.6 USD/MMBtu, and then dropped to $1.12 USD/MMBtu in 2018.



*'Japan Average' is roughly equivalent to crude oil-linked JCC prices; February-April 2020 are estimated taking into account the lag effect of crude oil prices in long term LNG contracts.

Figure 11 Prices of natural gas in Europe and Asia in 2008-2020

Source: Oxford Institute of Energy studies (2020)

By the beginning of 2020, spot prices both in Europe and Asia have fallen significantly and reached their historical lows. This fall was driven by the increase of global LNG supply by twenty-five per cent during the past five years. Moreover, the addition of ten per cent to global supply is expected in 2020. The main driver of increased demand for the past years was Chinese gas to coal switching policy; however, this period of historically high prices in Asian region is claimed to come to the end. The added capacity of new US projects that was welcomed by Asian buyers because of Henry Hub pricing may be not in demand if the consumption of Asian buyers will decrease further in 2020.

1.3.2 Global trends: Cooperation with OPEC

The main goal of production growth predominated in 2014-2016 was caused to shift because of the recent crisis. In the time of low oil prices Russia had to create a new strategy of managing the oil price via cooperation with OPEC countries, especially with Saudi Arabia. When Russia entered an OPEC agreement regarding the production cut, major Russian companies had to reduce or maintain the same level of production to follow the terms of agreement.

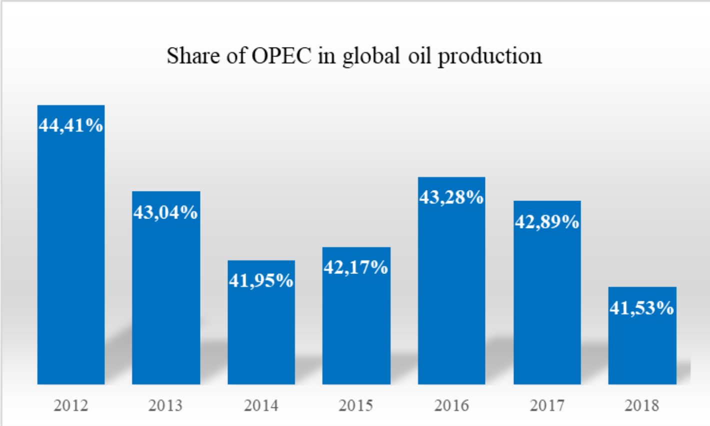


Figure 12 Share of OPEC countries in global supply

Source: made by the author

The agreement could be signed even earlier in 2016 when the oil price was around $30 per barrel, much lower than the one accepted in state budget. The allocation of production cuts used to be the main pain point of agreement. However, the agreement was reached in December and implemented in the beginning of January, with Russia contributing 300,000 bpd of the overall cut of 1,5 mb/d (Oxford Institute of Energy Studies 2019). This helped to fix the supply-demand situation and in order not to provoke a negative reaction of the market that may resulted from the end of the deal, the agreement was prolonged by June 2018.

Nevertheless, in the second half of 2018 the market became unbalanced again because of the warmer relations between US and Iran that eased the purchases of Iranian crude, recovery of production in Libya and Nigeria as well as the rapid growth of the US shale oil. With the oil below $60 per barrel, the second OPEC+ agreement of 1,2 mb/d reduction was reached in December 2018. Russia cut its production by 228,000 bpd from the production level of October 2018 (Oxford Institute of Energy studies 2019). This agreement was extended in June 2019 and lasted till March 2020. Overall, Russian companies demonstrated the high level of compliance with agreement during the whole deal period the cut was never less than 200,000 bpd, except once in 2018 when the agreement was expected to come to an end.

From May 1, 2020 the new OPEC agreement comes into force and OPEC members will reduce the production by 9,7M barrels/day from the production amounts of October 2018. Companies, that are not OPEC members promised to cut the production is well, US will reduce by about 600 thousand barrels/day, while Canada and Brazil plan to cut by 300 and 200 thousand barrels, respectively. Russia will limit the production by around 1,9M barrels/day. The three companies that will have to sacrifice the most are Rosneft - 0,73M barrels/day, Lukoil - 0,28M barrels/day and Surgutneftegas – 0,2M barrels/day. These actions may put at risk the state of the fields the stop of which may put more water into soil and reduce the quality of extracted oil.

However, according to the Vice President of Lukoil, if oil price stayed $15–20 the fields will had to be closed one way or another, especially given the fact that in March some deals were conducted with negative Urals price (Vedomosti 2020).

1.3.3 Global trends: Impact of Sanctions

US and EU sanctions against Russian energy sector can be divided into two waves. The initial sanctions were imposed by US in 2014, followed by those of EU in the same year. Then, in 2017 the US imposed additional sanctions with a quite vague content. All the sanctions fall into two directions: financial sanctions restrict provision of loans and share capital while technological ones are mostly concerned with provision of equipment and technologies. Thus, US Directive 2 that used to prohibit loans and share capital with maturity over 90 days revolutionized into the new one accepted in 2017 with the maximum maturity reduced to 60 days. The EU financial sanctions went even further and allowed for loans and share capital within 30 days maturity only (Skolkovo 2018).

However, while the US imposed financial sanctions on Rosneft, NOVATEK, Transneft and Gazprom Neft and technological sanctions Rosneft, LUKOIL, Gazprom, Surgutneftegas and on subsidiaries with a controlling stake over 50% in Russia (technological sanctions), EU sanctions did not cover any of gas producing companies, given the dependence of Europe on the Russian gas. Furthermore, in 2017 the US reduced the control stake requirement to 33% worldwide and put a foundation of possible sanctions against pipeline export. Now any entity may fall under sanctions if it sells services, equipment or technology that cost over 1M USD for Russian pipeline projects or invests in these projects at least 5 million USD in 1-year period (Skolkovo 2018).

Sanctions caused Russian companies to put on hold many of their joint venture projects. Since share in ownership was reduced the 33%, US oil and gas companies became very concerned of this fact, since their participation may be limited not only in projects in Russia but also projects with Russian companies worldwide. For example, ExxonMobil withdrew from its joint venture with Rosneft in developing of the following projects: East Prinovozemelsky, North-Kara, Ust-Olenek, Ust-Lensk, Anisinsky Novosibirsk, SeveroWrangel, South Chukchi and Tuapsinsky Deflection.

Moreover, the future of projects on which Russian companies work abroad is also put under question. LUKOIL now is a leader in terms of assets located abroad which represent about 13% of the company total production. The company operates in 35 countries and now its expansion plans are put under the question because of sanctions. Another company that had considerable expansion plans is Zarubezhneft, that planned to develop Iranian Aban and West Paydar fields together with National Iranian Oil Company. However, in order for the project to be put under sanctions, either against Iran or Russia, the company cancelled the agreement. Therefore, the intentions of Russian companies to expand and globalize their operations became limited because of the sanctions. According to Skolkovo experts, now the main goal of major Russian petroleum companies is to improve their efficiency and concentrate on developing the Russian fields rather than international ones (Skolkovo 2018).

Finally, it is argued that impact on sanctions will continue its influence in the form of "compound per cent" and the major consequences will be realized in the future both for local and international projects. Apart of upstream, such business segments as refining and marketing and even gas stations may experience some financing and short credit leveraging constraints in the long-term.

Limited opportunities to attract financing for new projects and strong dependence on imported technologies for project development especially the ones for hydraulic fracturing accompanied by high rates of reserves depletion of existing projects may result in decrease of production about 5% in 5 years.

1.3.4 Local trends: Concentration of Russian market and resource depletion

According to Skolkovo experts, another important trend of the Russian oil market is its high concentration and increase of the role of state-owned companies (Skolkovo 2018). The largest industry player is Rosneft with around 40% share of total national oil production. The experts of Skolkovo state that after Bashneft became state-owned again, the proportion of the market that belongs to companies with over 50% of state-ownership became around 48%. According to the Herfindahl–Hirschman Index, which is used to estimate a degree of market monopolization, the Russian oil market became highly monopolized after the Rosneft's purchase of TNK-BP. The index figure that is higher than 1800 speaks about high degree of monopolization though in 2012 the result was far less than the recent figures and the market reflected only moderate concentration (Skolkovo 2018).

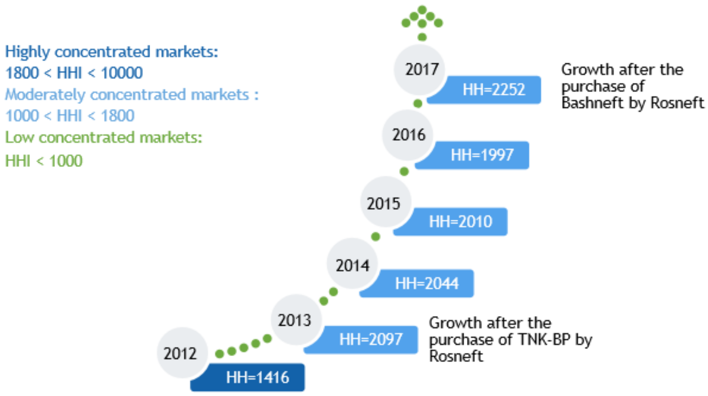


Figure 13 Herfindahl–Hirschman Index: assessment of market concentration

Source: Skolkovo Energy center (2018)

As for gas sector, the state-owned company Gazprom also has a dominant role, the company has exclusive rights on exporting pipeline gas abroad. The company is the leader of Russian and global production with 69% and 12% of market shares, respectively. Furthermore, Gazprom also has the largest reserves base that comprises 71% of total reserves in Russia and 16% of global gas reserves.

Gazprom also owns the National Gas Transportation system that stretches from European part to West Siberia and a number of systems that connect the Russian Far East. The second largest gas producer in Russia is NOVATEK, which owns a number of fields in Yamalo-Nenets Autonomous District and conducts two large LNG projects, such as Yamal LNG and Arctic LNG 2. Large oil companies such as Rosneft and Lukoil also have a number of gas fields, but their gas production is low compared to the volumes of oil they produce.

Another important trend on oil and gas market is the falling production of some major oil companies such as LUKOIL, Slavneft and RussNeft which is probably caused by a high rate of depletion of their resource base and lack of new expansion projects.

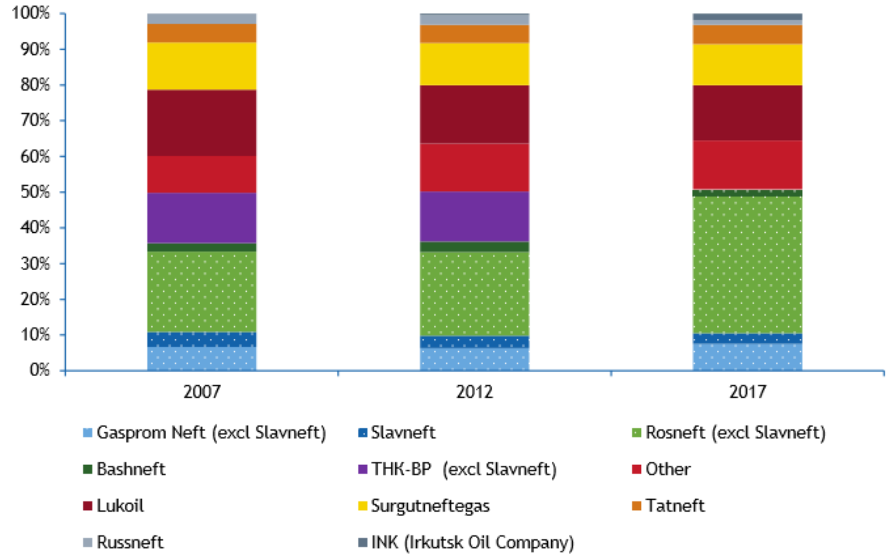


Figure 14 Oil production structure by company in 2007-2017

Source: Skolkovo Energy center (2018)

The largest increase during the period among the largest companies was demonstrated by Gazprom Neft and comprised around 5 million tons in total. However, the largest production growth of 35 million tons in 2013-2017 was demonstrated by "Other" companies that now together comprise 17% of total national oil output. Rosneft also increased its production, mostly after an acquisition of TNK-BP in 2013. Another asset expansion occurred in 2017 when Rosneft acquired a major stake in Bashneft. As for 2018, the production distribution has not changed much.

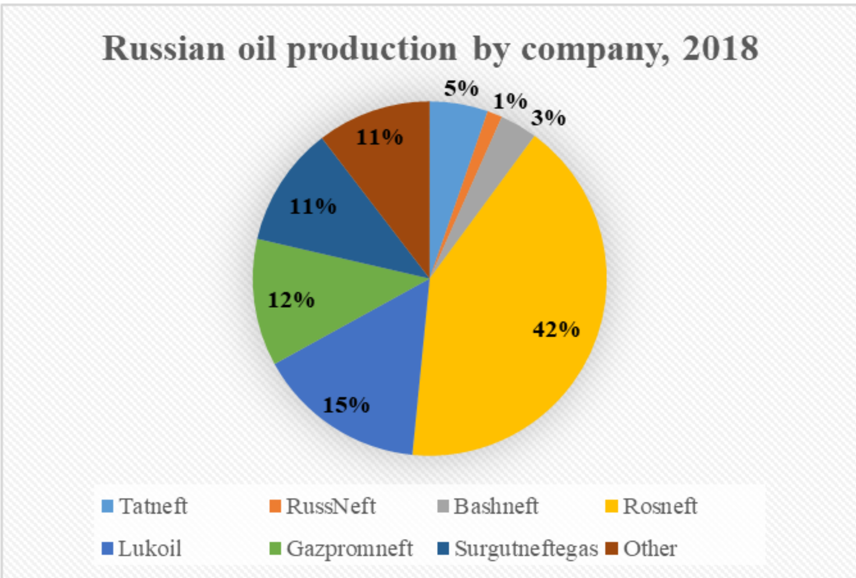


Figure 15 Oil production structure by company in 2018

Source: made by the author

The Russian oil production is dominated by Rosneft, with a 42% market share. The company successfully manages to increase production drilling at its mature fields in Western Siberia and hold back a decrease of the output caused by depletion of the resource base. The second, third and fourth largest producers are Lukoil, Gazprom Neft and Surgutneftegas. Other small companies not mentioned on the graph account for 11% of the Russian oil production.

