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# EVOLUTION OF VAC IN THE CONTEXT OF COAL INDUSTRY ADVANCE IN THE CONDITIONS OF DIGITIZATION IN RUSSIA

*The article shows the role and place of the modern coal industry in the stress-resistant development in Russia, including economy diversification, as well as removal of technological, structural and infrastructural constraints. The theoretical framework for the studies is the concept of value-added chains. This article provides a detailed analysis of the formation of the concept and the advantages of its use for the coal industry. It is shown that under the influence of the fourth industrial revolution that has begun, new value-added chains appear—cooperative VAC. The new type of chains is structurally similar to the chains of the market type, the specificity of assets and equipment makes the relationship between the participants within such chains of added value is closer to the network interconnections. The analysis of global coal companies shows that the captive-type VAC (coal companies within the energy-generating and metallurgical holdings) are characteristic of the modern coal industry. It is demonstrated that the beginning of digitization of all industries has led to the growth of alternative technologies for coal processing, but the final consumer is represented mainly by metallurgical and energy-generating companies. The main causes of "inhibition" in transformation of the coal industry in Russia are: replacement of coal with cheaper gas, long distances for transportation of coal products within the country and abroad, accumulated infrastructure constraints for switching to Industry 4.0. It is recommended: to develop and implement transition from upward to downward connections by restructuring value-added chains, to modernize mines and equipment from Industry 3.0 to Industry 4.0, to add the chains with scientific engineering and design centers, as well as with innovation and experimentation sites that can design and implement hybrid coal mining technologies to ensure safety of mining and coal production stimulation.*

***Keywords:*** *Fuel and energy sector, coal industry, value-added chain, upward and downward connections, transformation, coal companies, Industry 4.0.*
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## Introduction

The Russian Federation is the top coal producer in the world. The coal industry holds the key position in the economy of Russia. The competitive recovery of companies engaged in production, transportation and processing of coal is the critical task of the Energy strategy of Russia up to 2035. Currently Russian government is stoutly looking for technological innovations for the competitive recovery of the coal industry. The quintessence of the Energy strategy is efficient and integrated development of unique coal resources of the country, which will enable the industry to continue being the critical factor of the social and economic prosperity in the country by means of conversion from the economic upswing source to the stimulating infrastructure towards stress-resistant development of the country, including economical diversification, as well as technological, structural and infrastructural liberalization [1]. In this respect, it is imperative to analyze obstacles and find new sources of increase in competitive power of the coal industry.

Recently, both in Russia and in the world, increasingly more researchers treat competitive ability of companies and industries in terms of the value-added chains (VAC) which generally can be defined as "a full range of activities performed by a firm to deliver a product from an idea to a customer" [2]. The cost of the product rises as it moves along the chain. This process of the final product creation includes basic, auxiliary and supplementary stages of production, as well as research, design and marketing [3]. In this fashion, the competitive ability can be considered from the view point of creation of high added values and in terms of sustainability and development source [4].

Although relatively simple cognitively, the approach based on VAC possesses some competitive advantages over the classical market or industry analysis. Based on the review of the sequence of cost creation stages, as well on the nature of intra-firm and inter-firm interaction within the fully formed VAC, the approach allows comparing and identifying competitive advantages by their structure, profit contributor and management methods, correlating the past and the presence, revealing the most profound modifications and forecasting future of firms and industries. The strength of the approach consists in its ability to predict new sources of competitive recovery as well as value rise points, and to detect barriers (risks) of introduction of advanced technologies, creation, expansion and variation in the geography and configuration of markets, etc [5]. All this allows the value-added chain approach to propose specific recommendations on shaping a long-term strategy for individual companies and a governmental policy of development for industries and territories. Such predictive function is of particular demand for analyzing consequences of comprehensive technological changes due to digitization and the energetically evolving fourth industrial revolution. This explains the increasing popularity of examining prospects of competitive recovery of companies, industries, markets and countries using the value-added chain concept [6, 7].

