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RESILIENCE OF THE RUSSIAN COAL INDUSTRY IN THE CONTEXT OF ENERGY TRANSITION AND DECARBONIZATION

The authors undertake an assessment of growth prospects of the Russian coal industry in the modern world using the economic resilience concept. To this effect, the concept is adapted to the industry analysis. The modern research approaches to resilience—the engineering (equilibrium), ecological and evolutionary resilience—are compared, the strong points and vulnerabilities of each approach are discussed with a view to the coal industry analysis, and the time limits of the analysis are selected. The study identifies and substantiates the tools and criteria most suitable for the resilience analysis of the coal industry. The authorial procedure of assessment of the current and long-term resilience in the Russian coal industry synthesizes the general resilience index β_{rescom} and the aggregate resilience index β_{res}&β_{com}. The current and long-term resilience of the Russian coal industry is assessed over the period of 2011–2018, four segments with different current and long-term resilience are specified in the industry, and the companies in each segment are described. The accomplished analysis has allowed the authors to arrive at a well-found conclusion on the current and long-term nonresilience of the Russian coal industry between 2011 and 2018, and, moreover, the situation gets even worse under conditions of energy transition and economic sanctions. Yet the authors claim a differentiated approach to selecting development trajectories for individual segments of the coal industry can help stabilize the state of things.

Keywords: *coal industry, industrial resilience, short-term and long-term resilience, general resilience index, aggregate resilience index*
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Introduction

The global financial crisis of 2008, the nose-diving demand and prices for energy sources, the COVID-19 pandemic and the economic crash afterwards made the economic and social stabilization a particularly challenging problem and enforced researchers, politicians and businessmen to find novel development strategies for the coal industry.

The scientific community, both in Russia and abroad, increasingly more often denote the objectives of stabilization in economy and its sectors as resilience—resilience of companies, industries, regions, countries and of the world [1]. This new term emphasizes peculiarity of the crisis, highlights criticality of its overcoming using new avenues, and, also, gradually turns into a core of a new theoretical concept of the current and long-term economic development in the *new reality*. The concept of resilience turns the spotlight of economic appraisals from increment (in earnings, profit, etc.) on adaptability and flexibility, which dramatically updates the method and tools available to assess a company's or an industry's growth potential.

This article aims to adapt the concept of resilience to the industry analysis and to assess, on this basis, the growth potential of the coal industry in Russia.

Approaches to coal industry resilience

The short-/long-term resilience assessment in the coal industry, with revealed and examined factors of growth potential is an important theoretical and applied problem. For instance, shock definition or discrimination of current volatility and recession phenomena, or selection of resilience measures yet remain debatable issues. Thus, we believe it is necessary to adapt the resilience concept to the Russian coal industry analysis using a solid approach selected with regard to the analysis objectives, current trends, test industry, as well as availability and representability of data.

Economic literature distinguishes between three basic approaches to economic resilience: engineering resilience, ecological resilience and evolutionary resilience. These approaches differ by the theoretical framework (definition of resilience), object of analysis, specifics of objectives and methods of research. The details of the approaches can be found in the studies [2, 3]. The object of research is most often a region or a company, and less frequently is an industry.

The engineering approach often uses the general resilience index β_{rescom} to answer the question whether all components of a system have recovered equilibrium, and equilibrium is assumed as the system's development trajectory [4, 5]. To the authors' opinion, the engineering (equilibrium) approach estimates the current resilience of the system's components and, thereby, the current shock resistance of the system itself. However, this is a short-term estimate, which is the main limitation to using this approach in the long-term growth potential assessment and, accordingly, in the coal industry resilience analysis (**Fig 1**).