Currently Russian oil resource base demonstrates a declining trend of high-quality oil reserves: from the explored reserves that fall into ABC1 categories, two thirds are categorized as hard-to-recover reserves (Skolkovo 2018). The Ministry of Natural Resources states that without taking into account hard-to-recover oil reserves, the reserves at the developed fields will be available for twenty more years only; whereas if proficient technologies will be used to extract hard-to-recover oil, the available period will increase to 35-36 years (Skolkovo 2018). Moreover, if hard-to-recover oil will not be a part of total national oil production, after 2020 it will be impossible to maintain the current production level.

Currently the production mainly increases not due to of exploration of new deposits, but because of additional exploration at developed fields and improvement of technological base that helps to increase the ratio of oil recovery. However, the degree of depletion of explored reserves already reached more than 50% (Oxford Institute of Energy studies 2019). Furthermore, the pace of the discovery of new deposits does not keep up with the pace of new reserves discovery because of smaller sizes of the fields. In the past it was very common to discover a field with around 50 million tons of reserves in place and now oil companies regard a field with 3 million tons as a considerable discovery. The Skolkovo experts also state that the oil quality of new deposit usually has worse chemical composition, accounting for sulfur content and density. Low oil prices also negatively affect exploration of new reserves, since it is a highly capital-intensive process. Thus, in 2016 there was a lowest growth in reserves demonstrated by the industry that comprised less than 50 million tons (Oxford Institute of Energy studies 2019). Given the current fall of the oil price it is assumed that the investments into discovery of new fields will also fall in 2020.

1.3.5 Local trends: Liquified natural gas projects, Arctic and offshore

Given the growing number of LNG export all over the world, Russian largest gas companies also make high investments and develop their operations in this sector. Currently the two active LNG projects are Sakhalin 2 and Yamal LNG.

Sakhalin 2 project is a by Gazprom subsidiary, Sakhalin Energy Investment Company Ltd. Other company’s shareholders include Shell, Mitsui and Mitsubishi. The project is executed under production sharing agreement between the company and state. Under Sakhalin 2 project the first LNG plant in Russia was built in 2009. In 2019 the company exported 11,14M tons of LNG to the major destinations on the Asian LNG market: Japan, China, Taiwan and South Korea. Sakhalin 2 projects covers about 4% of total demand on Asian LNG market and about 3% of the global LNG demand (Sakhalin Energy 2019).

The second running project is Yamal LNG headed by NOVATEK, with the share of 50,01%. Foreign shareholders include Total with 20% ownership, CNPC with the share of 20% and Silk Road Fund holds 9,9%. The plant capacity is 17,4M tons per year, including 3 trains with capacity 5,5M tons each and additional train producing 900 thousand tons annualy. The first train started production in the end of 2017. The first year when all thre trains began producing was 2019, when Yamal LNG produces 18,4M tons of LNG and exceeded its capacity by 11%. The low cost of goods and superior logistic system allows Yamal LNG to export its LNG all over the world, including European and Asian destinations. NOVATEK also develops another LNG project – Arctic LNG 2, which already received final investment decision and is currently in the exploration and development stage. The new project is expected to produce 19,8M tons of LNG annually. Meanwhile, the development of new LNG projects currently experiences a slowdown because of the low price of LNG and market oversupply as well as the US sanctions imposed on Russian companies (NOVATEK 2020).

While developed onshore resources express high rate of depletion, the increase of total production can be sourced from offshore projects. Nowadays on Russian part of the Arctic shelf there is already more than 200 rigs drilled; however, most part of it is still unexplored: the level of exploredness of Russian shelf is twenty time less than the one of Norway and 10 times less than the one of the US part of Chukotka sea.

Some researches suppose that the current status of low explorations of Arctic shelf is caused due by the moratorium on licensees of 2012-2014: now licensees for the shelf can only be obtained by companies with at least 5 years offshore experience as well as more than 50% of state ownership and only Rosneft and Gazprom meet these requirements (Skolkovo 2018). Other companies, including the foreign ones, can be invited to participate on the minority terms. LUKOIL company preserved the right on some licensed fields in Kaspic and Baltic seas (Oxford Institute of Energy studies 2019).

Though Rosneft and Gazprom have sufficient experience as well as government support to deal with the consequences, of the sanctions, for example, high number of licenses – around 50 for Rosneft and 30 for Gazprom, giant areas of fields and tough deadlines for number of rigs drilled prevent companies from keeping up with the schedule. By 2018 the total offshore reserves of Rosneft's fields were estimated at 41,7 billion tons of oil equivalent, as for Gazprom, its offshore reserves of oil were around 61 million tons and gas reserves of 7,6 trillion of cubic meters. In the past these two companies preferred to attract other companies with offshore expertise like ExxonMobil or Shell for initial stages of projects and now minority terms and sanctions make these partnerships impossible (Skolkovo 2018). Companies without state ownership like Surgutneftegas or RITEK, which is now the part of LUKOIL also have their own experience of hydraulic fracturing and thermal dissolution methods of hydrocarbons extraction; however, because of moratorium such companies cannot get license for offshore projects now.

Nowadays the production in the Arctic shelf only started at one field: Prirazlomnoye, owned by Gazprom Neft with annual volume around 3,2 million tons (Skolkovo 2018). As for other projects, such as Leningradskoe; Ledovoe and a few more their geological exploration has not started yet because, as Gazprom states, current own prices make the projects not economically feasible to explore: the drilling of one rig may cost around 1 billion dollars. Therefore, Gazprom asked Ministry of nature to make changes in license agreements to postpone the deadlines for exploration and drilling after 2025 (RBK 2019). Apart from the price, another major issue of low pace of the Arctic shelf exploration is shortage of own drilling platforms and sanctions that make it difficult to lease or buy such equipment.

However, the Gazprom's and Rosneft's decision of current delay of Arctic shelf exploration by 5-10 years makes it possible to start production after 10-15 years only, and it is not obvious if such increase of supply will be needed given the increase of importance of renewables and current oversupply on the market (RBK 2019). Secondly, the more active exploration and development of the Artic shelf may foster the development of the Northern Sea Route.

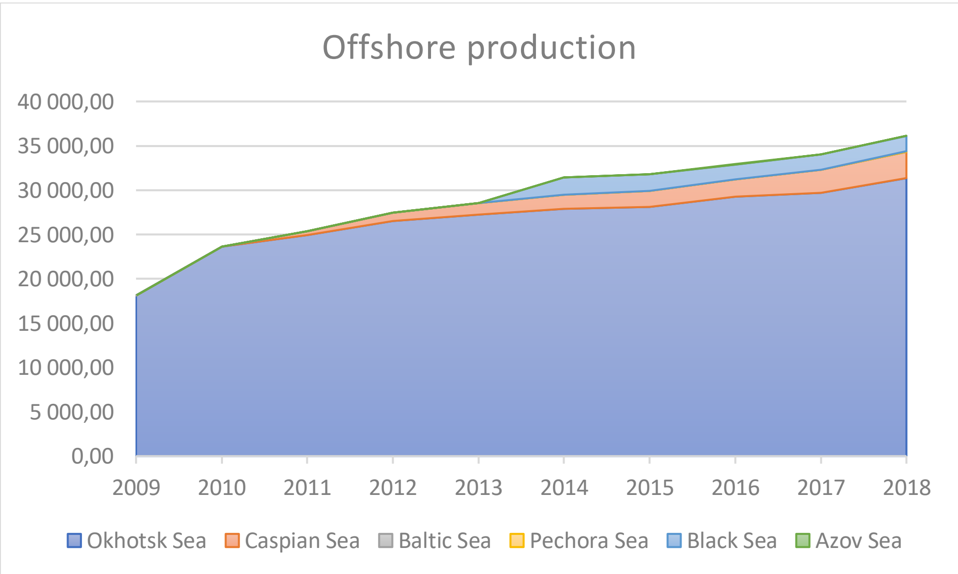


Figure 16 Russian offshore production in 2009-2018

Source: made by the author

Shelf of Okhotsk sea accounts for the largest share of total offshore production. The major Rosneft's projects include Sakhalin-1, the Northern tip of the Chaivo field and the Odoptu-more Northern Dome and Lebedinskoye fields. Gazprom is presented by Sakhalin 2 and Sakhalin 3 oil and gas projects that include several oil and gas fields. A considerable number of projects are also planned at the Arctic shelf and the Caspian Sea aquatorium, these projects are expected to account for a major shale output increase in the future. Currently the Russian Arctic shelf is only represented by one project of Prirazlomnoye field, operated by Gazprom Neft.

Nevertheless, most of such projects require import of foreign technologies or cooperation with foreign companies; which can be difficult to achieve under sanctions. For example, the foreign suppliers and contractors of Prirazlomnoye project, especially of its drilling phase, include Baker Hughes, Halliburton and Schlumberger. The US company Indrill International made and installed the drilling rig for the Prirazlomnaya platform. Overall, half of the total workload of drilling and service of operating systems stages were performed by the foreign contractors.

Now most of the shelf projects, Arctic in particular, got suspended because of the sanctions imposed and lack of Russian equipment and technologies. Many of these projects were expected to launch after 2020; therefore, the suspension of these projects did not affect the current production volumes.

Project	Participants	Description	Current status
Universitetskaya-1 well (the Kara Sea) and the Tuapse deposit in the Black Sea	Joint venture PJSC Rosneft 51% и Exxon 49%	In 2011 Exxon and PJSC Rosneft formed an alliance to develop potentially vast but largely untapped resources on the Russian Arctic shelf and in the Black Sea. In September 2014, ExxonMobil and Rosneft made a major discovery of vast oil and natural gas reserves after the completion of drilling at the Kara Sea well. However, following the second round of sanctions imposed a few days before the opening, ExxonMobil suspended the project and withdrew from Russian joint ventures under the sanctions, writing off 1 billion US Dollars.	On hold
Projects: East Prinovozemelsky-1, 2, 3; North-Kara, Ust-Olenek, Ust-Lensk, Anisinsky-Novosibirsk, Severo-Wrangel-1, 2, 3; South Chukchi, Tuapsinsky Deflection	The joint venture between PJSC Rosneft" 67% and Exxon 33%	Exxon, in accordance with the sanction regulations, withdraws from the described projects	PJSC Rosneft said it will continue to develop projects independently
Two blocks in the Barents sea and in the Val Shatsky oil deposit in the Black Sea	Joint venture PJSC Rosneft 67% and ENI 33%	In 2012 Rosneft and ENI signed an agreement on the joint development of offshore fields in the Barents and the Black Seas	On hold

Figure 17 Impact of sanctions on Russian offshore projects

Source: Skolkovo Energy Center

The project of Rosneft and Exxon in Kara Sea, Universitetskaya-1, had already received its first investment and exploratory well was drilled. Nevertheless, because of the sanctions Exxon could not any longer have 49% of the ownership and withdrew from the project with 1 billion dollars write-off. Furthermore, Norwegian North Atlantic Drilling Ltd. that entered an agreement with Rosneft until 2022 and was expected to drill six offshore drilling rigs as well as provide long-term lease of the West Alpha platform also deferred its participation (Skolkovo 2018). Another joint project Rosneft and ExxonMobil fell under the sanctions as a deep-water one and the development of the Tuapse Trough in the Black Sea was suspended.

1.3.6 Hypotheses statement

Overall, the research is aimed to determine what factors influence production efficiency of Russian petroleum companies and find out is share of government ownership negatively relates to efficiency.

It is argued that oil and gas reserves are highly significant in explaining variations in production (Eller et al. 2007; Basil and Lee 2014): the higher the amount of reserves in place the higher is firm's production. While Victor (2007) claims that companies that account for largest amount of reserves use them inefficiently and may account for slower rate of reserves development.

H1: The physical volume of oil and gas reserves is positively related to the production of oil and gas companies

All previous studies found that the state ownership variable has significant influence on the firm's technical efficiency and claim this impact to be negative (Al-Obaidan and Scully 1991; Wolf 2009; Eller et al. 2007; Hartley and Eller 2013). The study of Kapustina and Krylov (2008) goes in line with the studies of foreign colleagues and argues that higher government ownership results in lower technical efficiency. However, Afanasiev (2017) in his case study of Gazprom describes the company to be fully efficient in ability to generate physical output, which is oil and gas production.

Though all the previous studies found that share of state ownership negatively relates to the company's efficiency, some significant disparities arise when it comes to the Russian market. For illustration, state-owned company Rosneft turned out to be less efficient than Lukoil in the study of Kapustina and Krylov (2008) and less efficient than both Lukoil and Surgutneftegas in the study of Hartley and Medlock (2013). However, the results of the DEA model of Hartley and Medlock (2013) show that state-owned company Gazprom is about 20% more efficient than private company Surgutneftegas and from 80% to 20% as much efficient as private firm Lukoil, depending on the year studied. Similarly, Kapustina and Krylov (2008) found that Gazprom Neft, which is a state-owned company is about 5% more efficient than Lukoil.

H2: The number of employees is positively related to the production of oil and gas companies

The impact of labor on production was found insignificant in some studies (Wolf 2009; Basil and Lee 2014) in contrast to the results obtained by Eller et al., 2013. It must be stated, that the relationship of labor and oil and gas reserves was studied only on the sample of international companies; therefore, how these factors relate to production of Russian oil and gas companies needs to be clarified further.

H3: The share of state ownership is negatively related to the technical efficiency of oil and gas companies

This hypothesis was not tested by previous studies before, those the majority of researchers emphasize the importance of the company's depletion policy on the entire oil and gas value chain (Tordo 2015). Furthermore, Victor (2008) states that since national companies have higher reserves to production ratio, they develop their reserves too slowly which may negatively impact their efficiency. Similarly, Eller et al. (2007) regards the lower production rate of national companies as a demonstration of low efficiency. In contrast, Wolf (2009) argues that private petroleum companies typically have shorter production horizons and higher production rate, since the length of their licenses is generally lower. Finally, Wolf (2009) states that depletion policy may negatively relate to technical efficiency of oil and gas companies; however, does not test this assumption. Therefore, this study aims to test whether the relation of depletion policy with the firm's efficiency is significant and negative.

H4: Reserves to production ratio is negatively related to the technical efficiency of Russian oil and gas companies

Chapter 2. Empirical study

2.1 Research design and methodology

The research is based on data of Russian oil and gas companies and seeks to obtain information what factors significant in determining production efficiency of Russian petroleum companies, both national and private and whether there is a link between efficiency and share of state ownership and depletion policy.

