Patents for inventions in the Russian oil and gas sector: an analysis of the knowledge database complexity

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Abstract. The authors have analyzed invention patents in the Russian oil and gas sector (OGS) based on a knowledge database complexity index they designed for this purpose. The index takes into account the subclasses and sections of international patent classification (IPC) used in the patents. It has been demonstrated that opportunities for creating breakthrough technologies and radical innovations mostly arise within giant multinational oil and gas field service companies (e.g. Halliburton, Schlumberger, Baker Hughes). At the same time, Russian oil and service companies are noticeably lagging behind the foreign players and Russian actors in the sphere of science and education. The conducted analysis of the sectoral knowledge database revealed several significant risks for the development of the Russian OGS along the innovative trajectory. The risks (relative to the invention patents) arise from inadequate opportunities for creating breakthrough technologies.

1. Introduction

At present, both globally and in Russia, the oil and gas sector (OGS including geological prospecting, exploration, and production of hydrocarbons – the upstream phase) faces significant complications of conditions for oil and gas production. There is a dire need for elaboration and widespread use of new science-intensive technologies and solutions.

The incremental growth of oil and gas extraction must come from original knowledge and technologies as newly implemented methods are capable of more economically effective extraction of emergent deposits. According to the estimates of oil company BP p.l.c., by 2050, the technological development in the OGS will bring down the average lifecycle costs of oil and gas deposits by 30% worldwide.

The Russian OGS is taking some steps trying to move along the innovative development trajectory by applying the latest technologies. Thus, in Russia today a more significant role is played by physical-chemical and thermal methods of extraction. Oil production through these methods reached 30 million tons p.a. or 5–6% of the total extraction in the country.

The problem is that innovative development is going along very slowly and relies mostly on foreign knowledge, practices, equipment, technologies that have largely been generated by oil and gas field service companies. At the same time, domestic opportunities for technological development are hardly used.

2. Literature review
Knowledge is one of the key factors of long-term economic development. Researchers have been paying more attention to analyzing innovation processes relative to industries, regions, and companies. Such analysis allows elaborating more reasonable recommendations and development strategies as applied to respective industries including OGS.

Analysis and study of innovative processes in OGS embraces a wide range of problems including:
– the role of innovations in the development of OGS [1, 2];
– patent activity dynamics [3];
– institutional aspects of innovation policy [4];
– regional problems of new knowledge generation [5].

An important direction of innovation analysis in OGS is the study of processes in the field of patenting inventions [6, 7]. Important aspect is impact of resource base evolution on patent activity [8].

Coordination of innovative activity in OGS became the line of responsibility for mostly high-tech companies from countries with developed economies. The majority of them are large oilfield service companies that carry out large volumes of R&D [9]. This situation is part of mainstream trends of global technological development relative to emergent international networks that create new technologies and manage the entire process. Major international companies use their capacity of extracting benefits from a geographically distributed portfolio of new knowledge sources [10]. The organizational structure of multinational corporations operating in several countries is highly effective in obtaining and aggregating knowledge from all over the world [11].

One of the approaches to analyzing innovative processes presumes that new knowledge arises through a new combination (recombination) of disparate fragments of existing knowledge distributed among economic agents [12]. In some publications, industrial knowledge bases are reviewed in terms of technologies employed to generate new knowledge as patents for invention. This approach was used to evaluate the knowledge database of high-tech industries [13]. A knowledge database of a particular industry may be viewed as a network with nodes of quoted (in patent documents) subclasses (technologies) of international patent classification (IPC) and with ties between nodes as combinations of technological classes in the same patent [14].

We have used this approach in the empirical part of our research. The current article aims to study the internal structures and complexity of the knowledge database of Russia’s OGS as far as invention patents are concerned, and appraise the complexity of the sectoral knowledge database for various groups of actors.

3. Materials and methods
The sectoral knowledge database was appraised with the help of a complexity index developed by the authors. It characterizes the degree of complexity in combinations of IPC subclasses and a measure of variance in the technologies comprising the sectoral knowledge database. This index is determined based on the number of technologies utilized within each patent as well as depending on the technologies belonging to various IPC subclasses and major IPC sections.

The index is calculated with the help of a function having several features: the minimal possible range of indexed technologies in a patent gives it a value of one; on the interval of more than one it is growing and the value of its first-order derivative is between zero and one. The calculations, which are analyzed later, use the power function. As a result, technologies (indexed within one patent) from one IPC section get a lower value than in the case of two subclasses from two different IPC sections. The same approach is used with the appraisal of patents from one IPC section: technologies from different IPC subclasses get higher values than if they belong to one subclass.

The proposed index of complexity of the sectoral knowledge database:
– describes the total number of technologies used within each invention;
– takes into consideration the differences of used technologies between large IPC sections and IPC subclasses;
– might be computed for a given series of inventions from a knowledge database, e.g. for various actors (oil companies, universities, individuals), and regions.

