DOI: 10.18721/JE.14206
UDC 338.242

APPLICATION OF COMPLEMENTARY ASSETS IN MINING INDUSTRY: DEFINITION, NATURE, AND FEATURES

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The article is devoted to the analysis of the possibilities of increasing the efficiency of a mining company by managing specific assets using a complementary approach. The relevance of the work is caused by the fact that the mining industry differs from other sectors of the economy because of the specificity of the mineral raw materials and production processes. The mineral resources assets that form the company's mineral resources potential are unique in nature. Their main feature is the depletion and dependence of the value of mineral raw materials on the influence of a combination of factors, whose action can cause both its decrease and increase. In addition, the specifics of the mining processes determine the organization of activities, complicating the management of a mining enterprise, which, along with constantly changing external factors, forces the management of a mining company to look for new ways to improve production efficiency. The purpose of the study is to establish the role of digital assets in the activities of mining enterprises and determine the necessary requirements for their successful operation. In the course of the study, an analysis of Russian and foreign scientific literature was carried out, the experience of mining enterprises was studied, and methods such as comparative analysis, systematization and generalization of the results were used. The article discusses the growing importance of digitalization for mining enterprises. The problems of introducing digital assets in the mining industry have been identified. The authors substantiated the need for complex integration of digital assets with other assets, and identified the relationships between them. The concept of complementarity in the analysis of intangible assets is disclosed and the characteristics of complementary assets are clarified. It was revealed that it is the complementary assets that contribute to improving the efficiency of mining companies through the development of open innovations, provided that the necessary environment is created. The significance of this study is that it will allow the management of mining companies to make adjustments to the organization of production and management processes in order to increase their economic efficiency. The directions of further research are the presentation of a model for the integration of complementary assets and the development of a methodology for assessing the complex economic effects of the use of complementary assets in mining companies.

Keywords: mining industry, economic efficiency, assets, intangible assets, complementarity

Citation: D.A. Ivanova, T.V. Ponomarenko, Application of complementary assets in mining industry: definition, nature, and features, St. Petersburg State Polytechnical University Journal. Economics, 14 (2) (2021) 92–104. DOI: 10.18721/JE.14206

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ПРИМЕНЕНИЕ КОМПЛЕМЕНТАРНЫХ АКТИВОВ В ГОРНОЙ ПРОМЫШЛЕННОСТИ: ПОНЯТИЕ, СУЩНОСТЬ, ОСОБЕННОСТИ

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Статья посвящена анализу возможностей повышения эффективности горной компании за счет управления специфическими активами с применением комплементарного подхода. Актуальность работы обусловлена тем, что горнодобывающая промышленность отличается от других отраслей экономики специфичностью объекта работ и процессов производства. Минерально-сырьевые активы, формирующие минерально-сырьевой потенциал компании, являются уникальными по своей природе. Их основной чертой является исчерпаемость и зависимость ценности минерального сырья от влияния совокупности факторов, действие которых способно вызывать как ее снижение, так и увеличение. Помимо этого, особенности самих процессов горного производства определяют организацию работ, усложняя управление горным предприятием, что наряду с постоянно изменяющимися внешними факторами заставляет менеджмент горной компании искать новые пути повышения эффективности производства. Цель исследования – установление роли цифровых активов в деятельности горных предприятий и определение необходимых требований для их успешной работы. В ходе проведенного исследования был осуществлен анализ российской и зарубежной научной литературы, изучен опыт добывающих предприятий, а также были использованы такие методы, как сравнительный анализ, систематизация и обобщение полученных результатов. В статье рассмотрено растущее значение цифровизации для предприятий горной отрасли. Определены проблемы внедрения цифровых активов в деятельность горной компании. Авторами обоснована необходимость комплексной интеграции цифровых активов с другими активами, определены взаимосвязи между ними. Раскрыто понятие комплементарности при анализе нематериальных активов, уточнены характеристики комплементарных активов. Выявлено, что именно комплементарные активы способствуют повышению эффективности деятельности горных компаний за счет развития открытых инноваций при условии создания необходимой среды. Значение данного исследования состоит в том, что оно позволит менеджменту горных компаний внести коррективы в организацию производственных и управленческих процессов с целью повышения их экономической эффективности. Направлениями дальнейших исследований являются представление модели интеграции комплементарных активов и разработка методики оценки комплексных экономических эффектов от применения комплементарных активов в горных компаниях.

