EXPERIENCE OF MINING PROJECT IMPLEMENTATION

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Value chain stress resilience and behavioral strategies of companies in Russian coal industry

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Abstract

Under the current conditions, the Russian coal industry is under unprecedented external pressure: it is both the imposed sanctions and the need to meet strict environmental requirements that inevitably lead to the closure of part of the enterprises, the collapse of value chains (VCs) in the coal and related industries. As a result, a complex restructuring of the industry is required. To carry it out successfully, a reliable criterion is needed to assess the prospects for the long-term development of both individual companies and VCs as a whole. From the authors' point of view, the degree of stress resilience of VCs is the criterion needed.

The article deals with the evaluation of the long-term development prospects of the coal industry based on the established stress resilience of VCs and the related strategies of coal companies' behavior. The authors proposed an algorithm for assessing the stress resilience of VCs in the coal industry: a description of the aspects and typology of VCs in the Russian coal industry; an assessment of their current stress resilience; a description of the survival strategy of the companies included in the VCs; an assessment of the prospects for sustaining VCs under sanctions. Subsequently, this article presents theresults of the stress resilience assessment of 169 coal companies operating in 110 different VCs between 2010 and 2021.

The authors created a typology of VCs in the coal industry, which makes it possible to identify three basic types of VCs in the domestic coal industry: two integrated – the captive market and the hierarchical market – and one non-integrated market. Analysis of companies operating from 2010 to 2021 showed that 90 out of 169 businesses (53%) operated as integrated companies (hierarchical and captive VCs), the remaining 79 were classified as market ones.

For each type we measured overall stress resilience (β_{rescom}), indicating the VC degree of recovery from shocks; robustness (β_{res}), the VC ability to withstand (swallow) shocks; adaptability (β_{rec}), the VC flexibility CDS and the ability to recover quickly after a shock. The analysis conducted by the authors showed that the stress resilience of key segments of the coal industry is low and tends to decrease and will only decrease in the long run. The research also found that systemically important companies are in the most difficult situation. They belong to the hierarchical VCs, especially the energyand coal companies, which are mainly focused on foreign markets. Their cooperative survival strategy does not even maintain the current level of stress resilience. Market and relational VCs are in a more favorable position. As a result, the authors conclude that part of the coal companies will inevitably close and for the other part a profound restructuring will be necessary, while the current survival strategies of the companies will not allow to solve this problem by themselves and an active participation of the state will be necessary.

Keywords

coal industry, stress resilience, value chains (VCs), typical coal industry VCs, company behavioral strategies

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ОПЫТ РЕАЛИЗАЦИИ ПРОЕКТОВ В ГОРНОПРОМЫШЛЕННОМ СЕКТОРЕ ЭКОНОМИКИ

Научная статья

Стрессоустойчивость цепочек добавленной стоимости и стратегии поведения компаний в российской угольной отрасли

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Аннотация

В современных условиях российская угольная отрасль столкнулась с небывалым внешним давлением: это и введенные санкции, и необходимость соответствовать жёстким экологическим требованиям, что неизбежно ведет к закрытию части предприятий, разрыву цепочек добавленной стоимости (ЦДС), сложившихся в угольной и смежных отраслях. Требуется сложная реструктуризация отрасли, для успешной реализации которой необходим надежный критерий, позволяющий оценивать перспективы долгосрочного развития как отдельных предприятий, так и ЦДС в целом. По мнению авторов, таким критерием является уровень стрессоустойчивости ЦДС.

Статья посвящена оценке долгосрочных перспектив развития угольной отрасли на основе стрессоустойчивости сложившихся в ней ЦДС и связанных с ними стратегий поведения угольных компаний. Авторы предложили алгоритм оценки стрессоустойчивости угольных ЦДС: описание особенностей и типологизация ЦДС, сложившихся в российской угольной отрасли; оценка их текущей стрессоустойчивости; описание стратегии выживания компаний, входящих в состав ЦДС; оценка перспектив сохранения ЦДС в условиях санкций. Соответственно, в статье приведены результаты оценки стрессоустойчивости 169 угольных компаний, действующих в рамках 110 отдельных ЦДС в период с 2010 по 2021 г.

Авторами произведена типологизация угольных ЦДС, что позволило выделить три базовых типа ЦДС в отечественной угольной отрасли: два интегрированных – посреднические и иерархические рыночные, и не интегрированный – рыночный. Анализ компаний, действовавших в период с 2010 по 2021 г., показал, что 90 из 169 предприятий (53 %) действовало в составе интегрированных компаний (иерархические и посреднические ЦДС), остальные 79 были отнесены к рыночным.