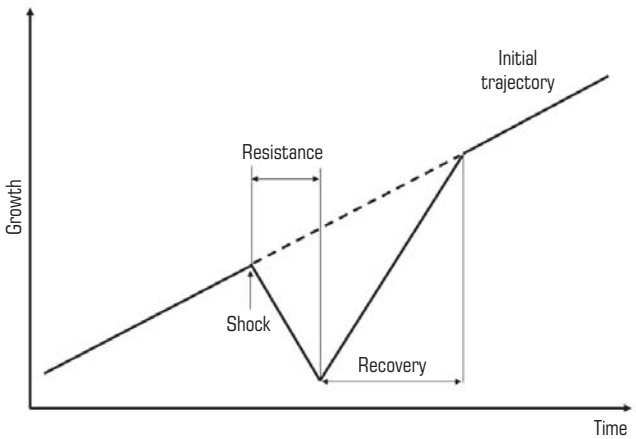

Fig. 1. Effect of a 'recession shock' on an industry's development trajectory: the industry recovers the pre-shock trend
Source: created by the authors based on Simmie et al [2]

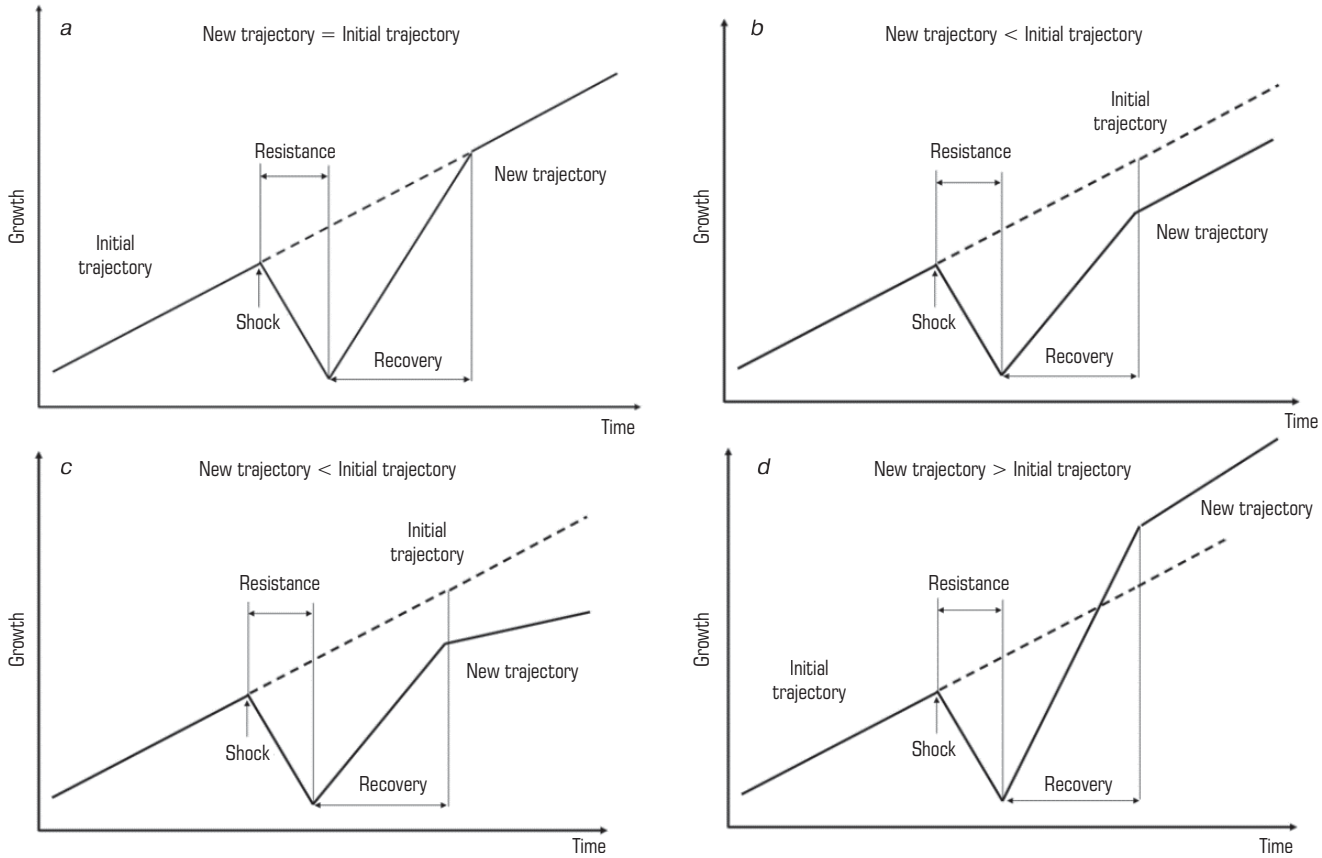

Fig. 2. Alternatives of a system's response to a shock:
a – recovery of initial equilibrium; *b* – the system is incapable to recover former equilibrium and follows the same (the same key factors) development trajectory but of lower resilience; *c* – the system recovers former equilibrium and follows a new (new key factors) development trajectory but of higher resilience; *d* – the system recovers former equilibrium and follows the previous development trajectory but of higher resilience [2]