The first method of analysis is econometric modelling, precisely, stochastic frontier analysis. The models were estimated using STATA software. The secondary data was collected from the annual reports and presentations of the companies as well as from the Energy Intelligence database, precisely Energy Intelligence Top 100: Global NOC & IOC Rankings, which was used to provide the missing data. Panel data was chosen to account for variations of efficiency over time. It should be noted that out of 8 major studies of efficiency of national and private companies of oil and gas sector, 6 authors used panel SFA models, one group of authors of the earliest study (Al-Obaidan & Scully 1991) used cross-section model since SFA panel models were not introduced in that times and one author used simple non-linear regression model (Victor 2008). After the estimation of all models, the results will be compared and discussed.

As it was mentioned in literature review, nowadays there are a lot of different specifications of SFA models and there is no evidence provided in literature that one or another model is superior over others, the choice depends on the assumptions of a researcher. The first criterion of model selection for our analysis was that model must allow technical inefficiency to vary over time, which leads us to a group of panel-data time-varying inefficiency models (Kumbhakar 1991).

The final criterion for our choice was an ability to include other factors, such as percentage of government share and reserves to production ratio to determine whether they can explain a deviation of a firm from the efficiency frontier. One possible way to include such factors is to produce an estimate for inefficiency component in the first step and then regress this inefficiency variable on some possible factors which can have significant impact on this component. However, Schmidt and Wang (2002) proved that this two-step method can produce biased results: first step is biased if inputs and other explanatory variables are correlated, which is also admitted in Kumbhakar and Lovell, (2000). Secondly, the estimates in the final step are argued to be biased downward or towards zero (Schmidt and Wang, 2002). Therefore, one-step SFA models are preferred. Given into account all the criteria above, the model of true fixed effects by Green (2004) was chosen.

Firstly, we ran the model in accordance to the common specification used by other researchers in order to figure out whether reserves and employment is significant to explain the variation of production in Russian oil and gas market. We also added in the model 1 year time lag of output to account for serial correlation of production with its result in the previous year.

$$logOut_{it} = \beta_1 logOutPrevYear_{it} + \beta_2 logResvs_{it} + \beta_3 logEmp_{it} + v_{it} - u_{it}$$

In this model $logOut_{it}$ represents logarithm of production for a i^{th}firm in period t, $logOutPrevYear_{it}$represents logarithm of production at period t-1 for a i^{th}firm, $logResvs_{it}$ is logarithm of reserves for a i^{th}firm in period t, and $logEmp_{it}$ is number of employees for a i^{th}firm in period t, u_{it} is a technical inefficiency component; v_{it} is a stochastic shock, β_1 and β_2 are model coefficients to be estimated.

The second model specification aimed to control for the state ownership and for depletion policy of oil and gas companies. Unfortunately, it is impossible to control for vertical integration of the companies, since most companies do not report the data necessary to calculate vertical integration ratio. Binary variable for vertical integration, included in other model specifications was proven to be insignificant, that is why it is omitted here. The following model specification allows two equations to be estimated at the same time: first equation is related to the specification of production function with inefficiency term. Second equation allows to estimate the direct impact of the share of government ownership and depletion policy, expressed as reserves to production ratio, on the inefficiency term. Reserves to production ratio measures how many years the company will be able to produce if its production rate stays the same as current.

$$logOut_{it} = \beta_1 logOutPrevYear_{it} + \beta_2 logResvs_{it} + \beta_3 logEmp_{it} + v_{it} - u_{it}$$

$$u_i = \gamma_0 + \gamma_1 govShare_i + \gamma_2 RatioResProd_i + \varepsilon_i$$

In this model $logOut_{it}$ represents logarithm of production for a i^{th}firm in period t, $logOutPrevYear_{it}$ represents logarithm of production at period t-1 for a i^{th}firm, $logResvs_{it}$ is logarithm of reserves for a i^{th}firm in period t, and $logEmp_{it}$ is number of employees for a i^{th}firm in period t, u_{it} is a technical inefficiency component for a i^{th}firm in period t; v_{it} is a stochastic shock for a i^{th}firm in period t, β_1 and β_2 are model coefficients to be estimated. The second equation, though estimated simultaneously with the first one, represents ordinary linear regression model, where $govShare_i$ stands for share of government ownership for a i^{th}firm, $RatioResProd_i$ accounts for reserves to production ratio for a i^{th}firm and ε_i is a random error component.

Since both parametric and non-parametric methods have both advantages and disadvantages, the second commonly used method of Data Envelopment Analysis (DEA), based on linear programming will be also applied to produce more unbiased results. Fist the DEA CRS and VRS classic input-oriented models will be estimated, using the *deafrontier* package (Zhu, 2020). The reason to estimate two models is that CRS DEA model assumes that all the firms operate with constant returns to scale. If this assumption will be not true, the technical efficiency score obtained by CRS model will be biased by scale effects. Therefore, firstly CRS model is estimated for each year and the returns to scale are calculated for each company using *deafrontier* package (Zhu 2020) to see whether CRS specification more appropriate and if no, then the VRS model is also calculated. It must be stated that all previous researches assumed constant returns to scale and estimated CRS model only, while in case of oil and gas industry this assumption may be not accurate (Eller et al. 2013; Kapustina and Krylov 2008; Tordo et al. 2015).

The classic input-oriented CRS envelopment form is:

$$min\theta_k$$

Subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_k x_{ik} \quad i = 1, 2, \dots, m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rk} \quad r = 1, 2, \dots, s;$$

$$\lambda_j \geq 0 \quad j = 1, 2, \dots, n.$$

Where

θ_k represents technical efficiency of the firm k;

λ_j represents the attributable weights of inputs and outputs of the firm k

After CRS model is estimated, the following VRS model will be estimated as well. The model specification remains the same, only the following restriction is added to account for scale differences.

$$\sum_{j=1}^{n} \lambda_j = 1$$

To be able to compare the results of DEA models and models done under SFA, company's production was chosen as output and labor and reserves were taken as model inputs. The models were calculated for the same time period 2013-2018, one CRS and one VRS model for each year or 12 models in total.

Overall, the following variables were used in the research:

Table 1. Description of variables

	Variable	Description
Independent variables	logOutPrevYear	Stands for production at period t-1.
	logResvs	Represent total reserves of the company, calculated a sum of oil and gas reserves measured in tons of oil equivalent.
	logEmp	Represents total number of employees in the company
	govShare	Represents the portion of company's ownership that belongs to the government
	RatioResProd	Stands for reserves to production ratio, calculated as total reserves divided by total production. The ratio shows how long the company will have reserves if it continues to produce at current production rate.
Dependent variables	outProd	Represents total annual production of the company, calculated as sum of oil and gas production measured in tons of oil equivalent
	U	Stands for inefficiency component, estimated by the econometric model

In this research the SFA and DEA methods were complemented by financial analysis of the sample companies. The method of in-depth semi-structured interview was also employed in order to provide the perspective of industry experts' answers on research question of the study. The major benefit of this method is that the respondent can express his or her thoughts freely in the scope of initial question and the method is focused on generating new insights regarding the topic rather than finding out frequencies of particular answers as in the case of structured interview (Fisher 2007). Under semi-structured in-depth interview, the list of main issues to be discussed with respondents was made and respondents had flexibility in terms of depth and length of their answer.

All interviews were conducted via direct calls with respondents and lasted about 40 minutes. During the interview the notes of expert answers were made. During the interviews the following topics were covered

- Definition of efficiency in oil and gas industry
- How efficiency is measured, regarding industry peculiarities
- Advantages of state or private ownership type in oil and gas industry

- Ways to increase efficiency

After the interview the thematic analysis was used in order to analyze the experts' answers. According to Braun and Clarke (2006), thematic analysis is a method of data analysis focused on identification, analysis, and reporting common patterns or themes within data. The main themes covered by industry experts were identified and based on them the conclusions were made.

2.2 Data description

2.2.1 Sample description: SFA and DEA methods

This study is focused on technical efficiency of largest Russian oil and gas companies, in terms of generation output and revenue from oil reserves, gas reserves, and employees. Our analysis covers the period of 2012-2018, to capture the results before after a sharp fall of the oil price in 2014, when companies had to adjust and change their business processes in order to be able to operate in a new environment.

Several selection criteria were applied to the sample:

- Industry classification is oil and gas, Upstream and Vertically Integrated companies
- Type: state-owned and privately-owned
- Availability of the operational and financial data reported

Based on the mentioned criteria the final sample consists of 11 companies, from which 8 companies are state-owned, and 3 companies are privately-owned.

Table 2. Overview of the sample companies

№	Company	Main activities	Ownership type	Ownership breakdown
1	Gazprom	– geological exploration – production – transportation – storage – processing and sales of gas, gas condensate and oil – sales of gas as a vehicle fuel	state-owned	Russian Federation – 50,23 % ADR holders – 24,13 Other entities and individuals – 25,64%
2	Rosneft	– exploration and appraisal of hydrocarbon fields – production of oil, gas and gas condensate – offshore field development projects – sales of oil, gas and refined products	state-owned	ROSNEFTEGAZ JSC – 50% BP – 19,75% QH Oil Investments LLC – 18,93% Free float – 11,32% one share is owned by the Russian Federation – Federal Agency for State Property Management

3	Gazprom Neft	– exploration and development of oil and gas fields – oil refining – manufacture and sale of petroleum products	state-owned	Gazprom – 95,68% Free float – 4,32%
4	Bashneft	– oil and gas production – oil refining – oil and petroleum products sales	state-owned	Rosneft – 69,28% Republic of Bashkortostan – 25,79% Free float – 2,61% Bashneft – 2,32% Government Pension Fund – 0,73%
5	Slavneft	– exploration and development of oil and gas fields – oil refining – sales of oil, gas and refined products	state-owned	Rosneft – 49,85% Gazprom neft – 49,85% Free float – 0,3%
6	Lukoil	– exploration and development of oil and gas fields – oil refining and gas processing – sales of oil, gas and refined products	privately-owned	Legal entities – 94,72% Individuals – 5,28%
7	NOVATEK	– exploration and production of natural gas – gas processing – marketing of natural gas and liquid hydrocarbons	privately-owned	Volga group – 23,5% TOTAL E&P Arctic Russia – 16,3% SWGI Growth Fund (Cyprus) Limited – 14,4% Levit LLC – 7,3% Other – 38,5%
8	Surgutneftegas	– exploration and production – gas processing and use – oil refining – marketing	privately-owned	Not available
9	Tatneft	– crude oil and gas production – petroleum refining – petrochemicals production	state-owned	Republic of Tatarstan –34% ADR program – 23% Treasury groups – 3% The Bank of New York Mellon – 22,85%
10	RussNeft	– oil and gas exploration and production – sales of oil and gas	privately-owned	OAO IK “Nadezhnost” –4,95% ZAO “Mlada” – 7,70% RAMBERO HOLDING AG – 23,46% BRADINAR HOLDINGS LIMITED – 12,05% "Trust" Bank (PAO) – 19,23% Bank VTB (PAO) – 8,48% Other shareholders – 24,13%
11	Zarubezhneft	– exploration, development and operation of	state-owned	Russian Federation – 100%

		onshore and offshore oil and gas fields ‾ design, construction and operation of refining facilities, tank farms and pipeline systems		

The final sample consists of 11 companies that represent around 90 % of total oil and gas production in Russia. NOVATEK, RussNeft, Surgutneftegas and Lukoil represent private companies while other companies have significant share of state ownership.

2.2.2 Descriptive statistics

The descriptive statistics of variables is presented below.

Table 3. Descriptive statistics of variables

Variable	Mean	Median	St. Deviation	Min	Max
outPrevYear	95,094	53,6	128,708	0,438	462,425
Resvs	2809,051	686,14	4904,031	24,2	17273,88
Emp	99034,97	34907,50	138274,8	289	469600
govShare	34,77%	50%	30,91%	0%	100%
RatioResProd	24,029	22,91	12,485	8,903	84,074
outProd	96,334	55,37	130,675	0,4381	477,145

As it can be seen from the table, the values of many variables are significantly dispersed. This is primarily below the amount of reserves that belongs to each oil and gas companies. Such companies as Gazprom and Rosneft, the largest producers of gas and oil in Russia, respectively have a resource base of about 17274B tons of oil equivalent. Given the current production rate, these companies will be able to continue their production for 84 years. Due to the vast resource base, their production is much higher than the one of oil and gas company with 24,2B reserves in place and these companies employ much more labor to support their production processes – about 469600 thousand people.

Given the large difference of results, median statistics will be more precise than the mean one if talking about the average oil and gas company in Russia. In general, the company produces 130,675M tons of oil equivalent per year, employs 34908 thousand people and have a resource base of about 686,14B tons of oil equivalent which will last for about 23 years if this company continues to produce at the same pace.

2.2.3 Sample description: In-depth interview

Companies' representatives who were asked to take part in in-depth interview were carefully chosen according to the following criteria:

- Department connected either to Strategy, Business development or Efficiency measurement
- Work experience of at least 5 years
- Agreement of participant to have an interview in a call format

The respondents asked to keep their names and names of the companies confidential in order not to disobey the ethics code implemented in their companies. It can be stated that the study covers the best practices regarding efficiency from the largest players in the Russian oil and gas industry, as well as insights about efficiency in oil and gas industry from Big 3 consulting company.

Table 4. Statistics of in-depth interview participants

Respondent number	Company	Respondent position
Respondent 1	Company A	Business Development Manager, work experience of 6 years
Respondent 2	Company B	The head of Strategy department
Respondent 3	Company C	Business Development Manager in Downstream, work experience of 5 years
Respondent 4	Company D	Business Development Manager, work experience of 7 years
Respondent 5	Company E	Manager in the Efficiency department, work experience of 5 years
Respondent 6	Company F	Consultant, work experience of 6 years in Oil and Gas projects in Big 3 consulting company

Therefore, the interview sample contains 6 respondents: 5 managers from oil and gas industry and 1 consultant from Big3 company. All respondents have 5 years or higher work experience in their field.

2.3 Empirical Results

2.3.1 SFA method

All variables proved to be highly significant in explaining physical output in the first specification of the model. However, different specification should be also run, since some authors found employment factor insignificant in explaining production (Wolf 2009).

Furthermore, this base model should be also controlled for state-ownership, since other studies found its impact on efficiency to be significant (Victor 2008).