Ключевые слова: горная промышленность, экономическая эффективность, активы, нематериальные активы, комплементарность

Ссылка при цитировании: Иванова Д.А., Пономаренко Т.В. Применение комплементарных активов в горной промышленности: понятие, сущность, особенности // Научно-технические ведомости СПбГПУ. Экономические науки. 2021. Т. 14, № 2. С. 92–104. DOI: 10.18721/JE.14206

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Introduction

A modern mining enterprise constantly faces various challenges, caused by both external and internal factors. Undoubtedly, the mining industry is unique, since it deals with mineral resources, which characteristics are determined by nature. They include the exhaustion and non-renewability, the volume and thickness of the underground mineral, the depth of occurrence, the lack of free access to it, the qualitative composition of raw materials and the presence of impurities, the heterogeneity of the distribution of useful components, the variability of the form of the deposit in the case of solid minerals, and so on. Along with the characteristics of the mineral itself, the characteristics of the host rocks are also determined by natural factors and do not depend on humans, for example, the strength of the enclosing rocks, a tendency to dynamic and gas-dynamic phenomena in the form of rock bursts, rock and gas emissions, water breakthrough into mine workings. This causes not only the possibility of unforeseen situations and accidents in the workplace, but also the impossibility of accurately predicting the costs, which complicates their management and optimization.

In addition to the specific features of mineral resources, the production process and the process of managing production assets also have a number of characteristics that distinguish them from processes in other industries.

Firstly, mining enterprises are characterized by low profitability. This is due to the fact that added value in mining is created mainly during the processing, while the number of consumers of mining enterprises is usually limited, which negatively affects the level of prices and profit. This is driving the need for mining companies to reduce the cost of owning, maintaining and repairing assets.

For example, we have calculated its profitability indicators of the North Urals Mine, the raw materials division of RUSAL company, on the basis of the financial statements posted on the company's website (Table 1).

Table 1. Analysis of the profitability of the North Urals Mine

Indicator	Value, %
Profitability of sales	7,6
Return on assets	3,94
Return on equity	6,77

Source: compiled by the authors based on https://rusal.ru

Profitability characterizes the degree of efficiency of the use of various resources: material, labor, finances, etc. At the same time, there are no standard indicator values of profitability, they vary depending on the industry and the enterprise. For mining companies, the indicators are in the range of 3–7%. This is due to the fact that many enterprises are raw material divisions and are practically devoid of independence in managerial decision making. This leads to limited planning opportunities when implementing investment projects, purchasing equipment, upgrading, etc.

Secondly, the industry is characterized by high capital intensity, which is associated with the need for a large amount of expensive equipment for the extraction of raw materials. As a consequence, one of the characteristics is high capital intensity and, consequently, low capital productivity. Here we can add that the requirement on equipment also determines the high material consumption due to the need for maintenance and repair of this equipment. For example, the construction of new capacities of mining and chemical holdings is estimated at about 1.5 billion US dollars per 1 million tons of P_2O_5 [1].

Third, mine workings as well as specialized buildings and structures have a significant share in the total volume and value of assets. Their specific feature is that, taking into account the proximity of mining production to the place of work and the location of the deposit at a considerable distance from the developed infrastructure, after the closure of the deposit and the liquidation of the enterprise, such fixed assets become illiquid. For example, due to the deterioration of mining and geological and production conditions, as well as the quality of the extracted raw materials at the Kashpir shale deposit, at the end of the last century, it was stated that the further work was inexpedient. As a result, a comparative analysis of the costs of conservation and liquidation of production was carried out, which showed that both options are quite costly. Thus, the conservation of the mine requires the expenditures for electricity, ventilation, pumping water and other processes, which was considered economically unviable. As a result, the mine has been closed, despite the fact that it also implies significant costs for backfilling inclined shafts, equipment removal, reclamation of disturbed land, but in comparison with conservation it is more favorable [2].

Fourthly, the extraction of raw materials is characterized by constant movement in space as the work progresses, which leads to an increase in transportation costs, the need for permanent equipment of the workplace, etc. For example, today, work in underground mines is carried out at a depth of up to 5000 meters, as is the case at the Tau Tona mine in South Africa [3]. This necessitates the solution to the problems of supplying communications, ventilation, equipment delivery using modern methods and new technologies.