The ecological approach is much alike the engineering approach but has another objective, namely, a system's adaptability: "capability of a system to preserve its structure, efficiency and identity after shock" [2]. Thus, the ecological approach admits potential unrecoverability of initial equilibrium both by the whole system and by its components. Equilibrium and disequilibrium are the system's development alternatives (**Fig. 2**). This is a tool to overcome the static nature of the engineering approach and to predict the system's development relative to the initially selected trajectory.

As against the engineering approach, the ecological approach uses a wider range of analytical tools, which enable assessment of the sectorial and inter-sectorial resilience, and allows identifying and estimating primary and secondary effects for allied industries, neighbor regions and individual companies. Alongside with the resilience indicators and ratings, the approach uses the Shift–Share instrument, Input–Output technique, etc.

Within the present studies, the authors attempted to synthesize the engineering (equilibrium) and ecological approaches to the resilience analysis on the ground of calculation and comparison of the general resilience index β_{rescom} and the aggregate resilience index $\beta_{res}\&\beta_{com}$.

Adapting the resilience concept to the Russian coal industry analysis requires selecting an approach and a tool, and needs to justify the data representability and the time limits. The authors reviewed the data on the coal industry performance in the time limits between 2011 and 2018. By 2011 the coal industry completed restructuring and recovered after the 2008 financial crisis, while starting from 2019, the industry gradually entered a new crisis. Thus, the timespan of the recession shock was 2011–2018.

Over the period from 2011 to 2018, the authors audited such values as the gross output of coal and the production increment (**Fig. 3a**), the national price level and the average contracted price of the exported Russian coal (**Figs. 3b** and **3c**), the income (loss) before tax and the number of loss operations (**Fig. 3d**).

The statistics shows that 2013 is the worst year for the coal industry. This study assumes 2013 as the peak of the recession shock. It is seen in Fig. 3a that the gross out of coal in 2011–2018 experiences the maximum drop in 2013 (increment 1%) and is maximum in 2011 and in 2018 (increments +6% and +8%, respectively). In 2013 the other performance measures of the industry, such as the internal prices (see fig. 3c), rates of increase in the external prices of power-generating coal (see fig. 3b) and the profit, were at the lowest level, and the number of loss operations was the highest. On this basis, the time limits of the stages of the recession shock are: the resistance period 2011–2013 and the recovery period 2013–2018.

The best measure for the resilience of the coal industry and its segments is the gross coal output. It demonstrates volatility, instability and asynchronous fluctuations in the industry's segments, and is free from the pricing-induced impact. The data on the gross output in the coal industry and per individual companies are available, are reflective of the problems in the industry and are applicable to assessing the general resilience and to identifying its constituents.