Для каждого из типов ЦДС были измерены общая стрессоустойчивость (β_{rescom}), которая показывает степень восстановления ЦДС после окончания шока; робастность (β_{res}) – способность ЦДС противостоять (поглощать) шокам; адаптивность (β_{rec}) – гибкость ЦДС и способность быстро восстанавливаться после шока. Проведенный авторами анализ показал, что уровень стрессоустойчивости ключевых сегментов угольной отрасли невысок, имеет тенденцию к падению и в перспективе будет только снижаться. В результате исследования выявлено, что в наиболее тяжелом положении находятся системообразующие компании, входящие в состав иерархических ЦДС, особенно энергоугольные, которые ориентированы преимущественно на внешние рынки, кооперативная стратегия выживания которых не обеспечивает поддержания даже текущей стрессоустойчивости. В более благоприятном положении находятся рыночные и отношенческие ЦДС. В итоге авторы делают вывод, что часть угольных компаний неизбежно закроется, а для другой части потребуется глубокая реструктуризация, при этом текущие стратегии выживания, выбранные компаниями, не позволят решить эту проблему самостоятельно и понадобится активное вмешательство со стороны государства.

Ключевые слова

угольная отрасль, стрессоустойчивость, цепочки добавленной стоимости (ЦДС), типичные ЦДС угольной отрасли, стратегии поведения компаний

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Introduction

The Russian coal industry has faced the need to adapt to increasing sanctions pressure and stringent environmental requirements. Under the fifth package of sanctions alone, the European Union banned the coal and other solid fossil fuels import and transit from Russia. This affected 25 % of all Russian coal exports, amounting to about €8 billion, and significantly limited the demand for Russian coal, whose production is almost 50 % foreign-oriented [1].

Sanctions lead to the collapse of established VCs in the coal and related industries, which in turn contributes to the formation of additional risks that are impossible to assess and reduce without analyzing the stress resilience of VCs.

In addition, the VCs analysis is an important tool for studying the formation and development processes of promising industries. In contrast to traditional microeconomic and macroeconomic analyzes of markets, VC analysis has a strong dynamic character. It makes it possible to define possible strategies for the industry and to assess the long-term sustainability of different groups of coal industry companies, identifying their full range of potentially available development paths, including those based on "clean" coal technologies and aimed at creating competitive products. Therefore, VC analysis, which focuses on finding promising transformation paths based on identifying the spectrum of available technologies, can become an effective tool for formulating strategies for the development of coal mining regions.

1. VCs stress resilience modern approaches review

The concept VC and stress resilience as a tool for evaluating the prospects for their long-term development are quite new. For this reason, it is necessary to clarify the content of the concepts before assessing the stress resilience of domestic coal mining companies .

Until the 90s of the XX century, the company was the basic unit of industrial analysis. However, the distributed (network) model of active formation of industrial technology, based on the division of branches of work, led to the strengthening of technological integration and became the basis for the formation of stable inter-firm cooperation – value chains (VCs). VCs began to play a leading role in ensuring the competitiveness of both individual companies and industries as a whole, which led to the VC concept creation [2–4]. The most famous VC definition was given by Timothy Sturgeon: "a value chain is a complete set of actions that is necessary to promote a product from its conception to the end consumer through all stages of production, including development and design, raw materials and provisional components supply, production itself, marketing and distribution, as well as providing after-sales service" [5]. Modern VCs are extremely diverse, they use various advantages of technological cooperation, companies organizational cooperation, therefore, within the VC concept there are many approach, using not only different terms to define VC, but also different notions [6, 7].

Modern literature introduces several approaches that use close notions to designate VC and describe its different aspects. Thus, M. Porter, 1985; Gereffi, 1994 [8, 9] use the concept of "commodity chains" and understand them as product creation stages within separate companies, represented by key and substantive activities. In technical studies that analyze alternative uses of intermediate products and/or industrial recycling of a resource/waste, VCs are called process chains. Research that examines ways to reduce the cost of end products by redesigning production processes, intra- and inter-firm logistics solutions refers to VCs as supply chains [10]. This approach is close to the added value chains and production networks researches, describing, respectively, the sequence of adding value stages to a product, starting from mineral resources extraction to the finished product, and the VCs organizational structures: the main types of actors, the mechanisms of chain management, and the nature of interaction between firms in the supply chain and with the external environment, especially markets, supporting infrastructure, and institutions [11–13]. The VC scale and structure can be traced in the concepts of "global, local or domestic VCs" (global value chain (GVC), domestic value chain (DVC) or local value chain (LVC) [14–17].

Despite the differences in the terms determined by the analysis and the scope of the research objectives, all the above approaches distinguish in the basic model of VC three VC key components that are interconnected:

– supply chain, which describes the key blocks in terms of distributed production – the key production and service stages in creating the final product or service;

– VC organizational model, which identifies the key chain organizational links, describes each and shows connections between them, characterizes the decision-making center and operation modes;

– value chain, which characterizes VCs in terms of how the value is formed and distributed between the VC main links.