Major foreign and Russian researches from the viewpoint of VAC are devoted to the analysis of manufacturing industries [4, 8, 9]. The use of VAC in finding and substantiating prospects and trends in the energy sector takes its rise [4, 10]. Despite the uttermost promising nature of auditing the fuel and energy sector, as well as the coal industry using the value-added chain, there are only a few studies which are based on this approach in the literature, or they are mostly modeling [4, 11–13]. Thus, the analysis of VAC forming in the domestic coal industry is topical both theoretically and practically.

This article aims to find points of increase in the competitive ability of the coal industry in Russia. With this end in view, the study attempts to reach three interrelated objectives: to demonstrate features of VAC as the coal industry exploration tool, to reveal specificity of VAC in the coal industry in Russia and to show their trends and conversion prospects in the modern conditions. These objectives are reflected in the structure of this article.

## The concept and creation features of VAC in the coal industry

Despite relative cognitive simplicity, the value-added chain approaches are not a unified concept but represent many comparatively independent conceptions which differently answer the question on the source of competitive ability of a company (industry).

The classical model of VAC is based on the description of VAC in the manufacturing industries and, first of all, in the motor industry [14]. This classical model includes the pre-production, production and post-production stages composed of such basic steps as: R&D, engineering, raw material supply, supply of deliverables, assembling, marketing, distribution and sales, as well as aftersales service enjoying active development in the recent decade [15–17].

The classical model of VAC can be and is used for describing raw material industries [18], including coal mining [19]. The value-added chain in the coal industry possesses some specific properties. Its first feature is that it is short and has only two stages of production and post-production. A standard value-added chain of the coal industry is presented in **Fig. 1**.

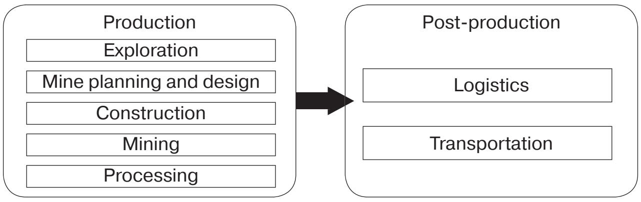


**Fig. 1. Typical value-added chain in coal industry [20]**

The coal industry's VAC lack the R&D stage. Even in the leading coal-mining countries with the developed market-oriented economy (Australia, Great Britain, USA, Germany), the patent stock in the coal industry is insignificant and mainly deals with engineering companies engaged with manufacturing of coal mining and haulage equipment, and being beyond coal VAC [21]. The production stage of the coal value-added chain includes steps of exploration, mine planning, design and construction, as well as coal extraction and dressing. The post-production stage is shorter and involves logistics and sales [22].

Unlike the manufacturing industries, the major part of the value-added chain in the coal industry is generated at the production stage by coal extraction, preparation and dressing. Here, the main source of the value-added chain is not innovation- and business-related profit due to the introduction of new technologies but the natural and absolute rent. The natural rent results from the cost difference of different-quality raw materials and from comfortable geography (close-spaced consumers, low transport expenses); the absolute rent forms from the monopoly on the market and due to specific relationship with government through direct assets ownership (Coal India), or via mechanisms of granting access to coal assets (licenses, concessions, etc.), which allows maintaining monopolies and stability of VAC. These facts in the aggregate reduce interest of the coal industry in modernization based on intensive development, lead to continuous replication of extensive extraction of natural resources and to establishment of strict control over suppliers and market in the framework of VAC [22].

The distribution expenses in the coal industry are lower than in the manufacturing industries. Despite the current increase in the number of the alternative conversion technologies for coal, its final consumer is mainly represented by the power generating and metallurgical companies [22].

The bigger part in the value-added chain formation in the coal industry is taken by the international global energy market. The most of the coal-exporting countries, including Russia, are involved based on the upward connections—export of raw material of low added value in exchange of import of finished product of higher added value. The export share of raw materials and the import dependence grow. The exception are the developed coal-exporting countries: USA, Australia, Great Britain and Norway. For instance, in Russian, according to the Central Fuel and Energy Sector Control, the export supply of coal grew from 29% in 2006 to 52% in 2018. In 2018, by the reports of the coal mining companies, Russia exported 193.2 Mt of coal. The major portion in the export belongs to power-generating coal—176.9 Mt (91.5% of the total coal export); the coking coal percentage in the total export made 8.5% (16.3 Mt). Such situation leads to a strong dependence of the coal industry on the external market and on the machinery import [23].