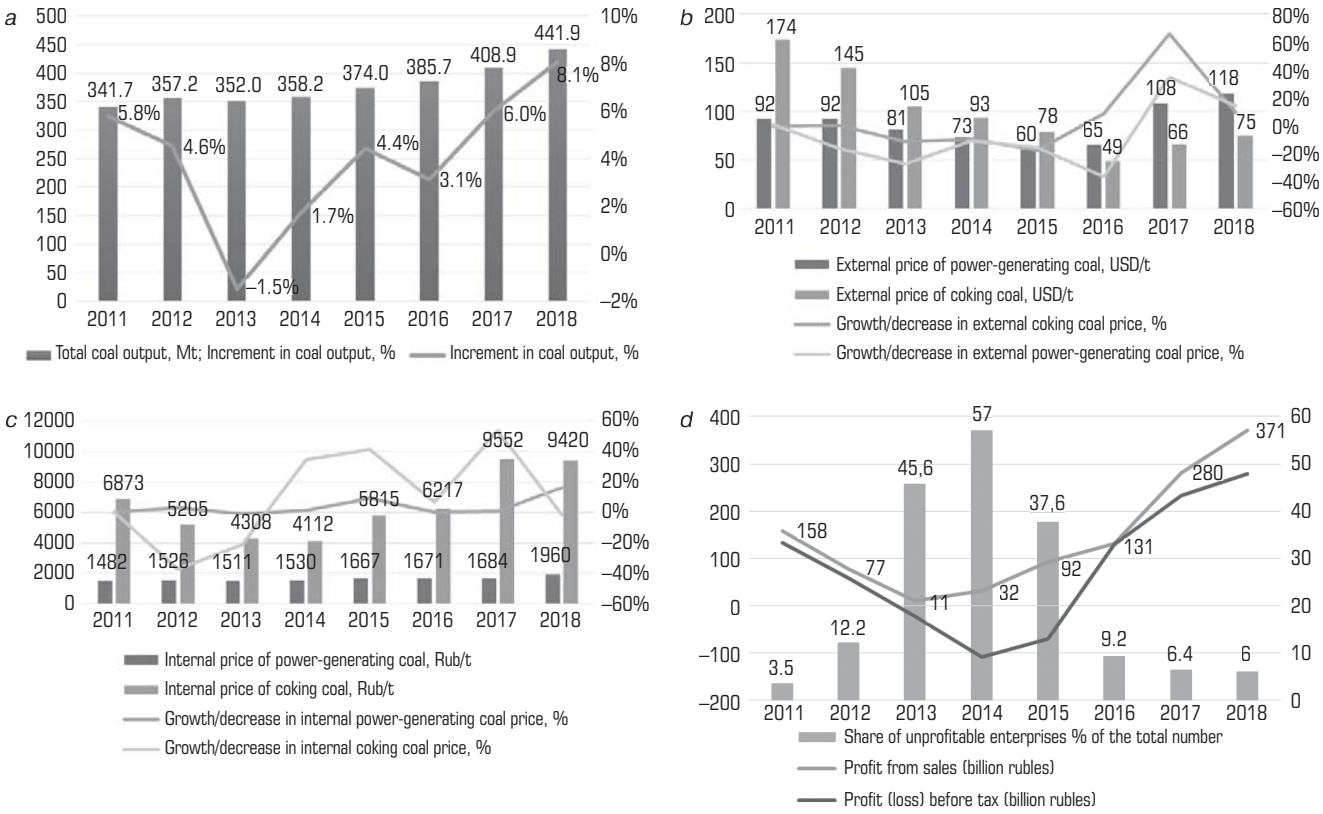

Fig. 3. 2011–2018 performance of coal industry:
a – coal gross output (Mt) and production increment (%); *b* – external price of power-generating and coking coal; *c* – internal price of power-generating and coking coal; *d* – sales profit, income (loss) before tax and number of loss operations.
Source: authors' estimates from the evidence of CDU TEK and Rosinformugol

Current resilience of the Russian coal industry

The data bank for the current resilience analysis of the Russian coal industry was the official information available from the Central Dispatching Department of the Fuel and Energy Complex (CDU TEK), Rosinformugol JSC and from the Federal Service for State Statistics of Russia (Rosstat) on coal production in Russia and per coal mining companies in 2011–2018. In Russia 53 underground coal mines and 162 open pit coal mines operated in 2021. They mostly operate in the Kuznetsk Coal Basin (Kuzbass) in the Kemerovo Region which provides more than half coal production in Russia (53% in 2020). On the whole, in 2011–2021, the number of surface and underground coal mines ranged as 162–208 but not all of them operated over the test period of time. The scope of our analysis embraced only companies operated between 2011 and 2018. For the companies composed of a number of surface and underground coal mines, only the general resilience was calculated. On the basis of these limitations, 77 companies were selected for the analysis.

Empirical assessment of economic sustainability can use a number of the existing methods and tools [6]. We selected the general and aggregate resilience measures calculated based on the dynamics of the gross coal output by analogy with [7–9]. The general index was the measure of the current resilience of a company, and the aggregate index was the estimate of the long-term resilience to reveal the companies with the similar trends of development.

For each out of 77 test companies, the general resilience index β_{rescom} is calculated from the formula:

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

where Q_t^c is the coal output of a company, kt; Q_t^i is the coal output of the industry, kt; t-1 is the first year of the recession shock period (2011); t is the final year of economic recovery (2018).