For these reasons, managing a mining enterprise, even under favorable external conditions, is a very complex process. And given that the external environment is also very changeable and makes its own ad-

justments, caused, for example, by changes in prices for raw materials, fluctuations in supply and demand, various political and economic factors, for effective management of mining production, a complex of organizational, technical and economic measures is required, designed not only for a specific enterprise, but also adaptable to constant changes.

The most important factor complicating the management of a mining enterprise is the specifics of the assets of a mining enterprise. The mining company has mineral assets which do not exist in any other industry. Despite the fact that mineral raw materials and mineral reserves are identified as a separate asset by many scientists [4, 5, 6], their characteristics as an asset and the processes of change in their cost are not widely reflected in the literature. At the same time, analyzing the course of the main production process associated with the extraction of mineral raw materials, it is obvious that as the extraction proceeds, the reserves decrease, which, as a result, affects the assessment of the value of the mineral asset. The value of mineral resources is a complex concept and is formed on the basis of a combination of factors that can be combined into several groups [7]: mining and geological, geographical and economic factors.

Mining and geological factors, in addition to reserves of raw materials, also include production conditions (structure, thickness, depth), quality of raw materials (estimated grade of an orebody, ore preparation characteristics), technical and environmental conditions of the deposit. Geographic factors describe the location of a deposit and take into account the availability of infrastructure, for example, transport accessibility. Economic factors include changes in demand in the domestic and foreign markets, fluctuations in raw materials prices, taxation system, and so on.

These groups of factors differ not only in their nature, but also in the degree of stability. According to experts [7], mining and geological and geographical factors are the most controllable, while economic factors are more difficult to predict and manage. A striking example is the changing situation on the rare earth metals market. The mining of rare earth metals began in the 19th century, but a rapid growth in demand was recorded at the end of the 20th century. So, if in 1980 the volume of production of rare earth metals in terms of oxides was 26 thousand tons, then by the mid-2010s it increased to 100–120 thousand tons [8]. This is due to the growing consumption of rare earth metals by the rapidly developing high-tech sector. Naturally, the change in the volume of demand for rare earth metals caused the development of the market and, as a consequence, changes in prices. So, if in the 1980s and 90s China was the leading producer of products, retaining monopoly control over the market thanks to government programs in the country, then from the early 2000s the situation changed, and China began to reduce export volumes. Naturally, given the absence of alternative suppliers at that time, this led to an increase in prices, whose volume was difficult to predict. As a result, if in 2009 the weighted average price of rare earth oxides fluctuated at the level of $10/kg, then in mid-2011 it reached the level of $190/kg [8], which confirms the above-mentioned complexity of forecasting economic factors and their spontaneous nature.

Therefore, it would be a mistake to say that the value of mineral assets definitely decreases with a decrease in their reserves, since the volume of reserves is only one of the factors influencing the evaluation. Considering the total value of the assets of a mining company, we can conclude that a decrease in the volume of mineral reserves makes its negative contribution, but in addition to tangible assets, the mining company also has intangible assets, whose number and variety is rapidly growing in the context of digitalization.

Today, digital assets deserve special attention, as their use affects various industries, including the mining industry. In the academic environment, the volume of publications devoted to the use of digital technologies in the process of extraction and processing of minerals is relatively large. At the same time, both in Russian and in the foreign literature, various kinds of issues are analyzed: from the use of new technical and digital achievements [9–17] to changes in management processes at a mining enterprise [18–20]. The existing publications are distinguished by a variety of approaches. Some authors [9, 10] focus on the kind of extracted raw materials, taking into account their characteristics and problems arising during extraction. Other researchers [11] focus on solving a certain production problem. Still others [12–15], on the contrary,

analyze the existing digital technologies and discuss the possibility of their introduction into the industry. The most popular technologies include the Internet of Things [12, 13] and the emergence and development of digital twins [14, 15]. The fourth [16–20] consider the problem comprehensively, from the point of view of the impact of the digitalization process on the industry as a whole, while emphasizing emerging trends and issues, as well as drawing parallels between similar processes in Russia and abroad. At the same time, the authors agree that, despite significant technological progress, the mining industry is not among the leaders in the implementation of digital technologies, also because digitalization is introduced partially. Companies do not always create the necessary infrastructure to operate digital assets, as these assets are viewed separately from their complementary assets.