These three blocks are closely related and mutually limit each other. The leading role belongs to supply chains because they "are complex systems consisting of organizational, informational, financial, technological, process, product and energy structures" and determine the basic options for the VCs construction. The organizational model and value chain narrow the range of options available, defining commercially successful options [18].

The dramatic increase in economic turbulence has led to another industry research innovation. The current competitiveness studying began to be expelled by the need to study the companies and industries ability to withstand internal and external negative factors (shocks). This led to the emergence of researches dedicated to the VCs stress resilience [18–20]. Stress resilience differs from classical competitiveness theory in that it allows describing the possibility of VCs sustainable functioning and modernization under conditions of continuously changing external environment. The OECD report defines it as "the ability of a system to flexibly recombine its elements and resources to achieve a dynamic equilibrium at either the previous or a new level of development in response to sudden external or internal perturbations" [21].

Before proceeding to the evaluation of the stress resilience of the Russian coal industry VCs, it is necessary to address another problem. The coal industry, like the majority of extractive industries, is falling "behind" in the VCs formation. This is due to the fact that, unlike manufacturing industries, extractive industries have predominantly developed within closed (enclave-like) vertically integrated enterprises based on additive supply chains, which are a series of successive stages of demand that cannot be carried out in parallel – all products of the previous stage are supplied to the subsequent stages as stock. The main competitiveness source of coal companies was the scale of operations expansion based on access to unique natural resources and location. For this reason it did not make good sense to build VCs and distinguish the main links affecting the risk level and competitiveness special sources. The intensification of mining processes under the influence of the depletion of readily available resources and the globalization of the economy resulted in the VC end-to-end productivity from coal mining to the market becoming a real source of added value, leading to an increase in the intensity of production, the role of ancillary industries and services, the complication of the structure of coal companies and the creation of sustainable links with companies from related industries. Accordingly, this opened up opportunities for a substantive study of the VCs aspects and their stress resilience factors in the extractive industries, including the coal one [22–26].

The authors of the article use the concept of "value chain" to denote the basic model of VCs and the concept of "supply chain" to denote the technological chain, and all these concepts are based on the concept of VC stress resilience (Aldrighetti R. et al, 2021) as "the ability of the enterprise to withstand, adapt, and recover from failures in order to meet customer demand, ensure target productivity, and sustain operations in a vulnerable environment" [18]. In relation to the coal industry, stress resilience means the ability of individual coal companies and groups of interconnected companies to anticipate and respond to change in order to survive in the short term (cost reduction, formation of new technological chains, etc.) and to seek and implement new development opportunities in the long term (formation of new supply chains in the implementation of the Industry 4.0 concept and response to external challenges: decarbonization, sanctions policy, energy transition, etc.).

2. Data and research methodology

Within the article, the authors proposed the following algorithm for the stress resilience of VCs in the coal industry: description of the aspects and typology of VCs in the Russian coal industry; assessment of their current stress resilience; description of the survival strategies of VCs; assessment of the prospects for the preservation of VCs under sanctions.

To identify VCs typical of the Russian coal industry, the authors analyzed official data from the Federal Service for State Statistics of the Russian Federation, the Central Control Administration of the Fuel and Energy Complex (CCA FEC), Rosinformugol JSC (AO), and the electronic accounting and inventory system (SBIS) for 169 companies operating in the period from 2010 to 2021. The time period was defined by the boundaries of two crises waves in 2010–2017 and 2018–2021.

The Gereffi, 2005 methodology was used to classify coal industry VCs, where five VC types were singled out: market, modular, relational, captive and hierarchical [27]. To clarify the nature of the relationships between the companies and with companies in related industries, interviews were conducted with five experts from among the top managers in the coal industry. Thus, based on criteria such as the structure of the supply chain and the organizational model, we were able to identify the basic types common to the domestic coal industry, highlight their aspects, and show the survival strategies of the companies that belong to them. As a result, of the five VC basic types

common to the coal industry, three VC types were identified: market, captive and hierarchy.

To assess the potential success as well as the ability to maintain the chosen strategy in the future under sanctions and a possible embargo on coal supplies, the stress resilience of both VCs and VCs companies was examined for the periods from 2010 to 2017 and from 2018 to 2021. For this purpose, all 169 companies were divided into three large VCs groups according to their proximity to basic model one or another type. Due to the fact that hierarchical VCs exhibit different survival strategies depending on their specialization, the hierarchical VC type was further divided into three subtypes. Subsequently, the stress resilience of VCs and selected VCs companies was evaluated based on the methodology of R. Martin, which proposes to evaluate the stress resilience of different systems based on the stress resilience coefficients (β) [28]. According to this methodology, the selected type and subtype were measured in each VC: general stress resilience (general stress resilience coefficient – β_{rescom}), which shows the VC recovery degree after a shock; robustness (resilience coefficient – β_{res}), which shows the VC ability to resist (absorb shocks); adaptability (recovery coefficient – β_{rec}), reflecting VC flexibility and ability to recover quickly after a shock.