Table 5. Model results, specification 1

Variable	Coefficient	p value
outPrevYear	-0,002	0.000
logResvs	1,02	0.000
logEmp	0,08	0.000

The second model specification accounted for the state ownership and for depletion policy of oil and gas companies. The model consisted of two equations that were estimated simultaneously. Second equation allowed to estimate the relation of the share of government ownership and depletion policy, expressed as reserves to production ratio with the inefficiency term.

Table 6. Model results, specification 2

Variable	Coefficient	p value
outPrevYear	0,000	0.851
logResvs	0,897	0.000
logEmp	-0,027	0.780
govShare	0,496	0.647
ratioResProd	0,024	0.000

Both models estimated have a high overall quality (Appendix 1, 2). In the second model specification both production of previous year and employment turned out to be insignificant, which support the conclusion of some recent studies in this field (Wolf 2009). In order to examine further the significance of the labor factor, total annual production was regressed against the total annual number of employees and it proved the significance of labor factor, which speaks in favor of result obtained in first specification.

A model shows that the reserves to production ratio has a positive relation on the inefficiency term or, in other words, a negative impact on the firm’s efficiency. This means that higher reserves to production ration implies lower efficiency, which has the grounds to be true. Generally, in the beginning of production on a new field, with a lot of reserves in place and high reserves to production, the firm uses its reserves less efficiently. While when the field is already depleted to some extent, higher efficiency is demonstrated, which is vital, since carrying out production of the field with significant depletion is harder than of a new one. The results may also illustrate that companies who have the largest number of reserves may use them less efficiently.

Another interesting finding is that the impact of government share is insignificant, which means that on the Russian market there is no advantage of national or private companies when it comes to efficient generation of physical output.

The second step was to predict technical efficiency, using estimator of Battese and Coelli (1988). On the graph below presented the estimates of technical efficiency for 2013-2018.

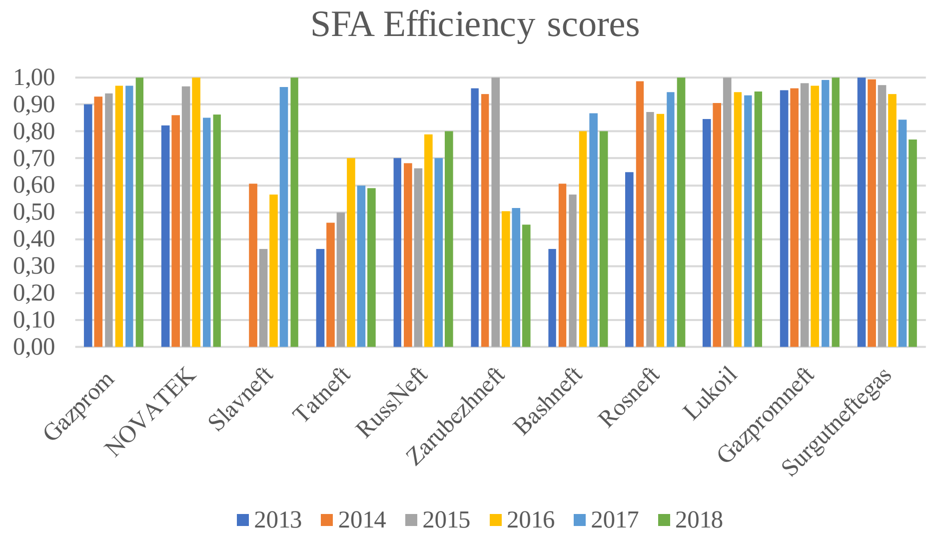


Figure 15 Efficiency scores obtained by SFA method

Source: authors calculations

The only company that demonstrated stable results over the period is Gazprom Neft, with an average efficiency score of 0,98. Increasing trend of production efficiency can be observed looking at Gazprom results with a score of 1 in 2018, Rosneft and Slavneft also considerably increased their efficiency over the studied period, both companies also demonstrated fully efficient production in 2018. Whereas, the decreasing trend is a case of Zarubezhneft and Surgutneftegas, with moving from frontier to the scores of 0,42 and 0,76 in 2018, respectively.

Companies that demonstrated the highest average efficiency during the period include both national – Gazprom, Gazprom Neft and private companies – Surgutneftegas, Lukoil and NOVATEK.

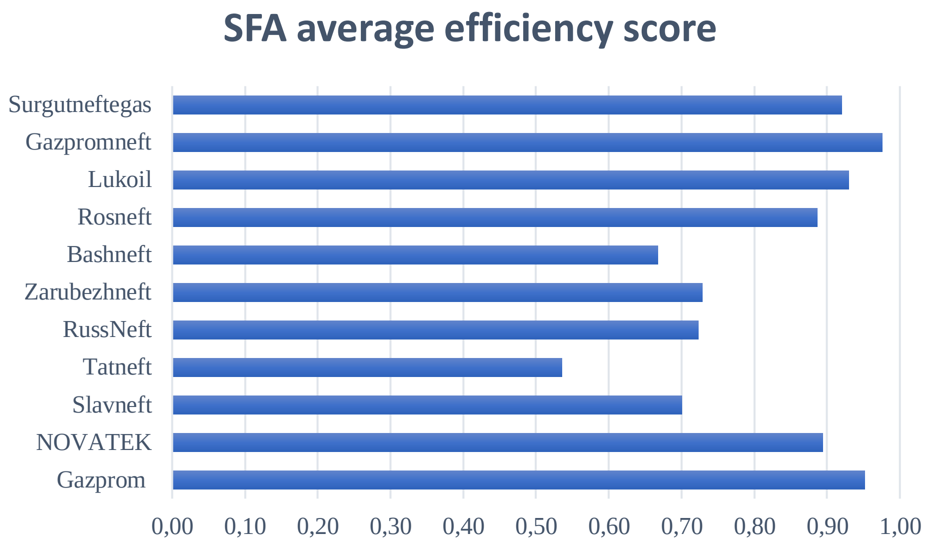


Figure 16 Average efficiency of companies over the period

Source: authors calculations

The average efficiency score for the group of national companies was lower compared to the score of private ones: 0,78 versus 0,87, respectively, which is consistent to other studies (Eller et al. 2007; Wolf 2009; Eller et al. 2013), this finding is also disputable. The average efficiency results of national companies start with 0,59 the lowest and 0,98 the highest; while the results of private companies are less dispersed, generating the higher efficiency score.

2.3.2 DEA method

According to the model results, currently 5 out of 11 Russian oil and gas companies are considered to be fully efficient in generating their production using their reserves and labor: Gazprom, Slavneft, Rosneft, Gazprom Neft and Lukoil.

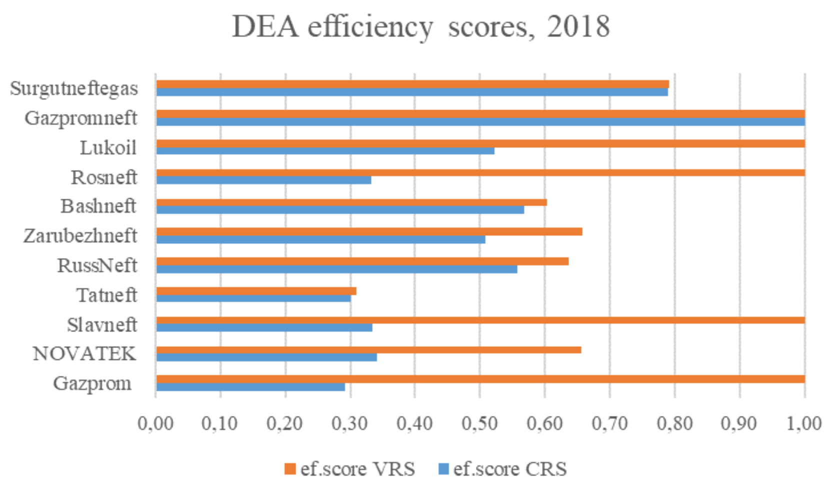


Figure 17 Efficiency scores of the companies under CRS and VRS specifications

Source: author's calculations

It can be seen from the graph that if the constant returns to scale (CRS) DEA model was estimated only, only Gazprom Neft would be considered as best-practice firm. This estimation bias would happen since under CRS DEA model assumption all companies estimated should have constant returns to scale. After calculations of returns to scale made in the deafrontier package, it was found out that constant returns to scale assumption is true only for Gazprom Neft (Table #). Decreasing returns to scale here mean that the increase of reserves and labour (inputs) leads to the proportionally less increase in production. In case of increasing returns the increase in the quantities of inputs involved generates higher proportional increase of production, while in the case of constant returns the increase will be proportionally the same.

Table 7. Returns to scale of Russian oil and gas companies. Output-production

Company	Returns to scale
Gazprom	Decreasing
NOVATEK	Decreasing
Slavneft	Increasing
Tatneft	Increasing
RussNeft	Increasing
Zarubezhneft	Increasing
Bashneft	Increasing
Rosneft	Decreasing
Lukoil	Decreasing
Gazprom Neft	Constant
Surgutneftegas	Increasing

Source: author's calculations

Therefore, after the calculation of returns to scale for each company and comparison of results of both models over the whole research period, variable returns to scale (VRS) model was chosen as a superior model for further analysis in order to account for returns to scale differences of the companies. The comparison of efficiency changes in 2013-2018 generated several new insights.

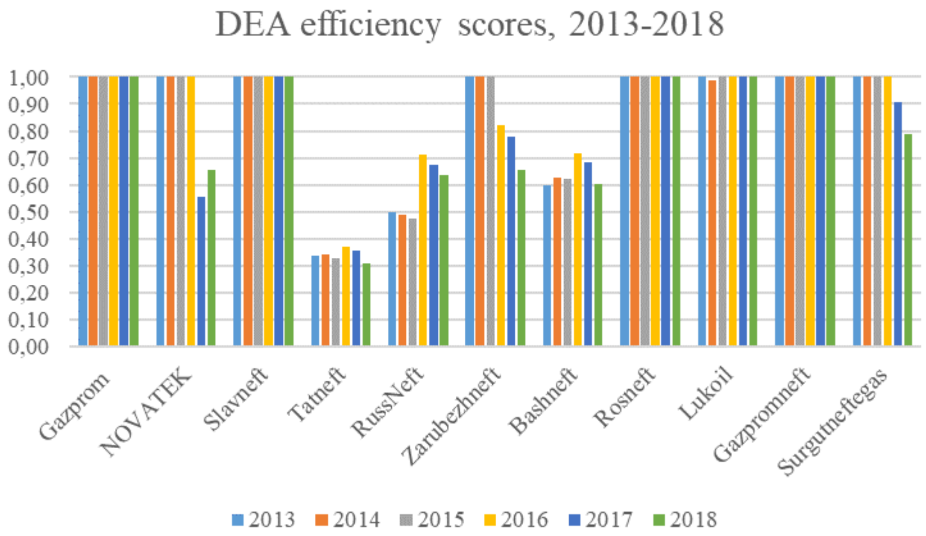
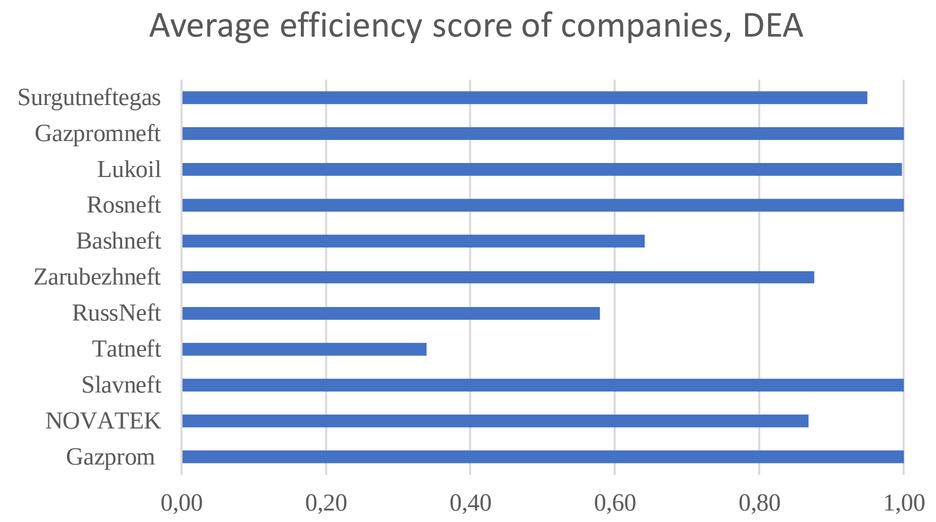


Figure 18 Efficiency scores of the companies in 2013-2018, DEA

Source: author's calculations

First of all, the companies that were able to maintain the efficiency score of 1 over the period were Gazprom, Slavneft, Rosneft and Gazprom Neft. These companies demonstrated the most efficient production generation by using optimal quantity of their reserves and number of employees to achieve the result. Lukoil can be also considered as a best practice firm, though its efficiency score was a bit lower than 1 in 2014. Considerable falls of efficiency compared to the results of 2013-2016 demonstrated NOVATEK and Surgutneftegas in 2017-2018, when the efficiency of NOVATEK decreased to around 0,65 and the efficiency of Surgutneftegas fell to 0,8. After being on the frontier of best practice for 3 years, Zarubezhneft also decreased significantly its results in 2016-2018. Finally, the last efficient firm in terms of production turned out to be Tatneft, with average efficiency score of 0,3 only over the studied period. The results lower than 1 demonstrate that all these companies may achieve the same amount of production by using less reserves and labor involved which consequently leads to less costs they may have experienced by using resources more efficiently.

In terms of average efficiency score for the period, frontier of best practice firms is dominated by national companies: Gazprom, Gazprom Neft, Rosneft and Slavneft, while only one private company Lukoil achieved an average score of 1 for the period.



The average efficiency score for the group of national companies was 0,84, while group of private companies achieved average efficiency score of 0,85.

2.3.3 Results of in-depth interviews

In this section the summary of all insights obtained from respondents is presented in order to conduct the thematic analysis that will allow to generate new perspectives on the efficiency topic and to compare them with main hypotheses from the literature review in order to assess similarities and differences. The key question all the participants were asked was how they define efficiency in oil and gas company and what are the crucial factors that may impact it.

"Efficiency is a various set of factors, including cost optimization, sustainable production, intellectual capital, corporate governance, relations with your shareholders and stakeholders, such as project partners, suppliers and obeying safety standards in every step of production process".