A positive-value general resilience β_{rescom} means that a company has lesser losses in the production output (or higher relative increment in the output) and / or recovers faster than at the average in the industry. That is, the company is more resilient than the coal industry as a whole. A negative-value general resilience β_{rescom} indicates a lesser resilient company than the industry as a whole. The general resilience index β_{rescom} illustrates the current condition of a company, namely, whether the company is resilient in the short term and is capable to recover the previous status. When β_{rescom} goes beyond the limits (–1; 1), it means that the company's resilience deviates greatly from the industry-wide values.

The implemented analysis showed that in 2011–2018, despite the growing coal production, the Russian coal industry was not resilient even in the short term: less than a half of the test companies (35 out of 77) had the general resilience index β_{rescom} higher than 0. The number of the companies with an essential decrease in the production output growth and with an essential deviation from the industry-wide performance ($\beta_{rescom} < -1$) was 27, or 35% of the total number of the test companies (**Table 1**).

Table 1. General resilience (β_{rescom}) of test companies N = 77

Company description	Number of companies	Percentage	Value of β_{rescom}		
			min	max	average
Nonresilience ($\beta_{rescom} < 0$)	42	55%	–4.207	–0.197	–1.778
Resilience ($\beta_{rescom} > 0$)	35	45%	0.061	34.933	5.007
Appreciable nonresilience ($\beta_{rescom} < -1$)	31	40%	–4.207	–1.007	–1.888
Slight nonresilience ($-1 < \beta_{rescom} < 0$)	11	14%	–0.943	–0.917	–0.509
Weak resilience ($0 < \beta_{rescom} < 1$)	8	10%	0.0610	0.871	0.362
Appreciable resilience ($\beta_{rescom} > 1$)	27	35%	1.009	34.933	6.480
Resilience ($-1 < \beta_{rescom} < 1$)	19	25%	–0.943	0.871	0.0548
Source: authors' estimates from the evidence of CDU TEK and Rosinformugol [10–12]					

Table 2. Companies grouped by the level of general resilience (β_{rescom}), N = 77

	Company	β_{rescom}	Size	Specialization*	Holding
Group 1. Appreciable nonresilience					
1	Razrez Inskoy Mine	–1.00684	Medium-size	C	
2	Polosukhinskaya Mine	–1.23692	Large	C	
3	Shitkinsky Open Pit Mine	–1.66436	Small	C	
Group 2. Slight nonresilience					
1	Stepnoy Open Pit Mine	–0.19749	Large	C	Russian Coal
2	Luchegorsky Open Pit Coal Mine	–0.23588	Large	C	Far-Eastern Generating Company
3	Zyryansky Open Pit Coal Mine	–0.57086	Small	C	
Group 3. Weak resilience					
1	Sibugol	0.870833	Large	C	
2	Chernigovets	0.21989	Large	C	SDS-Ugol
3	SUEK-Kuzbass	0.060666	Large	P	SUEK
Group 4. Appreciable resilience					
1	Permyakovsky Open Pit Mine	5.934517	Large	M	Stroiservis
2	Berezovsky Open Pit Mine	5.604258	Large	P	SUEK
4	Invest-Uglesbyt	2.7165	Medium-size	C	Razrez Yuzhny
Source: authors' estimates from the evidence of CDU TEK and Rosinformugol [10–13] *C—coal mining; M—metallurgical coal; P—power-generating coal					

Underground mines featured lower current resilience than surface mines had. In 2011–2018 the average value of the resilience index of underground mines agreed with the slight nonresilience level and equaled –0.771, that reliance index value of surface mines fitted the weak resilience and was 0.333. Our conclusion is that open pit coal mines ensure the current resilience in the industry. Correlation between the size, specialization and general resilience of a company went wrong (**Table 2**).

Pointedly, each group contains both dependent and independent companies of different size, location and specialization. This implies that the traditional factors of competitiveness, such as the big size of a company, its belonging to a holding, or favorite location, have no more weight and guarantee no even current resilience. In the meanwhile, the type of assets (power-generating or coking coal) and the method of mining (opencast or underground) greatly affects the companies' expenses and govern their competitiveness, which influences the short-term resilience of both individual companies and the whole industry.