These coefficients were calculated for two periods: the first period – from 2010 to 2017, the second one – from 2018 to 2021. The periods were determined basing on the analysis of the production volumes dynamics in the domestic coal industry. The beginning of the period was determined on the basis of the year in which the growth rate of production was the highest. The crisis year was determined based on the year with the lowest growth rate or the highest rate of decline in coal production. The final year is the year in which the growth rate of production has returned to the original value or the highest growth was recorded during the recovery period.

All three stress resilience coefficients were calculated using the same formula:

$$\beta = \frac{\left[\frac{Q_t^c - Q_{t-1}^c}{Q_{t-1}^c} - \frac{Q_t^i - Q_{t-1}^i}{Q_{t-1}^i}\right]}{\left|\left(Q_t^i - Q_{t-1}^i\right)/Q_{t-1}^i\right|},$$

where Q_t^c is the coal production volume within the VC group, in thous. tons; Q_t^i is the coal production volume of within the industry as a whole, in thous. tons; $(t-1)$ for β_{rescom} and β_{res} are the initial years of the pre-recession shock (2010 and 2018); for β_{rec}, the years of the largest production decline (2013 and 2019); t – for β_{rescom} and β_{rec}, the years of the recession recovery (2017 and 2021); for β_{res}, the peak production decline years within the industry (2013 and 2019).

The stress resilience coefficients calculations data for each VC type and subtype is introduced in the next section.

3. Domestic coal industry VCs aspects and their stress resilience level

The coal industry resource nature and industrial engineering aspects generate the coal industry VCs specific character in all three components. As noted by many authors [22–27], the coal industry primary costs constitute a significant part of the final product value and vary greatly depending on the coal assets specific characteristics and company location, so that not so much improvement as production losses determine the final value of coal value added. Due to the dependence on mining and geological conditions, as well as the qualitative and quantitative composition of the resources of the coal chain, most of the value added is in the production stage, which includes the preparatory stages, mining and processing [24]. Access to natural resources and the availability of transportation and logistics infrastructure largely determine the location of coal mining companies. For this reason, the coal industry has not been able to become distributed. Distributed production is an industrial engineering model focused on a detail-based labor division between highly specialized VCs participants working for each other. The creation process of the final product is distributed among a number of autonomous company-suppliers from different countries and regions, united under the leadership of one or more leading companies in the common project network VC, performing their narrow, highly specialized task in the project (VC link), consistently adding value to the final product at each stage of the production cycle [19]. The coal industry supply chain is still shortened and has a fairly lean additive structure [20, 22].

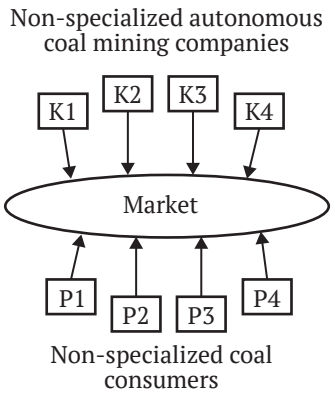
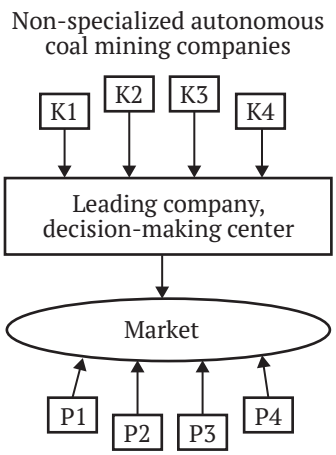
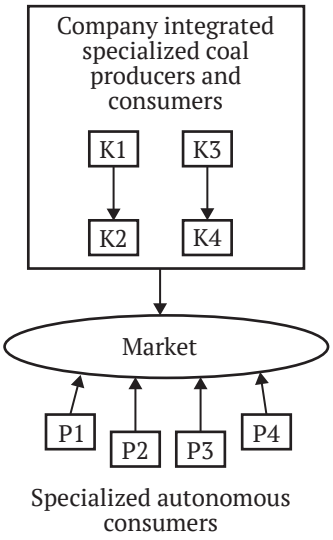
The authors dealing with coal industry VCs management and organizational structures refer them to vertically down controllable productions [20, 22, 25, 26]. The majority of VCs are referred to global closed (enclave) vertically integrated VCs of hierarchical type (Glencore, BHB Biliton, Anglo American, Siberian Coal Energy Company (SUEK), Kuzbassrazrezugol, etc.) [25, 26]. Experts point out the volatility of the coal industry, especially because of the strong negative impact of price and demand fluctuations in global markets [25, 26–31] and weak innovation susceptibility [26, 31].