Respondent 1 believes that efficiency is a very comprehensive notion and in order to be fully efficient, a company should look on various parts of its value chain and also manage relations both with internal and external parties involved. Other respondents addressed parts, described in this quote in more detail.

Cost optimization and other financial indicators turned out to be an important factor for Respondent 3 and 5 that both represent the Company C. Respondent 5 mentioned such factors as "*return on invested capital not lower than benchmark X*" and *"targeted ratio of total production/capital expenditures*".

Meanwhile, Respondent 3 emphasized digital solutions that Company C actively incorporates in its business processes, both in upstream and downstream sectors and described it as not only the "*focus on digitalization*" but also the "*focus on customization*". Digital solutions significantly improved the customer experience in downstream sector, as well as increased the efficiency of employees, performing such complicated tasks as drilling in upstream sector. To elaborate on that, Respondent 6 gave a case with offshore production when "*the quantity of hydrocarbons extracted depends to certain extent on what decisions and commands were made by the employee who operates the platform*".

In general, the more experienced employees tended to make less mistakes, while newcomers who firstly came across some difficult cases sometimes took not an optimal decision, which impacted the production process. Company F consulted Company C how these processes can be improved via digitalization and they made a platform that *"saves the decisions of each platform operator in particular cases, analyzes the decision impact on production so that when another employee faces the case that was already solved efficiently before, the platform recommends what actions would be the most optimal to take in this case*".

Speed of decision-making and greater autonomy of subsidiaries and individual departments was mentioned to have a great impact on efficiency by Respondents 2 and 4.

"Very low speed of decision-taking because of a lot of approvals that must be received often only by paper documents, not emails. Not enough delegation of responsibilities, high hierarchy are also the major pains".

Respondent 2 also stated that since Company B is the largest in its sector, the speed of decisions is not as high as in the companies of smaller size. This also hinders innovation and emergence of new ideas, which subsidiaries may introduce, given their experience in particular segments and geographical markets but usually the bureaucracy and not enough autonomy discourage them from submitting such initiatives.

On the contrary, Respondent 4 who comes from the foreign division of Company D states that "*due to geographical distance and constantly changing external environment the division is very agile and has significant autonomy of decision making, which positively impacts its business operations*".

All respondents emphasized the importance of sustainable production as one of the efficiency dimensions. Respondent 5 implied that *"steady compound annual growth rate (CAGR) in the main segments of company's operations. In order to achieve this steady growth, he emphasized the need to enlarge the overall resource base not less than by 100% annually and control the quality of existing fields".* Meanwhile, Respondent 6 disclosed that a "*large part of consulting projects in oil and gas sector focus on increasing production efficiency of existing fields and this dimension is highly perspective, especially given new technological advances*". Furthermore, apart from main sectors of operation it is important to minimize waste and discover ways how not key resources, like associated gas; can be used. For illustration, the target utilization of associated gas in company C is 95%.

Another important dimension in production efficiency is hard to recover reserves which can reach around 70% from the total resource base for some largest oil and gas companies in Russia. Though these reserves are more difficult and costly to extract, the advantage of their development is getting zero mineral extraction tax rate. Furthermore, development of hard to recover reserves, as well as offshore fields produced a lot of technological innovations. For example, "*before sanctions company B relied on technological expertise of its foreign partners and after they left the project, company B developed its own system of computer modelling simulations of extraction hard to recover reserves , which was also sold to some other players in the market"*. Respondent 1 gives another example of "*the innovative fourth train of NOVATEK, based on "Arctic Cascade" liquefaction technology created by NOVATEK".*

Meanwhile, the respondents were also asked to compare the advantages and disadvantages of national and private oil and gas companies. All respondents believe that being a state-owned company in Russia is more beneficial for several reasons. First of all, respondents mention "*the ability to get tax discount*s *and other benefits*" as one of the main reasons and "*more competitive positions to get new fields to develop*". Respondent 1 illustrated this comment by the example of the Arctic Russian shelf, where now "*all the licenses, except a few, belong to either Gazprom or Rosneft. Furthermore, due to the climatic peculiarities of these fields, the mineral extraction tax on them is zero"*.

Interestingly, all the respondents mentioned Gazprom Neft as a best-practice Russian petroleum company. The reasons were different, from the "*market orientation of CEO*", stated by Respondents 2 and 3 to "*sustainable production*", stated by Respondents 1 and 5, as well as "*diversification and digital solutions*" admitted by Respondents 3, 4 and 6.

Respondent 2 and Respondent 5 mentioned "*state funding*" as another important benefit of national companies, meaning that national companies have way more financial resources than the private ones. Respondent 5 also emphasized that "*financial resources allow national companies to make acquisitions of private companies, while the contrary is not the case. Therefore, there is always a threat for private company to be bought by the state one*". Meanwhile, Respondent 2 emphasized having state finding as an ability to spend more on research and development in comparison to private companies. Respondent 2 also highlighted "*strong collaboration with leading research universities, where not only innovative projects are made as a result, but also the employees of national companies get free additional qualifications in research and development and related topics*".

Nevertheless, the majority of respondents mentioned that "*national petroleum companies are significantly affected by sanctions*". In this light, being more closer links with local content policies gave national companies some advantages in terms of reduced dependency on foreign contractors. Respondent 4 stated that "*according to legal frameworks, oil and gas companies aim to increase the participation of local suppliers and other contractors rather than inviting the foreign ones. Even if a Russian contractor lacks some expertise, it can be a case when company helps this contractor financially to acquire the resources needed and contractor, in its turn provides company with discounts*". To illustrate, in the example of NOVATEK, the company claims that "*the fourth train of Yamal LNG will utilize Russian-manufactured equipment*". However, Respondent 4 notes that "*Russian companies still lack some technologies needed for deep water production and are highly dependent on foreign partners"*, while Respondent 5 also highlights *"the lower quality of geophysical studies made by Russian petroleum companies versus the foreign ones"*.

As for a popular hypothesis in academic studies of negative impact of subsidies made by national companies to the local market, respondents do not agree that this necessarily damages their efficiency. Firstly, Respondent 1 argues that "*there is an opportunity for the company to pay a portion of its taxes by physical production rather than cash which strengthens its liquidity position*". Moreover, Respondent 3 states that "*from the own experience even if the company provides, for example, the discounts on petrol for public transport, its revenue is still increased because of the high volumes of purchases*".

Finally, the study also aimed to get the perspectives of respondents of what should be done by Russian oil and gas companies to increase their efficiency. Most respondents emphasized the importance of diversification. For illustration, Respondent 5 shared that one of the efficiency key performance indicators Company C has is "*X% EBITDA from businesses not connected with upstream or downstream activities*". Respondent 4 also recommended to "*analyze the possible diversification in industries not related to oil and gas, for example, renewable energy*". Secondly, "*digitalization and other technical advancements remains the important factors*", as mentioned by Respondent 3 and Respondent 6. Thirdly, Respondent 2 advised to "*increase the market orientation of national oil companies by hiring more market-oriented employees with versatile experience to management and top management positions*".

To sum up, the interviews provided some new important insights that can be tested by researchers in their empirical studies. Furthermore, some of the hypothesis stated in the previous studies on this topic may be strengthened or revisited as well. For example, the highlighted importance of sustainable production strengthens the relevance of studying production efficiency, since its practical implications are in demand, especially given the sanctions and current economic situation. Interestingly, all the respondents disprove the major hypothesis of all previous studies about the lower efficiency of national oil and gas companies, considering the Russian market. Thirdly, another popular assumption of decreased revenue efficiency of state-owned companies because of the subsidies provide is also not supported, since given the higher sales of Russian national companies all the discounts provided are compensated either by volume sold or by other benefits obtained, as a result.

2.3.4 Financial performance and financial efficiency of the sample companies

Apart from conducting the analysis of efficiency using new methods, suggested in this study, the companies were examined using traditional financial indicators that demonstrate profitability, liquidity and solvency trends of the selected companies. In the most recent study regarding efficiency of oil and gas companies of Al-Mana et al. (2020), the SFA and DEA methods were complemented by the following financial indicators: return on equity, return on assets and return on capital employed. According to Brealey and Myers (2000), in order to identify potential problem areas in company's performance, key financial ratios must be calculated. Van Horne and Wachowicz (2008) defined profitability, liquidity and solvency ratios as key indicators to measure the company's financial condition over a certain period. Therefore, this study employs a broader set of financial ratios than the one of Al-Mana et al. (2020) to get a more detailed overview of the sample companies' performance.

To analyze the profitability of Russian oil and gas companies, several indicators were examined: net profit margin, return on assets, asset turnover ratio and return on equity.Net profit margin is calculated as profit divided by sales revenue and represents how much net profit was obtained by the company per dollar of revenue gained (Van Horne, Wachowicz, 2008). Return on assets (ROA) indicates the efficiency of a company to generate its profit from its assets and is expressed as net income divided by average total assets. Asset turnover ratio is expressed as a ratio of revenue to average assets and used to figure out how efficiently the company utilizes its assets for sales generation (Brealey and Myers, 2000). Return on equity (ROE) is equal to the ratio of a company's net income over its total shareholders' equity. It shows what amount of profit was made for each dollar of shareholder's equity and acts as a simple metric of investment return evaluation (Al-Mana et al., 2020). Together these profitability ratios contribute to the topic of efficient revenue generation by oil and gas companies, which was also covered in the previous studies (Eller et al., 2007; Hartley and Eller, 2013).

Liquidity represents the company's ability to meet its short-term liabilities by using its current assets (Brealey and Myers, 2000). Two primary measures of liquidity are current and quick ratios. While current ratio is equal to total current assets divided by total current liabilities, the quick ratio represents the similar proportion but only with most liquid current assets in the numerator. In the quick ratio inventories, prepaid expenses and supplies are excluded from the numerator since they are considered less liquid than other current assets like cash and cash equivalents. These ratios help to examine if a company can use its current assets to satisfy the current debt or it has a liquidity problem.

According to EY's study of efficiency, many oil and gas companies considerably increased the amount of financial leverage in the times of low oil prices (EY: Project efficiency in oil and gas 2016). Hence, solvency of the sample companies was also examined by calculating debt to equity and total debt to total assets ratios. Total debt to total assets ratio helps to identify the amount of assets that was financed by creditors while debt to equity ratio helps to assess whether the company's capital structure is characterized by more debt or equity financing. Debt to equity ratio accounts for the weight of total debt versus total shareholders' equity of the company.

To analyze the profitability of Russian oil and gas companies, several indicators such as net profit margin, return on assets, return on equity and asset turnover ratio were studied. Firsly, it must be said that several companies reported a net loss during the studied period: Slavneft and RussNeft during the first wave of oil crisis while Surgutneftegas and Gazprom Neft experienced the net loss in 2016, when the oil prices fell again. Average net profit margin of Russian oil and gas companies in 2013-2018 was 11,38%. NOVATEK consistently demonstrated high results with average net profit margin of 27,11%. The lowest result is attributable to RussNeft because of its financial difficulties in 2013-2015, though its net profit margin in 2018 was 8,31%. Asset turnover ratio shows how efficiently a company uses its assets in order to generate revenue. The most efficient companies in terms of asset utilization were Tatneft and Lukoil, followed by Gazprom and Gazprom Neft. For each dollar of assets these companies on average generated more than 1 dollar of sales. The industry average was set at 0,67. The lowest asset turnover results were reported by RussNeft and Surgutneftegas: RussNeft got on average 5 cents of revenue per every dollar of assets, while Surgutneftegas generated around 29 cents from every dollar of its assets.

In general, the more capital intensive is the industry the more difficult it is to generate high return on assets. Therefore, the average for Russian oil and gas industry was calculated first: for every dollar of assets Russian oil and gas companies on average generate 10 cents of their net income. NOVATEK, Tatneft, and Bashneft were the only companies that outperformed the industry average and generated 16, 13 and 12 cents of profit, respectively. The return of assets of the rest companies was in the range of 5-8 cents of net income per every dollar invested.

The final profitability indicator – return on equity was chosen to examine the ability of a company to make profit from the shareholders investments. The average return of equity of Russian oil and gas companies turned out to be 13%. Three companies, precisely Bashneft, NOVATEK and Tatneft demonstrated results above the industry average: 24%, 23% and 18%, respectively. While RussNeft and Zarubezhneft reported the lowest average results of 2% and 7%. It means that for every dollar of shareholders investment these two companies managed to generate only 2 and 7 cents in net income, respectively.

Table 8- Profitability indicators.