To capsule the assessment of the current resilience of the Russian coal industry, it is expected to observe its further reduction in the nearest future. The mainstream in the global policy and energy economy is the *climatic agenda* aimed to abate the adverse manmade environmental impact owing to reduced greenhouse gas emission. The 2015 Paris Agreement ratified by almost every member of the United Nations (including Russia) sets quantified goals on restraining or reducing greenhouse gas emission for each country [14]. Among other things, decarbonization entails abandonment of coal and hydrocarbons in favor of renewable energy sources and hydrogen energy. Many countries have already been reducing the use of coal. The 2022 economic sanctions against Russia tightened the grip over the export-oriented coal industry in the country.

This situation calls for adapting the coal sector to the external impact. The adaptation mechanisms should target at the long-term resilience maintenance with differentiation by groups of companies, and should contain:

- short-term balancing techniques;
- mid-term stabilizers oriented at gradual closure of some loss operations and at abatement of consequent social and economic tensions and ecological implications;
- tool and regimes of competitive recovery of the coal industry toward its long-term resilience growth.

To this effect, we should assess the long-term resilience in the coal sector.

Long-term resilience of the Russian coal industry

The long-term resilience assessment and its correlation with the short-term resilience involved calculation of the aggregate resilience index β_{res}&β_{rec} for 77 test companies.

The results were used to group the coal mining companies as follows:

Group I—Low resistance and slow recovery: $\beta^c_{res} < 0$ & $\beta^c_{rec} < 0$;
Group II—Low resistance and fast recovery: $\beta^c_{res} < 0$ & $\beta^c_{rec} > 0$;
Group III—High resistance and slow recovery: $\beta^c_{res} > 0$ & $\beta^c_{rec} < 0$;
Group IV—High resistance and fast recovery: $\beta^c_{res} > 0$ & $\beta^c_{rec} > 0$.

Groups II and IV are the companies with favorable growth prospects. Group IV is the companies which have high current and long-term resilience. The growth trajectory of these companies needs no amendment or governmental support. Group II unites the companies which suffer from current instability, with the higher drop in the rate of growth in crisis than it is at the average in the industry, but the long-term development strategy selected by these companies allows them to recover faster after shock.

Groups I and III are the companies with unfavorable trajectories of long-term development. They need special measures to be undertaken to alter the situation, or require involvement of the government

either to close a company gradually or to mitigate the impact of long-term adverse factors. The companies in Group II are relatively stable in terms of the current resilience and can manage crisis independently (high resistance), but in the long term, because of inability to recover quickly, these companies will plump into a hostile segment of the market. Maintenance of resilience of such companies may need mid-term stabilization activities as in Group II. Group I is the worst situation. These companies are unstable both in terms of the current and long-term resilience.

As in case of the general resilience assessment, each of the four groups above include all types of companies. Each group contains both dependent and independent coal mining companies of different size, location and specialization. Building a long-term resilience by a company may need introduction of new business models and upgrading of value chains.

From the analysis of the cost creation sequence stages and from the studies into internal and external interactions within these stages, it is possible to identify groups of resilience factors. The pioneer researchers tried to correlate competitiveness and prevailing value chains in industrial branches [15–22]. Finding, examination and explanation of linkage between the short-/long-term resilience, on the one hand, and the nature of value chains, on the other hand, is a critical trend of resilience research in the Russian coal sector.

Conclusions

The analysis accomplished by the authors shows that, despite the increasing output over the period of 2011–2018, the Russian coal industry was not resilient. In the teeth of the present zero generation, abandonment of coal generation and risk of the drop in demand for the Russian coal on foreign markets, it is yet possible to preserve the domestic coal industry using a differentiation approach to maintenance of individual companies and their segments identified with the help of assessment of their general resilience (β_{rescom}) and aggregate resilience (β_{res}&β_{rec}).

The authors believe the short-term and long-term resilience to be maintained requires introducing new flexible technologies and accounting for the specifics of individual companies. Finding the ways of building the long-term resilience needs analyzing business models and value chains from the viewpoint of their flexibility and adaptability. Such analysis is a critical trend of the further research of resilience in the coal industry.

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