An analysis of the companies operating between 2010 and 2021 showed that 90 of the 169 (53 %) op-

erated as integrated companies (hierarchical and captive VCs). They were united in 13 VCs, which composition was relatively constant. 79 enterprises were formally autonomous companies (market VCs). Among the 43 companies in the hierarchical VCs, the following specialization was found: 6 companies specialized in energy-coal, 6 companies specialized in metallurgy and coke-chemistry, and 1 company specialized in cement. Specialization was determined by the major firm consumer. 47 companies were part of 18 intermediary-type VCs –non-specialized conglomerates with no explicit specialization. Autonomous companies had no specialization and were part of market-type VCs. Brief descriptions, typical VCs schemes of the Russian coal industry, and examples are shown in Table 1.

Table 1

Typical Russian coal industry VCs (*N* = 110)

VC types/sample number	Market VCs	Captuve VCs	Hierarchical VCs
VCs sample number	79	18	13
Survivors number (operating from 2010 to 2021)	16	17	13
Supply chain structure	Coal supply chains that include only production links: exploration and extraction preparation, extraction and beneficiation	Coal supply chains grouped around a decision-making center with supporting functions: marketing, logistics, transport etc.	Coal and non-coal supply chains (energy, metallurgical, cement) subordinated to a decision-making center with back-office functions: R&D, marketing, logistics, transport etc.
VC scheme			
Organizational structure	Autonomous non-specialized companies	Group of non-specialized transaction-dependent from acquiring companies – sales and management centers in the form of a large management or large mining company	Closed, vertically integrated structure based on commodity integration of non-autonomous companies forming specialized supply chains within the vertical structure (energy, metallurgy, coke and chemicals, cement)
VCs examples	LLC (OOO) open-pit mine “Kaichakskiy-1”; JSC (AO) open-pit mine “Kanskiy”; FSUE SS (FGUP GT) Arktikugol; OJSC (OAO) mine “Ugolnaya”	LLC (OOO) “SIBUGLEMET holding”; JSC (AO) “SDS-Ugol” holding company; LLC (OOO) “Kolmar coal mining company”	JSC (AO) Siberian Coal Energy Company (SUEK); PJSC (PAO) Severstal; PJSC (PAO) Mechel; EN+ GROUP; JSC (AO) “Sibirskiy cement” holding company

Source: compiled by the article authors basing on the Gereffi, 2005 adapted scheme, CCA FEC data, and electronic accounting and inventory system database.

After dividing companies into VCs types, general stress resilience, robustness and flexibility indices were calculated for each group. Table 2 below and Fig. 1 show the dynamics of the general stress resilience, robustness and flexibility indices from 2010 to 2017 and from 2018 to 2021.

The above data clearly shows that the overall stress resilience, robustness, and flexibility of all types of VCs decreased during the second wave of crisis from 2018 to 2021, suggesting that all selected strategies need to be adjusted to maintain competitiveness and survival. Whereby hierarchical VCs, especially those with energy-carbon specialization, fared worst in terms of stress resilience.

To assess the obtained results, the index value was compared with the companies information received from the experts. This allowed to reconcile the obtained data, to establish a correspondence between the VC type and the business model of the constituent companies, and to evaluate and explain the dynamics of stress resilience of VCs in the coal industry in the long run.

4. Russian coal industry VCs business models and survival prospects under sanctions

The market of VCs in the domestic coal industry is represented by small, autonomous, non-specialized companies (without a main customer). In general, these companies are unstable, their life cycle is much shorter than the average 15-year investment cycle of the coal industry and is about 5 years. Of the 79 companies assigned to this type, only 16 (less than 10 %) operated continuously throughout the analysis period. Most have low profitability or do

Table 2

Stress resilience dynamics indices of the main Russian coal companies VCs types from 2010 to 2021

Specialization and VC type	2010–2017			2018–2021		
	General β_{rescom}	Robustness β_{res}	Flexibility β_{rec}	General β_{rescom}	Robustness β_{res}	Flexibility β_{rec}
Metallurgical and coke-chemical hierarchical	−0.04	0.18	−0.16	0.07	0.05	−0.05
Energy-coal hierarchical	5.23	13.74	-0.11	−5.01	−0.06	−1.80
Cement hierarchical	1.59	0.62	1.93	0.28	−1.02	1.80
Non-specialized “aggressive”	2.68	3.94	1.30	1.22	−0.10	0.61
Non-specialized market	0.62	0.78	0.45	12.18	0.53	3.61

Source: the authors' calculations based on the CCA FEC data.