From the perspective of this approach, we analyzed the industrial knowledge database of Russia’s OGS. This analysis involved inventions – a connecting link between the R&D, on the one hand, and the development and application of new technologies, on the other. We used the database of the Federal Institute of industrial property concerning Russian invention synopses, in particular those published in the official bulletin of the Federal service of intellectual property “Inventions. Utility models”. We have reviewed the IPC subclass E21b “Earth or Rock Drilling; Obtaining Oil, Gas, Water …” that most completely illustrates the process of knowledge generation in OGS. This subclass is part of the IPC section “E – Fixed constructions and mining”.

4. Results and discussion

What actors have their sectoral knowledge database more aligned with applying technologies from outside the IPC section “E – Fixed constructions and mining” and the subclass “E21b”? And consequently, what actors have more opportunities for creating breakthrough technologies, and radical innovations [15]? Reference points for these questions help estimate the complexity index of the sectoral knowledge base for major groups of actors including oil and gas, oil service companies, scientific and educational establishments.

Complexity appraisals of knowledge database of sectoral actors demonstrate that Russian oil companies have indicators below the average level (a separate place belongs to the oil company “Tatneft” – the largest owner of patents in Russia), the Russian service business in general, and individuals (figure 1). Notably, the Russian service includes all actors except for the scientific and educational establishments (Science and Universities), oil and gas companies, and individuals.

![Figure 1](image_url)

**Figure 1.** The index of complexity for invention patents in OGS: main groups of actors.

The minimal value of the complexity index belongs to oil company “Tatneft”, which owns the highest number of patents. Having a high number of patents reduces the average indicators of knowledge database complexity that reflects the frequency of using knowledge from other IPC
subclasses and sections. At the same time, the patent activity of the company focuses on several key areas that are critical for stabilizing and increasing extraction on the territory of Tatarstan:

– raising the efficiency of work on depleted subsoils;
– development of effective oil extraction technologies from hard-to-recover reserves.

There is no surprise about the low level of complexity of individuals’ knowledge database. Usually, the knowledge of individuals is highly specific and conducive mostly to innovations bordering on rationalization proposals. Moreover, individuals largely represent Moscow and Tatarstan. As for Tatarstan, there are a large number of small and medium companies operating in the OGS of the republic that are not particularly engaged in the patent activity. It is quite probable, therefore, that a part of new knowledge on technologies for developing complicated deposits of the republic obtained in these companies is represented in patents submitted by individuals.

The level of complexity of other (i.e. excepting PAO “Tatneft”) Russian oil and gas companies (OGC) is higher than that of individuals and service companies but it is lower than the average national level. Among the extractive companies, leading positions belong to structures within the “Gasprom” group.

Russian actors with the knowledge database complexity higher than the national average are represented only by scientific research institutes of RAS (Science) and higher educational establishments (Universities). The role of research organizations is strongly associated with carrying out research studies, obtaining breakthrough knowledge including that on the junction of various scientific fields. Institutes of higher education also have some prerequisites for that. Many of those (first of all, universities) teach various disciplines and allow their exponents to exchange and share ideas (find partners in pursuit of inventions). This puts in effect the factor of organizational ‘proximity’[16],[17].

The foreign corporations we reviewed (oil extraction, big oilfield service, other services) have higher complexity of knowledge databases. At the same time, the foreign extractive companies (Foreign OGC) take relatively little interest in patenting their inventions in Russia. Their role in Russian oil production is limited (the role in joint projects is that of junior partners of large Russian companies). The services they use are provided by Russian and foreign companies.

A much larger role is played by foreign oil and gas field service companies (OGFS – Halliburton, Schlumberger, Baker Hughes) and service in general (Foreign Service): from big international companies of chemical profile to relatively small “players”. Patent documentation of these foreign companies typically uses many technologies from diverse fields of competence, which determine a high level of complexity index for their knowledge database.

5. Conclusion

The place and role of the OGS in Russia’s economy as well as its growing in complexity resource base demand the necessity of active innovative policy of resource companies. The OGS technological development that stands up to contemporary challenges requires closer interaction of a wider range of innovation participants: oil production companies, oil and gas field service, R&D centers, scientific organizations, higher education establishments, machine-building enterprises. Such joint efforts may become an important premise for more fruitful work in the area of innovation in the OGS [18].

Innovative processes in Russia’s OGS (including the patent activities) could be accelerated through the development of its organizational structure. There is a need for government incentives in generating and expanding high-tech specialized service companies, which often initiate and lead innovation processes in international practice. Another significant trend is creating a competitive playing field in oil and gas extraction, which may produce an important boost for innovative technological development of oil and gas companies. It is critical to support the development of small and medium extractive companies.

It is necessary to create conditions and effective incentives for putting Russia’s OGS on the innovative trajectory relying on domestic knowledge, inventions, equipment, and technologies. The
evolvement of Russia’s OGS along this trajectory would facilitate the advancement of socio-economic benefits arising from hydrocarbon resource development.

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