All above-listed features of the coal industry have resulted in the formation of linear and inflexible VAC controlled by large vertically integrated companies of captive or hierarchical structure. In the first case, coal companies are included as the resource assets in VAC of metallurgical or energy holdings, e.g., BHP Billiton (Australia), Rio Tinto (USA), Glencore International (Switzerland), Norilsk Nickel, Evraz Holding or Mitchel (Russia) [24]. The analogous VAC are built in Russia's largest energy holding SUEK. In the second case, the vertical coal holdings are formed with considerable participation of government, for instance, Coal India (India or Coal China (China). The Russian coal industry had the same structure before restructuring in the early 1990s [11].

## Industry 4.0 and upgrade of VAC in the coal industry

As of today, the coal industry enjoins sustainable development in Russia. By the data of BP Statistical Review of World Energy 2019, Russia holds nearly the third of the global coal reserves and close to 15.5% of the proven coal reserves—160.3 Bt, which is sufficient for almost 400 years given the current level of production [21]. The coal output in Russia in 2018 totaled 439.3 Mt. In 2019 it is anticipated to reach the record production of 400 Mt of coal in modern Russia [23], which will bring Russia among the world's top coal producers (4.5% of the global coal output) after China, USA, India, Australia and Indonesia [21].

The structure of the coal industry and the nature of the value-added chain management in it in many respects conform with the global tendencies. As in the whole world, Russia's coal industry experiences production concentration and elongation of VAC owing to construction of the transport infrastructure. In Russia VAC are shorter than in USA, Australia or even India, Brazil and China. In many ways, this is connected with the upward nature of interrelations inside VAC in Russia and with features of the industry restructuring in 1992–2005 [23, 25].

The restructuring in the coal industry reduced the number of coal mining companies. All in all, 203 mines (188 underground mines and 15 surface mines) of federal ownership were closed together with dressing plants to cut down expenses. The rest companies were stripped from service bodies, non-core businesses and social agencies in which the Russian coal companies acted as the lower echelon of the upward hierarchical VAC. Coking coal mines were integrated with metallurgical holdings. Ten largest management companies and holdings ensure the three fourth of the cumulative coal production in the country [11, 24].

Russia experiences sustainable rise in volumes of coal mining and dressing, commissioning of new mines, renovation of production capacities and increment in budget contribution. At the same time, the coal industry faces considerable challenges calling for comprehensive transformation of VAC and economic upgrade of the industry.

The key challenges for the upward tendency and construction of stable VAC in the coal industry in modern Russian include:

- the foreign market: highly volatile oil prices and global market uncertainty; reduced share of coal in energy balance and vicious increasing competition of coal producers on the markets due to energy jump and explosion of technological innovations (first of all, renewable energy sources, electric energy storage units, area energy resources, unconventional gas production methods, energy sector digitization and transition to a new industrial advance paradigm—Industry 4.0, complicated geopolitical climate due to nonrivalry economic warfare in the form of sanctions, pressure on consumers and growing protectionism);
- the domestic market: downward tendency due to deteriorated quality of mineral raw materials, higher production and logistics cost in view of the capital stock wear, eastward geographical shift of coal production and supplies and the associated increase in the distance and rates of coal product transport, as well as extra infrastructural constraints at railways stations and sea ports [11, 12, 24].

A way out of the situation can be the upgrade of the value-added chain in the coal industry using the technology Industry 4.0.

Parilli, Blazek and Kondratiev [22] define the economic upgrade as "the advance of economic agents (actors)—firms or man power—from production with low added value to production with high added value in global VAC." The task of the value-added chain upgrade is to find conditions, directions and promising fields of the industry modernization [22]. Table 1 describes four types of the upgrade.