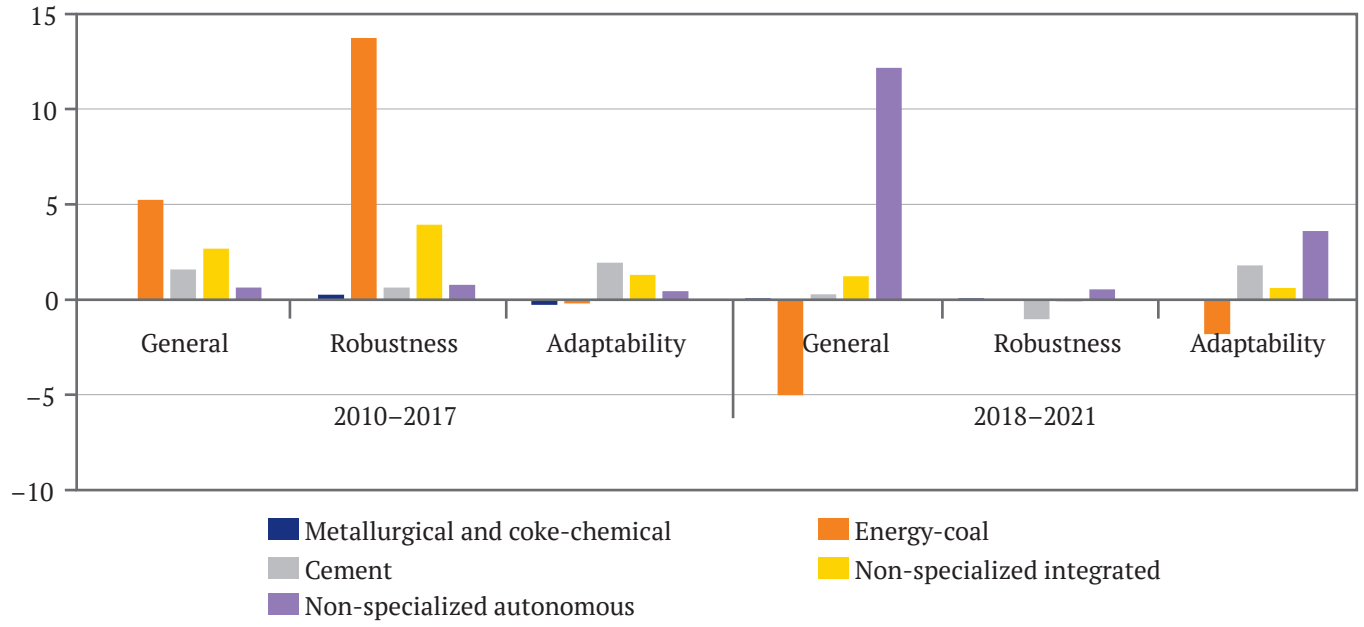


Fig. 1. Stress resilience dynamics indices of the main Russian coal companies VCs types from 2010 to 2021 (Source: authors' calculations based on CCA FEC data)

not cover their costs at all. Thus, according to CCA data, in 2020, at the height of the second wave of the crisis, only 12 companies that constituted market VCs were profitable, with profits in many cases supported by government contracts. It is significant that by 2021, 4 of these 12 companies had already filed for bankruptcy. These data suggest that the majority of autonomous companies follow a survival strategy: enter the market quickly during the boom phase of the industry and exit quickly when the market situation deteriorates. Some companies join formal and informal intermediary VCs during the boom to access the external market to balance sales volume.

The survival strategy in particular explains the unusual current stress resilience indices dynamics of such companies. The relatively low stress level of 0.62 between 2010 and 2017 rose sharply to 12.18 between 2018 and 2021. This is due to the fact that the recovery from the first wave of the crisis in 2013–2017 was due to the production growth of large companies due to increased demand in external markets. Under these conditions, the autonomous companies market niche was small and did not allow the necessary flexibility. During the second wave shock in 2020–2021, on the contrary, the production recovery was driven by the increase of supplies to domestic markets and by autonomous enterprises. The large integrated companies followed a more restrained policy regarding production output and less increased coal production.

It is also important to note that despite these impressive positive dynamics, the absolute increase in output at the expense of autonomous companies has been small, so they can hardly be considered as a stabilization and growth base for the stress resilience of the industry as a whole. It is also of importance to stress that the market companies independence was often purely formal. As part of the survival strategy, they often resorted to all sorts of informal cooperation strategies: they entered into supply contracts with each other, entered and exited the intermediary and hierarchical VCs, actively used state support, and participated in the fulfillment of state contracts. It is also important to note that it was the market VCs that used bankruptcy procedures for the survival purpose in order to reduce credit obligations. Assessing the prospects of VCs in the context of the coal embargo, we can see that while they have provided relatively high current resilience for the coal industry in 2018–2021, they are unlikely to be able to accomplish this task on their own in the long term beyond transparent collaboration with other companies.

The authors of the article refer to the intermediary VCs formed by companies of different sizes, grouped around distribution and management centers, in which function the management or large mining companies that operate in both foreign and domestic markets. They act as an integrative center to which decision-making functions are attributed and provide financial, logistics, marketing and transportation services to their affiliated companies. The relationships of intermediary VCs are based on the integration of commodities (sale of similar commodities), so the integration itself is unstable – it is a conglomerate, but more stable than the market VC. Entering the market through a central distribution company allows intermediary VCs companies to diversify sales and make demand for mined coal more stable, better control prices, and reach a wide range of large consumers, including those abroad. Thus, over the 2010–2021 period, despite changes in the composition of firms included in certain intermediate VCs, only 1 in 18 VCs ceased to exist.