Despite the fact that the emergence of the definition and concept of complementarity dates back to the nineties of the XX century, these ideas have become relevant in recent years in connection with the development of digital assets. Moreover, if abroad they attract the attention of specialists from different industries [21–22], then in Russia they have not become widespread yet [23–26]. At the same time, today the complementarity of the assets of a mining enterprise remains a topic characterized by a lack of research.

This paper examines the role of new digital assets in the development of a mining enterprise and their impact on the efficiency and value of assets of mining companies.

The object of the research is the Russian industrial enterprises of the mining industry, in particular, the North Urals Mine.

The subject of the research is the economic and managerial relations arising during the formation and functioning of complementary assets at mining enterprises.

Purpose of the study

The purpose of the study is to establish the significance of complementary assets for increasing the economic efficiency of a mining enterprise. To achieve the goal, the following tasks have been set:

- analysis of problems arising in the implementation and use of digital assets;
- determination of the conditions for the most effective functioning of digital assets;
- research into the digitalization of the industry from the point of view of the concept of complementarity;
- determination of the characteristics of complementary assets.

Methodology

We analyzed Russian and foreign literature, including the academic sources and the experience of mining enterprises, devoted to the problems of the industry digitalization, the role of digital assets in the production and management process and the introduction of a complementary approach in management. Current trends are identified, existing methods are systemized, and obtained results are generalized.

Results and discussion

Digitalization today finds application in all areas of the economy, and the mining industry is no exception [19]. The flagship industries in the implementation of digital products and technologies are IT, banking, education, biotechnology and medicine, but the mining industry can also show some success. The heterogeneity is clearly visible in this case, what is expressed in the development of digitalization in the oil and gas industry and in the lagging behind of other sub-sectors. The reasons for this lag are the lack of qualified personnel, the low level of production automation, and the cyber threat defense system that needs to be improved [9, 27]. Existing examples show that while most Russian and foreign oil and gas companies such as Eni S.p.A. (Italy), Equinor (formerly Statoil) (Norway), PJSC Gazprom, PJSC Lukoil are digitizing their fields and developing programs for the development of digital technologies; digitalization has not yet achieved outstanding results at enterprises for the extraction of solid minerals.

At the same time, experts agree that, despite the conservative nature of the industry and the existing problems, digitalization should be considered as a "new paradigm" of development that can significantly improve production performance [9, 10].

Therefore, the company management, who wants to make the production process more innovative, introduces new technologies, not paying enough attention to the current conditions for implementation. Thus, there are examples showing that the acquisition of fixed assets not only will not have a positive effect, but also will lead to problems. For example, Eni S.p.A. had to close the HPC3 hybrid computer project, which was intended for use in the exploration and production of hydrocarbons. The reason, according to the experts, was the incompatibility of the computer with the data obtained from other existing equipment [9], i.e., in fact, digital technologies turned out to be incompatible. Unfortunately, situations of this kind are quite common, despite the fact that the thesis about the insufficiency of the isolated introduction of new technologies has been formed and clearly substantiated in the academic community [20]. In the era of digitalization and the rapid development of technology, a transition to digital thinking is necessary, and it should be carried out at the stage of the company strategy development. Then the management solutions will be integrated into the mining company's strategy in such a way that they will complement and improve the existing ones and contribute to the growth of their efficiency.

An integrated approach to the digitalization of mining companies should be based on the consideration and assessment of factors in relation to assets. Speaking about the combination and mutual influence of assets, it is necessary to note the theory of complementary assets, introduced by Paul Milgrom [28]. The term "complementarity" reflects the interrelation of changes. Milgrom extended this concept to the resources or assets of the company, which he called complementary, if the effect obtained from the joint use of these assets exceeds the total effect from the use of these assets separately, which can be expressed by the formula:

$$E(A1, A2, A3) > E(A1) + E(A2) + E(A3),$$

Source: compiled by the authors

where E (A1), E (A2), E (A3) are the effects of using assets 1, 2 or 3, respectively, E (A1, A2, A3) is the total effect of the joint use of assets.