An illustration of the first type upgrade is the dynamic digitization in the coal industry. The introduction of the Industry 4.0 key technologies built up its technological core comprising robotic or remote-control equipment (independent), remote centralized control, highly accurate station positioning of machines, portable health control devices, 3D modeling in mine planning and management, predictive analysis of geological data and everything concerned with production process. These activities improved efficiency of coal mining, reduced operating costs and optimized other performance indicators. By estimates of the International Economic Forum and Accenture company, digitization can bring about 298 billion euro of extra profit to coal mining companies between 2016 and 2025 owing to enhanced productivity and cut down energy consumption and other operating expenses [22].

The application range of the digital technologies in the coal industry is diverse while the maximum effect is reached when they are applied jointly, which requires transformation of connections inside VAC. It is necessary to change from the captive relationship, when the lower chains are completely subordinate to the higher chains in terms of priorities of development, investment and resources, to the equitable partnership within cooperation VAC.

As digitization advanced in the logistics and transport sector, VAC of large metallurgical and power-generating holdings changed. Management and profit centers in these VAC started drifting closer to engineering, logistic and shipping companies. The value-added chains became more flexible and decentralized. Even the developing economies, which especially long preserved the government-supported and vertically integrated coal companies with centralized VAC, began culturing new kinds of competition, and the sector itself more and more joined the network economy [11, 12, 24].

In the global chains of value of raw materials, the upgrade policy lays emphasis on the expansion of the network interactions between companies in order to broaden cooperation contacts in the industry, including government and research institutions. The consequence of the energy jump and digitization in the industry was the elevated role of medium-size and small independent mining companies focused at local markets. Transition to the digital technologies created conditions for the working relationship of these companies in the framework of cooperation VAC with involvement of research institutions, education bodies and government. The interindustry cooperation in the energy-generating sector grew. Producers and consumers of coal had to adapt to the extreme market volatility and were forced to diversify business, including engagement of small coal companies working on local markets. As a result, fragmentation and flexibility of VAC in the coal industry increased, and small coal companies became involved in the downward chains on the basis of parity and independence.

For the sustainable investment, the governmental support of the coal industry develops new forms of partnership between the public authority, business and science [11, 12, 24]. There are many historical examples and specific cases when programs initiated by mining companies acted as accelerators of advance in the allied industries.

**Table 1. Economic upgrade in coal industry [22]**

| Type of upgrade | Example |
|---|---|
| Technology | Introduction of new basic and auxiliary technologies: robotic and unmanned, digital, internet of things and Big Data processing—Smart Mine, Smart Open Pit, etc. |
| Product | Coal blending—“premium” coal for a specific user’s wants |
| Functioning | |
| Partial transformation of VAC:<br>— joining a group of suppliers with higher added value;<br>— abandoning functions with low added value;<br>— production of new commodities and formation of new markets;<br>— upgrade through merging and takeover;<br>— contracting and voluntary activities of functions transferred by suppliers with high added value | Outsourcing of development and blasting, transition of functions connected with coal transport and logistics to special operators.<br>Waste and tailings management<br>Introduction of modular degassing plants capable of cogeneration (joint generation of electrical and thermal energy) |
| Total transformation of VAC:<br>—upgrade within a value-added chain or a cluster;<br>—fusion of businesses within a value-added chain | Clustering in deep coal and methane conversion.<br>Cooperation of small coal companies for focalization of suppliers of equipment. |

It is important that the four types of the upgrade are tightly interconnected. For instance, the digital technologies are incapable to function to the full extent without modification of the auxiliary stages in VAC, draw up changes and innovations in transport and logistics, as well as call for creation of brand-new VAC with new sequences and relationships of stages and steps. A classical example is the product upgrade by means of shaping of an international market of ‘premium coal’: special coal blending to satisfy the wants of a specific user. Such program has been implemented for five years by SUEK Coal and Energy Holding in Russia. Its early-stage implementation already called for cardinal transformation of the company’s logistics—it was required to introduce optimizing systems capable to coordinate coal production schedules for different deposits and to optimize haulage and blending of different grade coals to sale to a final consumer at maximal margin and minimal expense. The approved manufacture of the called-up coal blends, the geographical proximity to Japan, South Korea and Taiwan, as well as the mature marketing network allowed SUEK to expand its presence on the attractive markets: the company’s supplies to the mentioned countries increased by 40% [11, 12, 24].