Company	Indicator	2013	2014	2015	2016	2017	2018
Gazprom	Net profit margin	22,20%	2,81%	13,26%	16,32%	11,71%	18,59%
	ROA	9,18%	1,10%	5,00%	5,87%	4,36%	7,83%
	Asset turnover ratio	0,41	0,74	0,71	0,72	0,72	0,79
	ROE	12%	2%	7%	9%	6%	11%
NOVATEK	Net profit margin	36,87%	10,32%	15,59%	49,32%	28,54%	22,00%
	ROA	20,72%	5,69%	9,39%	28,75%	16,58%	16,19%
	Asset turnover ratio	0,56	0,55	0,60	0,58	0,58	0,74
	ROE	29,47%	9,54%	17,31%	40,30%	21,46%	20,63%
Gazprom Neft	Net profit margin	12,41%	7,49%	2,07%	-1,00%	13,46%	16,11%
	ROA	12,91%	6,92%	1,49%	-0,67%	9,84%	12,43%
	Asset turnover ratio	1,04	0,92	0,72	0,67	0,73	0,77
	ROE	18,71%	11,21%	2,74%	-1,18%	16,25%	20,13%
Tatneft	Net profit margin	17,22%	20,50%	19,14%	18,29%	18,19%	23,23%
	ROA	12,01%	13,88%	13,81%	11,21%	11,25%	18,33%
	Asset turnover ratio	0,70	1,30	1,38	1,06	1,23	1,52
	ROE	15,54%	16,78%	16,08%	14,97%	17,24%	27,23%
Bashneft	Net profit margin	8,24%	6,75%	9,74%	8,85%	21,23%	11,34%
	ROA	10,18%	8,86%	11,41%	9,42%	21,58%	13,10%
	Asset turnover ratio	1,24	1,31	1,17	1,06	1,02	1,15
	ROE	19,63%	21,12%	24,34%	19,67%	37,21%	21,52%
Surgutneftegas	Net profit margin	N/A	N/A	N/A	-6,08%	16,57%	54,65%
	ROA	N/A	N/A	N/A	-1,56%	4,77%	18,14%
	Asset turnover ratio	N/A	N/A	N/A	0,26	0,29	0,33
	ROE	N/A	N/A	N/A	13,82%	17,34%	16,03%
RussNeft	Net profit margin	-6,69%	-55,70%	-24,77%	12,80%	5,65%	8,31%
	ROA	N/A	N/A	6,04%	6,27%	3,32%	6,18%
	Asset turnover ratio	N/A	N/A	0,06	0,06	0,03	0,06
	ROE	N/A	N/A	-42,07%	21,78%	10,93%	18,96%
Lukoil	Net profit margin	4,45%	7,19%	5,06%	3,96%	7,05%	7,71%
	ROA	7,32%	9,62%	5,97%	4,12%	8,18%	11,30%
	Asset turnover ratio	1,65	1,34	1,18	1,04	1,16	1,47

	ROE	9,71%	12,97%	9,01%	6,41%	12,00%	15,20%
Zarubezhneft	Net profit margin	13,00%	17,91%	16,07%	11,42%	15,76%	8,55%
	ROA	6,08%	7,31%	7,13%	5,22%	7,66%	5,41%
	Asset turnover ratio	0,47	0,41	0,44	0,46	0,49	0,63
	ROE	6,12%	7,22%	7,13%	5,35%	7,93%	5,97%
Rosneft	Net profit margin	11,82%	6,36%	6,91%	4,03%	4,94%	7,88%
	ROA	9,75%	4,30%	3,87%	1,94%	2,55%	5,11%
	Asset turnover ratio	0,82	0,68	0,56	0,48	0,52	0,65
	ROE	17,51%	12,15%	12,15%	5,39%	7,10%	13,88%
Slavneft	Net profit margin	4,95%	-5,70%	8,76%	13,57%	8,97%	9,94%
	ROA	3,38%	-3,86%	6,38%	8,93%	5,82%	7,13%
	Asset turnover ratio	0,68	0,68	0,73	0,66	0,65	0,72
	ROE	5,94%	-8,02%	12,28%	15,46%	10,31%	12,95%

To analyze the liquidity of Russian oil and gas companies, current and quick ratios were calculated. The highest results were demonstrated by Zarubezhneft – with average current ratio of 18,33 and quick ratio of 18,24 in 2013-2018. This is explained by a focus of this 100% state-owned company on equity financing with extremely low debt levels. Meanwhile, the private company Surgutneftegas also demonstrates impressing results, in 2016-2018 its average current and quick ratios were 3,8 and 3,5, respectively. Basneft also demonstrates an increasing trend in liquidity: its quick ratio reached 2,25 in 2018.

Companies that reported current and quick ratios less than 1 during the period are RussNeft, Rosneft and Slavneft. However, Slavneft considerably increased its score from 0,35 to more than 1 by 2018 and Rosneft also seems to compensate for its liquidity drop in 2016-2017. One of the possible factors of improved results can be the oil price normalization and decrease of global market oversupply due to the OPEC agreement that came into force in 2017.

Table 9. Liquidity indicators

Company	Indicator	2013	2014	2015	2016	2017	2018
Gazprom	Current ratio	2,06	1,86	1,88	1,68	1,34	1,70
	Quick ratio	1,65	1,50	1,50	1,31	1,04	1,34
NOVATEK	Current ratio	1,38	1,56	0,71	1,22	1,83	2,74
	Quick ratio	1,28	1,47	0,66	1,14	1,70	2,58
Gazprom Neft	Current ratio	2,08	1,88	1,46	1,37	0,88	1,18
	Quick ratio	1,65	1,47	1,17	1,02	0,63	0,91
Tatneft	Current ratio	1,83	2,64	2,60	1,16	0,93	0,90
	Quick ratio	1,47	2,16	2,14	1,05	0,80	0,75
Bashneft	Current ratio	1,19	1,22	1,09	1,14	1,71	2,71
	Quick ratio	0,94	0,98	0,85	0,87	1,49	2,25
Surgutneftegas	Current ratio	N/A	N/A	N/A	3,84	3,92	3,64
	Quick ratio	N/A	N/A	N/A	3,44	3,67	3,39
RussNeft	Current ratio	0,78	0,15	0,31	0,39	0,61	0,46

	Quick ratio	N/A	N/A	0,19	0,26	0,42	0,31
Lukoil	Current ratio	1,79	1,59	1,75	1,51	1,36	1,62
	Quick ratio	1,11	1,15	1,26	1,02	0,95	1,20
Zarubezhneft	Current ratio	13,73	33,65	31,69	13,68	8,23	9,01
	Quick ratio	13,38	33,54	31,63	13,66	8,22	9,00
Rosneft	Current ratio	1,05	1,05	1,32	0,83	0,60	1,05
	Quick ratio	0,90	0,93	1,20	0,73	0,51	0,91
Slavneft	Current ratio	0,73	0,35	0,35	0,37	0,91	1,48
	Quick ratio	0,63	0,28	0,25	0,27	0,79	1,35

In terms of solvency the studied oil and gas companies can be divided in three groups: companies with prevalent investor financing, companies with prevalent creditor financing and companies that use equity and debt more or less equally to finance their operations. Zarubezhneft is the company with almost zero debt proportion, which can be explained by the fact that is fully state-owned company with high level of confidentiality. Gazprom keeps the low debt strategy, there is on average one third as many liabilities than there is equity. On the contrary, companies where credit financing is prevalent are Rosneft and RussNeft with debt to equity ratio around 2: two-thirds of the capital is derived from debt. Nevertheless, both companies now indicate gradual deleveraging trend.

Table 10. Solvency indicators

Company	Indicator	2013	2014	2015	2016	2017	2018
Gazprom	Tot debt/tot assets	0,13	0,18	0,20	0,17	0,18	0,19
	Debt/Equity	0,19	0,27	0,32	0,25	0,27	0,28
NOVATEK	Tot debt/tot assets	0,38	0,45	0,51	0,32	0,26	0,27
	Debt/Equity	0,60	0,81	1,06	0,47	0,35	0,37
Gazprom Neft	Tot debt/tot assets	0,36	0,46	0,50	0,43	0,43	0,43
	Debt/Equity	0,57	0,86	0,99	0,76	0,77	0,77
Tatneft	Tot debt/tot assets	0,25	0,21	0,18	0,35	0,35	0,35
	Debt/Equity	0,34	0,26	0,21	0,54	0,54	0,55
Bashneft	Tot debt/tot assets	0,47	0,61	0,53	0,55	0,48	0,40
	Debt/Equity	0,89	1,57	1,13	1,21	0,92	0,67
Surgutneftegas	Tot debt/tot assets	N/A	N/A	N/A	0,12	0,15	0,14
	Debt/Equity	N/A	N/A	N/A	0,14	0,17	0,16
RussNeft	Tot debt/tot assets	N/A	N/A	0,71	0,71	0,70	0,69
	Debt/Equity	N/A	N/A	2,47	2,48	2,37	2,25
Lukoil	Tot debt/tot assets	0,28	0,36	0,36	0,36	0,33	0,29
	Debt/Equity	0,39	0,55	0,55	0,55	0,50	0,41
Zarubezhneft	Tot debt/tot assets	0,01	0,01	0,03	0,04	0,06	0,16
	Debt/Equity	0,01	0,01	0,03	0,04	0,06	0,19
Rosneft	Tot debt/tot assets	0,58	0,67	0,69	0,66	0,66	0,64
	Debt/Equity	1,37	2,03	2,27	1,96	1,92	1,81
Slavneft	Tot debt/tot assets	0,43	0,53	0,49	0,45	0,48	0,49
	Debt/Equity	0,76	1,14	0,96	0,81	0,92	0,96

Another ratio that was examined is debt to assets ratio. Its results support those of debt to equity ratio. On average, 65% and 70% of assets in Rosneft and RussNeft are financed by creditors versus 58% of industry average. Overall, the highest results of both ratios were attributable to the crisis period of 2014-2015, when most of companies expressed considerable financial difficulties because of low oil prices.

Overall, in terms of profitability, such companies as NOVATEK, Tatneft, Bashneft, Gazprom, Gazprom Neft and Lukoil on average demonstrated better results than the rest of the group. Secondly, Zarubezhneft, Surgutneftegas and Bashneft were proved to have higher average liquidity than the rest of companies. Thirdly, Zarubezhneft and Gazprom were found out to keep the low debt strategy and rely more on equity financing. Finally, RussNeft was proved to be inefficient in terms of asset utilization to generate revenue, to have lower liquidity and to rely heavily on debt financing.

2.3.5 Discussion and Conclusions

The main goal of this research was to identify the factors that have an impact on production efficiency of Russian petroleum companies. Moreover, the relationship between the efficiency of Russian oil and gas companies and the share of state ownership was also studied. Overall, the results of the methods used to achieve the research goal complement each other and give an opportunity to generate some interesting insights. First of all, under the methods of SFA, DEA and in-depth interview Gazprom Neft was found to be the most efficient Russian oil and gas company, speaking both about efficient utilization of reserves and labor in its production that was proved via SFA and DEA methods to some general best practice methods of conducting its operations, highlighted by all interview participants. Along with similar results for Gazprom Neft, both SFA and DEA also indicated Gazprom and Lukoil companies as having relatively high efficiency, while also both identified a decreasing trend in efficiency of Surgutneftegas. Tatneft was found as the least efficient company under both methods.

Secondly, SFA method revealed that share of state ownership does not have a significant impact on the firm's efficiency in a specific case of Russian oil and gas as it was previously considered by other researches. This result is proved in the DEA analysis, since best-practice firms identified were both national and private oil companies. Overall, on the basis of SFA and DEA methods, the following results regarding research hypothesis were achieved.

Table 11. Comparison of hypotheses with obtained results

Hypothesis	Result of SFA method	Result of DEA method
H1: The physical volume	Accepted	Cannot be supported or

of oil and gas reserves is positively related to the production of oil and gas companies		rejected
H2: The number of employees is positively related to the production of oil and gas companies	Accepted	Cannot be supported or rejected
H3: The share of state-ownership is negatively related to the technical efficiency of oil and gas companies	Declined	Declined
H4: Reserves to production ratio is negatively related to the technical efficiency of Russian oil and gas companies	Accepted	Cannot be supported or rejected

The results of the study indicate that labor and oil and gas reserves indeed positively relate to the production of oil and gas companies. There is no possibility to either accept or decline the H1, H2 and H3 under DEA method, since this method mainly serves as a source of benchmarking. Nevertheless, both under SFA and DEA methods the most common hypothesis of previous studies that the share of state-ownership negatively relates to the technical efficiency of oil and gas companies was declined. This means that on the Russian market the general conclusion of previous studies does not hold and there is not direct preference of ownership type when it comes to efficiency results. Finally, the higher reserves to production ratio proved to be negatively related with the firm’s efficiency.

Meanwhile, financial analysis was used as a supplement method to make more in-depth insights about the sample companies. Though the study is mostly concentrated on operational efficiency, the results of both operational and financial sides allow to look at the efficiency problem from different angles and should be used together in practice. Despite a series of global oil price falls, most Russian companies demonstrated healthy profitability trends and efficient asset utilization to generate revenue and net income. In terms of liquidity results, such companies as Zarubezhneft, Surgutneftegas and Bashneft showed the highest average liquidity during the period while another company, Slavneft, demonstrated a considerable improvement of its results in 2018. Some companies from the sample preferred to rely more on creditor financing, while such companies as Zarubezhneft and Gazprom followed more equity financing strategy. Finally, RussNeft was found to have low efficiency results in terms of using assets to generate revenue, the company is also characterized by low liquidity results and significant utilization of debt financing.

Nevertheless, in order to have a more detailed picture and generate new insights, quantitative methods of measuring efficiency should be supported by qualitative ones. This is especially important, considering the results of previous studies that were only concentrated on quantitative conclusions and hold a firm view that state-owned companies are inefficient compared to private ones. However, it is essential to obtain the industry expert view on the problem that will tell more about specifics of oil and gas industry at a market. According to the experts, the efficiency of oil and gas companies operating on Russian market depends not only on managing reserves, which is still highly important, given the increasing depletion rate of the major oil and gas producing regions. The possible strategies of increasing efficiency also include digitalization of both upstream and downstream sectors, higher agility that can be mostly improved by the increase of decision-making speed and higher autonomy of subsidiaries and diversification to other, not related to oil and gas sectors, such as renewable energy.

Finally, there is an outline of some techniques Russian oil and gas companies currently use or start employing to increase their efficiency. Firstly, the depletion of the existing fields is one of the main production challenges. To overcome this issue, Russian companies should improve reservoir management techniques and increase their drilling efficiency. For instance, while the annual natural decline rate for Western Siberia fields is currently around 10-15%, over the past decade such production companies as Lukoil West Siberia, Noyabrskneftegas, owned by GazpromNeft and Yuganskneftegas, Purneftegas, owned by Rosneft demonstrated an average decline rate of 2% (Oxford Institute of Energy studies 2019). Particularly prominent example of improved reservoir management is the case of Lukoil: the company increased the number of horizontal wells in its West Siberian field, which in its turn increased the drilling efficiency and decreased the natural decline. Furthermore, Lukoil currently also started to use wells with a smaller diameter. This allows to make the costs lower and optimize the performance.

Another method of improved reserves management, applied by the sample companies, was enhanced oil recovery (EOR), which includes such tertiary methods as steam injection, which is the most prevalent one, chemical flooding and several others (Oxford Institute of Energy studies 2019). EOR methods are successfully employed on some fields of Tatneft, for example, Romashkinskoye field in the Volga-Urals region. Another success in applying EOR is demonstrated by Gazpromneft: together with Shell, the companies apply alkalinesurfactant polymer (ASP) flooding method to boost recovery rate of the Salym field. The results are already encouraging: the recovery rate of certain areas of the field has been increased from forty-eight per cent to sixty-five per cent (Gazpromneft 2017).