The stress resilience indices dynamics of this VCs group is interesting, as it is opposite to the market VCs. Stress resilience was relatively high in the crisis first wave and fell sharply in the second. This is largely due to the maintaining competitiveness strategy, which was resorted to by the intermediary VCs companies. Between 2010 and 2017, they pursued a new business acquisition (incorporation into VC) and maintaining the core strategy of VCs, which consists of the most profitable companies with premium coal qualities. The purpose of acquiring new assets was to ensure control over the market. Such strategy was especially “successful” at the domestic market. The VCs stress resilience of at the first stage was largely ensured by the state support. Non-specialized conglomerates were created with the participation of both private companies and state institutions for development. Examples of the latter are ROSATOM and the Irkutsk Region Development Corporation. However, commodity integration and dependence on the parent company did not allow the companies that were part of the intermediary VCs to maintain long-term stress resilience, which hit them during the second wave of the crisis.

In assessing the intermediary's business strategy VC and the prospects for its long-term stress resilience, it is important to note that many of the risks associated with market VCs remain unaffected. Market VCs stress resilience decreases sharply during a recession but recovers more quickly during a revival when profits grow faster than costs. At the

same time, both the current and long-term stress resilience is lower and decreases faster if a large extractive company acts as a sales center. This can be explained by the fact that the position of the small, non-autonomous firms included in the intermediary VCs is similar to that of the autonomous firms: They stabilize the market for the parent company by reducing risks and costs during a recession, and easily join the VCs and ramp up production during the recovery. But the small companies bear the risks and costs. This was especially evident during the second wave of the crisis, when the parent companies chose the strategy of discarding the problem companies that had been added to the conglomerate during the period of price decline and, on the contrary, actively adding new small companies during the period of price increase. It can be said that the survival strategy during the crisis and the stress resilience of the intermediary VCs, just like the stress resilience of the market VCs, were maintained at the expense of the instability of their constituent firms. The difficulty of implementing such a strategy during the crisis second wave led to a decrease in all stress resilience coefficients. Under the conditions of the embargo on coal supplies, this trend is expected to continue and VC this type of stress resilience as well as its total number may be further reduced. This is likely to lead to an increase in the unstable market VCs number formed due to the cooperative links breakdown. Nevertheless, according to the authors, in this case we can expect less sanctions negative impact on this segment of the coal industry.

The group of hierarchical VCs included specialized closed vertically integrated holdings organized on the additive manufacturing basis. The group included a 13 VCs sample. Unlike the first and second groups, such VCs have a wide range of auxiliary services and productions: human resources services, in-house research and education facilities, service, engineering, transportation, logistics, distribution, and financial units that enable them to effectively manage personnel, keep companies resilient over the long term through technological innovation, market and distribution management, and optimize logistics plans and save on transportation costs. Finance and sales departments coordinate and control the company's business units activities and act as the decision-making center.

Sales diversification and supply large scale play a significant role in the hierarchical VCs sustainability. Most of the systemically important coal companies form part of the hierarchical VCs. The monopoly position in the market allows companies to react flexibly to external and internal shocks, including at the expense of production volume reduction. Own transport and logistics system allows companies to even out market fluctuations and to shift supplies from one market to another. The values of stress resilience coefficients show that companies have chosen the optimal business strategy in the period from 2010 to 2017: diversification of sales and deliveries on a significant scale provided the ability to absorb external and internal shocks (the robustness coefficient β_{res} was the highest – 13.74). However, already in this period hierarchical VCs were characterized by low flexibility (the adaptability coefficient β_{rec} was negative – –0.11). A significant role in ensuring companies stress resilience was played by their status of systemically important companies and close contacts with federal and regional authorities. However, during the second wave of the crisis, as the influence of distributed production targeting resources with predetermined characteristics greatly increased, the stress resilience of hierarchical VCs began to falter. Their closed nature, dependence on external markets, and desire to amortize the effects of the crisis by controlling output and prices led to a sharp decline in overall stress resilience. The general stress resilience index β_{reccom} dropped 10 units at once, from 5.23 to –5.01.

The analysis showed that the strategy choice and long-term stress resilience of hierarchical VCs directly correlate with the specialization of chains. Thus, companies representing metallurgical and cement holdings had low stress resistence during both periods (close to the industrial average). This occured mainly due to the coal companies subordinate position within the holdings, their strict peg to the major consumer and financial flows redistribution in favor of the main, non-coal production. During the first wave of the crisis, metallurgical and cement companies adapted more easily to the price reduction due to the relatively low cost of coal production and reduced coal production volumes less than the industry average. The constituent companies were the lowest non-autonomous link of the VCs, strictly tied to specific metallurgical or cement companies. The internal supply chains were part of a diversification policy based on commodity integration, and a means to protect against falling revenues in times of crisis. Metallurgical and cement VCs managed to retain their coal assets.