Scaling and replication of the program implementation results is impossible without digital technologies meant for: generation and continuous updating of electronic data bases on coal, mines, consumers and dressing plants; development of mathematical models and intelligent systems (simulation, transport-and-logistics, mathematical economy, etc.) embodied in artificial neural networks. Fulfillment of these targets needs adding VAC with new stages of R&D and engineering, and branching VAC into the horizontal connections and cooperation with science and education institutions. The program has already engaged the Federal Research Center of Coal and Coal Chemistry of the Siberian Branch, Russian Academy of Sciences, which, based on the available electronic database on coals, initiates the Coal Blending and Monitoring Center to ensure efficient coal utilization (including difficult, low-quality and off-grade coal) [25] .

Owing to this, it appears to be possible to create new high-tech VAC in mineral processing, for example, coal dressing by the unique dry pneumatic-and-vacuum method, which greatly reduces expenses and produces the highest quality concentrate while allowing re-processing of waste (slime) of wet outdated technologies in compliance with the highest international standards [11].

Another technology capable to draw the allied industries into upgrade and creation of new VAC is methane recovery by modular drainage plants. The task of the modular drainage plants is pre-mine drainage of coal beds and pumping of methane–air mixture from mines to ensure mine safety. Methane recovered by co-generation drainage plants can be used as a heating source [25, 26].

Despite the apparent success, modern flexible and branched VAC yet lack prevalence in the coal industry. A possible explanation to this face is offered below.

Position of coal mining companies as the lowest members in VAC results in that profit and management centers are arranged at the parent (main) companies which perform absolute control over resources and finances. A good part of the profit of the coal companies is withheld and redistributed in favor of capital assets of the parent companies (metallurgical plants and power-generating stations). A few small and medium-size companies attend the municipal housing economy and generate market-type VAC [27].

A high obstacle to formation of modern branched and centralized VAC in the domestic coal industry is its dependence on importation of mining and transport equipment, which curbs even greater the slow patenting and innovation activities in this area. For instance, by the data of the Central Fuel and Energy Sector Control, the average share of the imported equipment in surface and underground mining is more than 84% and 64%, respectively, and this dependence continuously grows [11]. Coal companies back out of the patenting activities [28].

The part of R&D in VAC of the Russian companies is also small. According to the Federal Service for Intellectual Property (Rospatent), all in all 134 patents were published between 1993 and 2017 (116 patents in underground coal mining and 28 patents in surface coal mining) [26]. Moreover, the majority of these patents are not devoted to mining machinery designs but to application of specific equipment in different conditions [29].

The facts described above explain why conventional centralized VAC based on the upward connections are yet preserved in the Russian coal industry. The way out of this situation can be the introduction of mine drainage and commercial use of methane. To develop this trend in the coal industry, the Ministry of Energy of the Russian Federation accepted the Coal Industry Development Program 2030 [30]. Furthermore, the Power-Generating Coal Processing Program was embraced. According to these programs, it is assumed that the volumes of coal dressing would increase to 345 Mt by 2030, which would be twice as much as in 2015. The deeper conversion of coal and mining waste will produce up to 130 types of chemical products and more than 5000 types of products in the allied industries. Such approach will build a well-balanced and sustainable R&D sector capable to ensure expanded knowledge reproduction as well as enhanced efficiency of infrastructure towards commercialization of intellectual activity results [31].

Another important line of the coal industry modification in Russia could be focalization and advancement of the domestic coal mining machine building, including development of pointwise manufacture [31]. Finally, Industry 4.0 offers Russia a chance to change the coal industry value-added chain and its role in the global economic competition.

### Conclusions

Summing up the analysis of the current situation and tendencies in VAC in the coal industry of Russia, the coal industry is at the very beginning of the energy jump. Until Russia holds prevailing vertical, upward and closed VAC, the current competitive advantages of the coal industry are ensured by the expensive production and export of coal. Russia' coal industry has launched some projects in the framework of development programs and digitization towards introduction of modern digital technologies and formation of decentralized and flexible VAC. Yet, these projects are singular and need a strong governmental support.

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