Furthermore, it is important to replenish the resource base with new sources of production, for illustration, hard-to-recover reserves that will also provide companies with considerable tax breaks. For instance, a hard-to recover field Russkoye, operated by Rosneft, is projected to generate 130,000 barrels per day in five years, thanks to the new efficient drilling programme. Lukoil uses steam injection technology to ramp up the production of its Yaregskoye and Usinskoye fields. Thirdly, there is a high potential in the development of offshore projects: for instance, Gazprom Neft has been very active in bringing new offshore fields, such as Novy Port and Prirazlomnoye into development (Oxford Institute of Energy studies 2019).

Meanwhile, diversification to other industries is another way to proceed with efficiency improvement. Gazprom Neft is considered to be a pioneer of this strategy: together with Gazprombank and RBK the company established a venture found dedicated to investing in national and foreign startups that develop up-to-date innovative technologies for petroleum and energy industries (Vedomosti 2019).

Finally, technological innovation is a significant source to increase the efficiency in oil and gas industry and decrease the dependence of Russian petroleum companies on foreign technologies. The first example in this category is the fourth LNG train of NOVATEK at Yamal LNG project: it is based on internally developed liquefaction technology “Arctic Cascade” and utilizes equipment from Russian manufactures (Oxford Institute of Energy studies 2019). Second good example is Rosneft’s unique simulation technology of hydraulic fracturing that was developed to replace imported software that was commonly used for hydraulic fracturing operations. Finally, Slavneft views the use of big data and machine learning as one of the key efficiency drivers. Its innovative drilling center that currently uses such technologies allowed to optimize costs by lowering sums paid to foreign service companies and empowered the company to conduct predictive analysis of potential drilling problems and increased the overall drilling efficiency and speed by fifteen per cent (Slavneft 2019).

2.4 Theoretical and managerial implications

The results of the study have both theoretical and practical implications. Firstly, this study was aimed to examine research gap about the conclusion of previous researches that the share of state ownership negatively relates to the company’s efficiency, while several Russian companies examined in previous studies demonstrated opposing results. It was found that this relationship does not hold on the Russian market which provides the need to check this hypothesis on other emerging markets, such as China where largest oil and gas companies are also state-owned and not necessarily inefficient in comparison to their private rivals. Second theoretical contribution was to analyze the relation of depletion policy to company's efficiency that was highlighted as important by previous researches but never studied before. Since this relationship was proved significant, it can be included in the models with wider sample, for instance, international one to test it further. Thirdly, by incorporating such factors generated from interviews as corporate governance, research and development activities, relations with key stakeholders, degree of digitalization and many other into empirical studies will make the study of efficiency in oil and gas companies more comprehensive and allow to generate new important insights.

Practical implications of the research include the following directions. First of all, the methods of SFA and DEA can be applied by managers to measure the efficiency of individual existing projects within the company. Especially now, when under OPEC agreement companies are forced to decrease their production, optimal decisions on which fields to cut the production and by how much should be made. Efficiency analysis can be one of the metrics of this decision, especially for large national companies that have a large field base: identifying best-practice fields and outsiders will help not to cut too much in production of most efficient fields or put them on hold, which can cause total quality damage of hydrocarbons produced. Secondly, sometimes the decision to dismiss labor force to cut cost results in actual cost increase. Separating the field base according to efficiency scores will help not to lay off essential labor force at projects where all labor is used in the most productive way and, at the same time, to identify projects where less employees can perform the same amount of work to optimize the number of labor force.

Thirdly, the proposed efficiency measures can be also used as metrics by financial professionals when taking investment decision of project expansion or establishment. Since all these projects are costly and include high risk, if it is unidentified that there are some current projects that are currently underperforming and can generate more production, it may be more cost-effective to enhance the performance of existing projects rather than investing in new ones. Furthermore, efficiency metrics can be also used in budget justification process, when before budgeting a new drilling rig or hiring additional labor force can be performed to see whether these additional resources are actually needed to spend money on. Finally, managers can use numerous insights of industry experts presented in this study to search for increasing efficiency of their company.

2.5 Limitations

Although all the methods implied have their own considerable advantages, all of them also have some important limitations. Firstly, estimating efficiency under SFA method is significantly vulnerable to production function specification and the number of observations. Furthermore, the frontier of target efficiency scores is calculated mathematically, while in reality best practices are usually set by real-life companies. Thus, in order to use SFA results, obtained in this study, they should be preferably compared with other methods.

In this situation, DEA is considered as more efficient tool of benchmarking, since its frontier is calculated from best practices from the industry. However, in order for the model not to lose its discriminative power, a number of companies in the case of two inputs and 1 output should be not less than nine. Therefore, in the case of the sample decrease, DEA results can produce biased estimates.

The major limitation of the study is that it concentrates only on efficient generation of physical productions using such production factors as labor and reserves. If Russian oil and gas companies will be compared using other dimensions or some dimensions, for example, corporate governance will be added, the results of the study may be different. Furthermore, given the specifics Russian petroleum market, the results of this study should not be generalized on other markets.

In terms of other possible dimensions to look at, the in-depth interviews concluded can be very helpful. However, the results of these interviews should not be generalized as they represent perspectives of six specialists in oil and gas field. Therefore, the results can be biased to some extent, for instance, anonymity and confidentiality can produce some biases or personal experience of respondents may also affect their thoughts regarding the topics discussed (Anderson, 2010).

Although the research contains several limitations, the results obtained based on sample of companies that account for 90% of oil and gas production in Russia have clear practical implications. Limitations are discussed not to undermine results of empirical analysis but rather to generate directions for future research.

Conclusion

Today the Russian oil and gas industry goes through rather difficult times, considering low oil prices, production cut under OPEC agreement and sanctions that hinder the development of new projects and limit the sources of financing. Therefore, now it is extremely relevant to use all the resources efficiency, since it may have a significant impact on its financial performance, competitiveness and even survival. For illustration, not efficient performance of projects that got final investment decisions may lead to large overspending, the delay of deadlines that will, as a result delay the potential revenues or even the project abandonment that will also be costly for a company.

The main research question that was addressed in this paper was what the key factors affection production efficiency of Russian petroleum companies are and whether the portion of state ownership affects the efficiency of Russian oil and gas companies. Therefore, the research aimed at identification of factors that impact efficiency of Russian petroleum companies and examination of relationship between the share of state ownership and efficiency of Russian oil and gas companies.

To achieve the research goal a number of objectives were stated and achieved. Firstly, the examination of theoretical background was carried out on the topic of efficiency and methods to measure it. Then the application of methods of efficiency measurement in oil and gas industry was analyzed and methods of Stochastic Frontier analysis (SFA) and Data Envelopment Analysis (DEA) were chosen for the empirical study. On the basis of methods identified the empirical study of factors related to the efficiency of oil and gas company was conducted. Furthermore, in order to complement the methods of SFA and DEA, financial analysis was used to get more detailed overview and in-depth interviews with 6 industry from leading Russian oil and gas companies, as well as from consulting Big3 company were conducted to determine the practices of efficiency measurement in oil and gas industry. Finally, the results of research methods applied created a number of important theoretical and practical implications.

The data used in models was collected from the annual reports and presentations of the companies and from the Energy Intelligence database: Energy Intelligence Top 100: Global NOC & IOC Rankings. Overall, based on methods of econometric modelling, SFA, in particular and linear programming – DEA the following results were obtained:

- The number of labor force and amount of oil and gas reserves indeed positively relate to the production of oil and gas companies.
- The share of state-ownership in Russia is not significant in explaining the efficiency of oil and gas companies

- The average efficiency of private Russian companies though the studies period of 2013-2018 is about 5% higher than efficiency of public ones, though in 2018 the majority of best practice firms were state-owned companies that indicate the faster efficiency growth over the period
- Depletion policy of oil and gas companies have a significant impact on the firm's efficiency: higher reserves to production ratio implies lower efficiency results.
- Gazprom Neft company was identified as a best-practice company with highest efficiency scores via all methods employed

Based on results obtained a number of practical and theoretical implications were derived. First of all, the study contributed to the elimination of research gap regarding the general conclusion of higher efficiency of private companies that does not hold in case of Russian market realities. Therefore, the efficiency of state-owned companies in emerging markets should be studied in more detail. Secondly, the result regarding significance of depletion policy that was not discussed before, as well as a number of other dimensions such as level of research and development, effective corporate governance that were obtained during in-depth interviews give a potential for further research.

The main practical implications include application of efficiency analysis in benchmarking of current projects in place in the company to find out best-practice projects and underperforming ones in order to improve the performance of the latter. Furthermore, in case of OPEC production cut, the companies may be able to preserves the efficient projects while cutting more on the underperforming ones. Furthermore, SFA and DEA methods can be applied by financial specialists when taking investment decision of project expansion or establishment, since it may be more cost-effective to enhance the performance of existing projects if underperformance is detected rather than investing in new ones. Furthermore, efficiency metrics can be also used in budget justification process, when before approval of spending on a new drilling rig or hiring additional labor force, a financial manager can examine whether these additional resources are needed. Therefore, by using efficiency measures, the allocation of financial resources may be improved.

Since the study was concentrated on the specifics of Russian oil and gas market, the results should not be generalized on other markets. Furthermore, in-depth interviews represent personal opinion of respondents and conclusions obtained by this method cannot be generalized. Although the research contains some limitations, the results were obtained using the sample of oil and gas companies that cover 90% of total oil and gas production in Russia generate valuable implications.

References

1. Afanasiev, A. (2017). Forecasting of Gazprom gas production and its potential under the foreign economic restrictions. *Economics and Math Methods* 53 (4): 26-35.
2. Aigner, D. J., Chu, S. F. (1968). On Estimating the Industry Production Function. *The American Economic Review* 58 (4): 826-839.
3. Al-Mana, A., Nawaz, W., Kamal, A., Koc, M. (2020). Financial and operational efficiencies of national and international oil companies: An empirical investigation. *Resource Policy* 68: 1-15.
4. Al-Obaidan, A. M., Scully G. W. (1991). Efficiency differences between private and state-owned enterprises in the international petroleum industry. *Applied Economics* 23 (2): 237-246.
5. Aracioglu, B., Candemirc, C., Zalluhoglu, A. (2013). Measuring and Evaluating Performance within the Strategic Management Perspective: A Study on Performance Measurement of a Seafood Company. *Procedia – Social and Behavioral Sciences* 99: 1026-1034.
6. Banker, R., Charnes A., Cooper, W.W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science* 30: 1078-1092.
7. Banker, R.D., Charnes, A., Cooper, W.W., Swarts, W., Thomas, D. (1989). An introduction to data envelopment analysis with some of its models and their uses. *Research in governmental and nonprofit accounting* 5 (1): 125-163.
8. Barney, J. B. (1991). Firm resources and sustained competitive advantage. *Journal of Management* 17: 99–120.
9. Barrows, C.P., Sampaio, A. (2004). Technical and allocative efficiency in airports. *International Journal of Transport Economics* 31 (3): 355-377.
10. Basil C. I., Lee H. (2014). Measurement of the efficiency and productivity of national oil companies and its determinants. *Geosystem Engineering* 17 (1): 1-10.
11. Bashneft shareholder structure. Accessed March 2, 2020. Retrieved from: https://markets.businessinsider.com/stocks/bashneft/company-profile
12. Bendickson, J., Chandler, T. (2019). Operational performance: The mediator between human capital developmental programs and financial performance. *Journal of Business Research* 94: 162-171.
13. Bindemann, K. (1999). Vertical Integration in the Oil Industry: A Review of the Literature. *Journal of Energy Literature* 5 (1): 3-26.

14. Bisbea, J., Malagueno, R. (2012). Using Strategic Performance Measurement Systems For Strategy Formulation: Does It Work In Dynamic Environments? *Management Accounting Research*, 23: 296-311.
15. Bojnec, S. (2014). Determinants of Technical Efficiency in Agriculture in New Eu Member States from Central And Eastern Europe. Acta Oeconomica, 64(2): 197-217.
16. Bloom, N., Sadun, R., Reenen, J. (2016). Management as a Technology. Working Paper 22327, National Bureau of Economic Research.
17. Boussofiane, A., Parker, D., Martin, S. (1997). The impact on technical efficiency of the UK privatization programme. *Applied Economics* 29 (3): 297-310.
18. Bozec, R., Dia1, M., Bozec, Y. (2010). Governance–Performance Relationship: A Re-examination Using Technical Efficiency Measures. *British Journal of Management* 21: 684–700.
19. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, 3 (2), 77-101.
20. BP Statistical Review of World Energy. (2019). Accessed March 11, 2020. Retrieved from https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf
21. Charnes A., Cooper W.W., Rhodes E. (1978). Measuring the efficiency of decision-making units. *European Journal of Operational Research* 2: 429-444.
22. Coelli, T., Rao, D.S.P., Battese, G. (2005). *An Introduction to Efficiency and Productivity Analysis.* 2nd ed. Springer Science and Business Media, LLC.
23. Cooper, W.W., Seiford, L.M., Tone, K. (2007). *Data envelopment analysis: a comprehensive text with models, applications, references and DEA-solver software.* 2nd ed. Springer, New York.
24. Dyson, R., Allen, R., Camanho, A., Podinovski, V., Sarrico, C., Shale, E. (2001). Pitfalls and protocols in DEA. *European Journal of Operational Research* 132 (2): 245-259.
25. Eller, S. L., P. Hartley, Medlock K. B. I. (2007). Empirical Evidence on the Operational Efficiency of National Oil Companies. Working Paper, The James A. Baker III Institute for Public Policy, Rice University.
26. EY (2016) Project efficiency in oil and gas. Accessed January 7, 2020. Retrieved from: https://www.ey.com/Publication/vwLUAssets/ey-project-efficiency-in-oil-and-gas/$FILE/ey-project-efficiency-in-oil-and-gas.pdf
27. Fare R., Grosskopf S., Lovell, C.A.K. (1994). *Production Frontiers*. New York: Cambridge University Press.