On the contrary, during the crisis wave of 2018–2021, when production costs approached the industry average, these companies were forced to divest non-core coal assets to reduce costs. In addition,

it was during the second wave that distributed production began to actively penetrate the metallurgic and cement industries. VCS set increasingly stringent requirements for metal and cement with specified properties, and accordingly the requirements for coal quality became more stringent. Previous coal assets did not always meet these requirements, and commodity integration as a tool to diversify activities and hedge against risks no longer fulfilled its role. It is significant that companies did not abandon their coal plants during the recession, but during the recovery period when prices and demand for coal were rising rapidly.

As an example, we can cite the Severstal and EVRAZ VCs. In early December 2021, Severstal Mining and Metallurgical Company shareholders signed a binding agreement with Russkaya Energia LLC to sell Vorkutaugol. In December 2021, EVRAZ transferred its coal assets (seven mines, two open-pit mines and three ore-processing plants in the Kemerovo Region and one mine in the Tuva Region) to Raspadskaya Coal Company and began the process of separating it into an independent business[1]. The sanctions imposed on EVRAZ shareholders put this process on hold. Nevertheless, we can state that the coal assets partial denial allowed the metallurgical VCs to recover faster in the face of the revival and keep the value of the general stress resilience index in 2018–2021 within the positive limits of 0.07 and 0.28, respectively. However, these values are small, given the distributed production expansion and the uncertainty of the metallurgical VCs long-term strategy, they are unlikely to cover the negative stress resilience of all specialized VCs, especially energy-coal, which suffered the greatest decline in coal demand. All this leads to the conclusion that cooperation ensures the maintenance of a higher level of current stress resilience of VCs, but in the long run, the maintenance of current business strategies of metallurgical VCs may lead to their reduction.

Unlike metallurgical and cement VCs, energy-coal VCs have always focused on global coal markets; therefore, coal mining companies and divisions have played and continue to play a leading role. The control center and the financial center are often located in the company coal mining or sales divisions. The cooperative strategy implementation made it possible to accumulate and redistribute an income considerable part in favor of the coal division and actively develop it. This ensured a high level of stress resilience for the energy and coal holdings in 2010–2017. The general stress resilience and robustness coefficients in this group of companies were the highest in the industry, 5.23 and 13.74, respectively. However, the dependence on foreign markets meant that already in the second wave of the crisis all coefficients became negative and the overall stress resilience became the lowest in the industry – 5.01. Under the Russian coal embargo, the energy-coal VC strategy is the most vulnerable, and the positive effects of the cooperative strategy can hardly offset the negative effects of reduced foreign demand. In the long run, therefore, we can expect a further decline in both current and long-term stress resilience, which could lead to the closure of some companies that are part of the energy-coal VCs, which is unacceptable given the share of systemically important companies in energy-coal VCs and the possibility that VCs will morph into a simpler relational and market-oriented form.

Conclusion

The analysis conducted has shown that the coal industry is in a difficult situation, the stress resilience of its key segments is low, tends to decrease and will only decrease in the future. In the most difficult situation are the systemic companies within the hierarchical VCs, especially the energy-coal companies, which were mainly focused on external markets, the cooperative survival strategy does not even provide support for the current stress resilience. Market and relational VCs are in a more favorable position. However, the indicator of coal production volume, the volatility of VCs, are not able to provide reliable development of the coal industry. All this suggests that part of the coal companies will inevitably close and the other part will need deep restructuring. At the same time, the current survival strategies of companies do not allow them to solve this problem alone and require the active participation of the state. In the initial phase, government support can be aimed at maintaining demand for coal for systemically important companies by redirecting coal exports eastward through transportation infrastructure development, but in the long term, stress resilience of VCs and the coal industry as a whole can only be ensured by developing cooperative relationships based on technological integration with long-term government sup-

[1] Metallurgical companies are distancing themselves from coal. EVRAZ shareholders approve Raspadskaya separation. Neftegas.ru, 11 Jan 2022. URL: https://neftegaz.ru/news/coal/720353-metallurgi-distantsiruyutsya-ot-uglya-aktsionery-evraza-odobrili-vydelenie-raspadskoy/ (Reference date: 22.02.2022)

port. This integration can be based on promising low-carbon energy technologies focused on the production of blended fuels with specific properties; digital technologies that ensure efficient logistics and maintenance of safety; robotic equipment that guarantees safety and high productivity thanks to internal collaboration with engineering companies. Precisely these technologies will make cooperative links more sustainable and the cooperative strategy less costly and more efficient. Such an approach, according to the authors of the article, will initiate the introduction of decentralized production elements in coal VCs and ensure the industry's development and stress resilience in the long term.

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