28. Fare, R. and Lovell, C.A.K. (1978). Measuring the Technical Efficiency of Production. *Journal of Economic Theory* 19: 150–162.
29. Farrell, M.J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society* 120: 253-281.
30. Fisher, C. (2007). Researching and writing a dissertation: an essential guide for business students. Pearson Education.
31. Folan, P., Browne, J. (2005). A Review of Performance Measurement: Towards Performance Management. *Computers in Industry*, 56: 663-680.
32. Forsund et al. (1980). A Survey of Frontier Production Functions and of Their Relationship to Efficiency Measurement. *Journal of Econometrics* 13: 5-25.
33. Friedman, L., Sinuany-Stern, Z. (1998). Combining ranking scales and selecting variables in the DEA context: The case of industrial branches. *Computers and Operations Research* 25 (9): 781-791.
34. Gazprom shareholder structure. Accessed March 2, 2020. Retrieved from: https://www.gazprom.com/investors/stock/structure/
35. Gazprom Neft shareholder structure. Accessed March 2, 2020. Retrieved from: https://ir.gazprom-neft.com/share-data/shares/
36. Gazprom Neft press center. Accessed April 5, 2020. Retrieved from: https://www.gazprom-neft.com/press-center/news/salym-petroleum-development-confirms-success-with-alkaline-surfactant-polymer-asp-flooding-technolog/
37. Golany, B.A., Roll, Y. (1989). An application procedure for data envelopment analysis. *OMEGA* 17 (3): 237-250.
38. Greenwald, B., Stiglitz J.E. (1986). Externalities in Economies with Imperfect Information and Incomplete Markets. *The Quarterly Journal of Economics* 101 (2): 229-264.
39. Greene, W. (2004). Distinguishing Between Heterogeneity and Inefficiency: Stochastic Frontier Analysis of the World Health Organization's Panel Data on National Health Care Systems. *Econometric and Health Economics* 13: 958-990.
40. Greene W. (2005). Reconsidering Heterogeneity in Panel Data Estimators of the Stochastic Frontier Model. *Journal of Econometrics* 126: 269-303.
41. Gimbert, X., Bisbe, J., Mendoza, X. (2010). The Role of Performance Measurement Systems in Strategy Formulation Processes. *Long Range Planning*, 43: 477-497.

42. Hard-to-recover reserves as an objective reality. *Siberian oil journal* 149. Accessed November 7, 2020. Retrieved from https://www.gazprom-neft.ru/press-center/sibneft-online/archive/2018-march/1489610/
43. Hawdon, D. (2003). Efficiency, performance and regulation of the international gas industry—a bootstrap DEA approach. *Energy Policy* 31 (11): 1167-1178.
44. Hartley, P.R., Medlock III, K.B. (2008). A Model of the Operation and Development of a National Oil Company. *Energy Economics*, 30(5): 2459-2485.
45. Hartley, P.R., Medlock III, K.B. (2013). Changes in the operational efficiency of national oil companies. *Energy Journal* 34 (2): 27-57.
46. Hauser, J., Katz, G. (1998). Metrics: you are what you measure! *Eur. Manag. J. (EMJ)* 16 (5): 517–528.
47. Hronec. (1993). Vital Signs. Using Quality, Time, and Cost Performance Measurements to Chart Your Company's Future. Working paper, New York, American Management Association.
48. Johnston, D. (1994). International Petroleum Fiscal Systems and Production Sharing Contracts. Tulsa: PennWell Books.
49. Kapustina, K., Krylov, D. (2007). Comparison Analysis of efficiency of national and private oil companies. [In Russian.] *Journal of New Economy* 3 (22): 26-32.
50. Kaplan, R.S., Norton, D.P. (1992). The balanced scorecard measures that drive performance. *Harvard Business Review*: 71-98.
51. Kim, T.Y., Lee, J.D., Park, Y.H., Kim, B. (1999). International comparisons of productivity and its determinants in the natural gas industry. *Energy Economics* 21: 273-293.
52. Kumbhakar. S.C. (1987). Production frontiers and panel data: An application to U.S. class 1 railroads. *Journal of Business and Economic Statistics* 5, 249-255.
53. Kumbhakar, S.C. (1988). On the estimation of technical and allocative inefficiency using stochastic frontier functions: The case of U.S. class 1 rallroads. *International Economic Review* 29, 727-743.
54. Kumbhakar, S.C., Tsionas, E.G. (2005). Estimation of stochastic frontier production functions with input-oriented technical efficiency. *Journal of Econometrics* 133 (1): 71-96.
55. Kumbhakar, S.C. (1991). Estimation of technical inefficiency in panel data models with firm- and time-specific effects. *Economics Letters* 36 (1991): 43-48.

56. Krishna, K., Gian S. (1991). Technical Efficiency in Bangladesh Manufacturing Industries. *The Bangladesh Development Studies*, 19 (1/2): 89-105.
57. Lukoil shareholder structure. Accessed March 2, 2020. Retrieved from: https://www.Lukoil.com/InvestorAndShareholderCenter/Securities/sharecapital
58. Malakhov, D., Pilnik, N. (2013). Methods of Estimating of the Efficiency in Stochastic Frontier Models. [In Russian.] *Journal of Higher School of Economics* 4: 660-686.
59. McKinsey. Global Oil Supply and Demand Outlook. Accessed March 12, 2020. Retrieved from https://www.mckinsey.com/solutions/energy-insights/global-oil-supply-demand-outlook-to-2035/~/media/231FB01E4937431B8BA070CC55AA572E.ashx.
60. Meesun, W., Broeck J.V.D. (1977). Efficiency estimation from cobb douglas production functions with composed error. *Int. Econ. Rev.* 18 (2): 435-444.
61. Melnyk, S.A., Stewart, D.M., Swink, M. (2004). Metrics and performance measurement in operations management: dealing with the metrics maze. *Journal of Operational Management* 22, 209–217.
62. Mommer, B. (2002). Global Oil and the Nation State. Oxford: Oxford University Press.
63. Munir, M., Jajjaa, M., Chathab, K., Farooqc, S. (2020). Supply chain risk management and operational performance: The enabling role of supply chain integration. *International Journal of Production Economics*: 1-14.
64. Neely, A. (2007). Business performance measurement: Unifying theory and integrating practice. Cambridge University Press.
65. Nyman, J., Bricker, D., Link, D. (1990). Technical efficiency in nursing homes. *Medical care* 28(6): 541-551.
66. NOVATEK shareholder structure. Retrieved from: https://journal.open-broker.ru/visit-card/NOVATEK/
67. Oxford Institute of Energy studies (2019). The Future of Russian Oil Production in the Short, Medium and Long Term. Working paper, Oxford.
68. Oxford Institute of Energy studies (2020). ‘Finding a home’ for global LNG in Europe: understanding the complexity of access rules for EU import terminals. Working paper, Oxford.
69. Pedraja-Chaparro, F., Salinas-Jimenez, J., Smith, P. (1999). On the quality of the data envelopment analysis model. *The Journal of Operational Research Society* 50 (6): 636-644.

70. Peresetskiy, A., Ipatova, I. (2013). Techniceskaya effectivnost predpriyatiy otrasli proizvodstva resinovih i plasmassovih izdeliy. [In Russian.] *Applied Econometrics* 32(4): 71-92.
71. Perrin, B. (1998). Effective use and misuse of performance measurement. *Am. J. Eval.* 19 (3): 367–379.
72. Pollitt C (1999). Integrating Financial Management and Performance Management. Working paper, OECD, Paris.
73. Porter, M. E. (1985). Competitive Advantage: Creating and Sustaining Superior Performance. New York: The Free Press.
74. RBK (2019). Gazprom predlozhil udvoit sroki geologorazvedki na shelfe. [In Russian.] Accessed March 15, 2020. Retrieved from: https://www.rbc.ru/business/09/04/2019/5cac65f49a79473c8af01054
75. Rejc, A. (2004). Toward Contingency Theory of performance measurement. *Journal of East European Management Studies* 9 (3): 243-264.
76. Reuters. Q&A: What is a gas trading hub, and how are they established? Accessed December 29, 2019. Retrieved from https://www.reuters.com/article/us-china-gas-exchange-q-a/qa-what-is-a-gas-trading-hub-and-how-are-they-established-idUSKBN1EN0I1
77. Ritson, N. (2011). Strategic Management. Ventus Publishing.
78. Rosneft shareholder structure. Accessed March 2, 2020. Retrieved from: https://www.rosneft.com/Investors/Equity/Shareholder_structure/
79. RussNeft shareholder structure. Accessed March 2, 2020. Retrieved from https://RussNeft.ru/eng/shareholders/capital_structure/
80. Sakhalin Energy (2019). About the company. Accessed March 7, 2020. Retrieved from http://www.sakhalinenergy.ru/ru/company/overview/
81. Schmidt, P. (1976). On the Statistical Estimation of Parametric Frontier Production Functions. *The Review of Economics and Statistics* 58 (2): 238-239.
82. Schmidt, P. (2011). One-step and two-step estimation in SFA models. *Journal of Productivity Analysis* 36 (2): 201-203.
83. Seiford, L.M., Thrall, R.M. (1990). Recent developments in DEA: the mathematical programming approach to frontier analysis. *Journal of Econometrics* 46 (1): 7-38.
84. Skolkovo (2018). The future of Oil Production in Russia: Life under Sanctions. Working Paper, Skolkovo Energy Centre. Accessed February 12, 2020. Retrieved from: https://energy.skolkovo.ru/downloads/documents/SEneC/research04-en.pdf

85. Slavneft shareholder structure. Accessed March 2, 2020. Retrieved from: http://www.slavneft.ru/eng/company/history/
86. Slavneft Megionneftegaz. Megionneftegaz povyshaet effectivnost burenia s pomochiu zifrovih technologiy. [In Russian]. Accessed April 3, 2020. Retrieved from: http://www.sn-mng.ru/press-sluzhba/press-relizy/megionneftegaz-povyshaet-effektivnost-bureniya-s-pomoshchyu-tsifrovykh-tekhnolog/
87. S&P Global Platts. Platts JKM™ (Japan Korea Marker). Accessed January, 2019. Retrieved from https://www.spglobal.com/platts/en/our-methodology/price-assessments/lng/jkm-japan-korea-marker-gas-price-assessments
88. Stevens, P. (2008). A Methodology for Assessing the Performance of National Oil Companies. Background Paper for a Study on National Oil Companies and Value Creation, World Bank, Washington, DC.
89. Stiglitz, J. E. (2007). What Is the Role of the State? In Escaping the Resource Curse, New York, Columbia University Press: 23–52.
90. Tatneft shareholder structure. Accessed March 2, 2020. Retrieved from: https://www.tatneft.ru/for-shareholders/pjsc-tatneft-equity-capital-structure?lang=en
91. Tordo, S., Tracy, B., Arfaa, N. (2011). National Oil Companies and Value Creation. Working Paper 218, World Bank.
92. Tordo, S. 2008. Fiscal Systems for Hydrocarbons: Design Issues. World Bank Working Paper No. 123, World Bank, Washington, DC.
93. Van Horne, S.M., Wachowicz, Jr. (2001). Fundamental of Financial Management. 12th ed. Prentice-Hall, Inc., IAI.
94. Vedomosti (2019). Gazprom Neft, Gazprombank i RBK sozdaut venchurniy fond na 4 mlrd rubley. [In Russian]. Accessed March 12, 2020. Retrieved from: https://www.vedomosti.ru/technology/articles/2019/04/15/799215-gazprom-venchurnii-fond
95. Vedomosti (2020). Rossia i OPEC zakluchili krupneishuy sdelku ob ogranichenii dobichi nefti. [In Russian]. Accessed March 12, 2020. Retrieved from: https://www.vedomosti.ru/business/articles/2020/04/12/827839-rossiya-opek-zaklyuchili-krupneishuyu-ogranichenii
96. Victor, N. M. (2007). On Measuring the Performance of National Oil Companies. Working Paper 64, Program on Energy and Sustainable Development, Stanford University.

97. Waelde, T. W. (1995). The Current Status of International Petroleum Investment: Regulating, Licensing, Taxing and Contracting. *CEPMLP Journal* 1(5): 39-51.
98. Wolf, C. (2009). Does ownership matter? The performance and efficiency of State Oil vs. Private Oil (1987–2006). *Energy Policy* 37: 2642–2652.
99. Wolf, C., Pollitt, M.G. (2008). Privatizing National Oil Companies: Assessing the Impact on Firm Performance. Working Paper 02/2008, Cambridge Judge Business School.
100. Zarubezhneft shareholder structure. Retrieved from: https://www.zarubezhneft.ru/en/about_company/

Appendix 1. Estimation of the model specification 1 (SFA)

True fixed-effects model (exponential)	Number of obs = 65
Group variable: id	Number of groups = 11
Time variable: year	Obs per group: min = 5
	avg = 5.9
	max = 6
	Prob > chi2 = 0.0000
Log likelihood = 49.3007	Wald chi2(3) = 1.19e+11

logOut	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
OutPrevYear	-.0023541	7.86e-08	-3.0e+04	0.000	-.0023543	-.002354
logResvs	1.018909	.0000103	9.9e+04	0.000	1.018889	1.01893
logEmp	.074888	6.57e-06	1.1e+04	0.000	.0748751	.0749009
Usigma						
_cons	-3.51685	.2480755	-14.18	0.000	-4.003069	-3.030631
Vsigma						
_cons	-33.01726	149.5836	-0.22	0.825	-326.1958	260.1612
sigma_u	.172316	.0213737	8.06	0.000	.1351277	.2197388
sigma_v	6.77e-08	5.06e-06	0.01	0.989	1.47e-71	3.11e+56
lambda	2546431	.0213737	1.2e+08	0.000	2546431	2546432

Appendix 2. Estimation of the model specification 2 (SFA)

```
True fixed-effects model (truncated-normal)          Number of obs =          65
Group variable: id                                   Number of groups =       11
Time variable: year                                  Obs per group: min =      5
                                                                    avg =    5.9
                                                                    max =      6

                                                     Prob > chi2     =    0.0000
Log likelihood =     64.7881                         Wald chi2(3)    =     38.56
```

logOut	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
OutPrevYear	.0001463	.0007808	0.19	0.851	-.001384	.0016765
logResvs	.8972009	.1732623	5.18	0.000	.557613	1.236789
logEmp	-.0273531	.0978733	-0.28	0.780	-.2191812	.1644749
Mu						
govShare	.4961426	1.081867	0.46	0.647	-1.624277	2.616562
ratioResProd	.0235064	.0024803	9.48	0.000	.0186451	.0283678
_cons	1.044216	.	.	.	.	.
Usigma						
_cons	-4.967096	.2209868	-22.48	0.000	-5.400222	-4.533969
Vsigma						
_cons	-6.895486	.	.	.	.	.
sigma_u	.0834466	.0092203	9.05	0.000	.0671981	.1036242
sigma_v	.0318174	.	.	.	.	.
lambda	2.622676	.	.	.	.	.