Separately, we note that it would be wrong to talk exclusively about a positive effect, and there are no linear dependencies between changes in one asset and the efficiency of a mining enterprise. In some situations, a change in one asset leads to a worsening of the situation in the enterprise due to the lack of the necessary complementary asset, which happened in the above stated example with Eni S.p.A.

As for the existing approaches to the consideration of complementary assets, in the most general classification they are divided into three groups: human, structural and computer capital [29].

Human capital is the ability and motivation of employees, their culture, values, relationships.

Structural capital is the organization of activities, its principles and approaches. This also includes decision-making models, the formation and transfer of responsibility, the rules and standards adopted in the company and the business processes. In this case, we are talking about different levels of the organization: from individual work groups and departments to the entire organization as a whole and its interaction with external agents.

Computer capital includes data and systems for their storage, processing and transferring.

Sometimes this classification can be found in a modified form: economic competence, innovative property, computerized information [30]. Moreover, these components can be correlated with the above-mentioned classification, namely:

- economic competencies include human capital, brand, organizational changes;
- innovative property is a narrower category, in contrast to the previous classification, and includes only R&D;
- computerized information contains data and software.

All three components are present in companies, and if the organization itself is stable, then these assets are complementary. However, this statement is true in terms of a static picture. The organization is a dynamic system where all the components interact with each other and change. Therefore, two clarifications deserve special attention.

Firstly, an important asset characteristic is their stability. Assets change under the influence of various factors, but to varying degrees. It is related to their nature and their sensitivity to certain processes. Thus, an asset (or a group of assets) changes faster than others, which, in turn, begin lagging behind. Of course, complementary connections do not allow this gap to become critical, so the system passes into a new stable state, which remains so until the next change. For example, in the mining industry, this can be observed when purchasing new, more modern and high-performance equipment or when implementing hardware and software. The development of computer capital in this way entails the need for employee training, because otherwise this introduction will not make sense. For example, within the framework of the "Technological Breakthrough" program, OJSC MMC Norilsk Nickel has introduced a planning and control system for ore flow, which allows continuous monitoring of the intensity of the ore flow in order to manage the ore blending processes [11]. The functioning of this system implies the presence of a unified geological database and a system for automated accounting of ore movement. At the same time, one of the most important requirements is the creation of a dispatching system for organizing operational management and production control, which is implemented in the company. Thus, the computer capital initiates the development of the structural capital, and taking into account the fact that the efficiency of the system will also be influenced by the motivation of employees and their skills, consequently, the human capital as well. Improving these two components is essential to get all the advantages that were expected by the implementation of a computer asset.

Secondly, it is important to note that assets, in spite of their inequality, cannot be classified in terms of importance. Their mutual influence does not make it possible to single out the main asset, whose value would exceed the value of other assets. The solution to the problem can be possibly found only at the micro level, where the main asset can be determined based on the analysis of the specific enterprise, the industry, the production indicators and goals.

For example, considering a mining enterprise and taking into account the specifics of its work and the requirements for employees, the leading role among the three components of complementary assets should be given to the structural capital. The need for conducting the operations in hazardous conditions makes compliance with rules and standards extremely important. This is also due to the high dependence on natural factors, whose prediction is not always possible even with the use of the most modern technologies. The second place in importance for the enterprise is taken by computer capital, whose development is proceeding at a high rate and, taking into account the non-lagging of other complementary assets, can bring significant benefits. Human capital at a mining enterprise will close this list, despite the development of the concept of corporate social responsibility and its proven need for the society. The mining industry does not belong to the industries where the human capital plays a major role and directly predetermines the efficiency of an enterprise, at the same time underestimating the human capital is also a serious mistake.

So, taking into account the above-described situation, it is impossible to draw a conclusion about its stability. The basis for making managerial decisions on the extraction of raw materials is technical projects, R&D, instructions and regulations. Formerly the structural capital of the company was built on the basis of a minor use of digital technologies due to their weak development. Today, thanks to the growing degree of digitalization of the mining industry, exactly the digital assets provide data on all activities occurring at the field and facilitate their processing and visualization. Thus, over a relatively short period of time, the share of digital asset use has increased significantly, which confirms the high degree of variability of complementary assets. For example, the North Urals Mine today is operating at a depth exceeding 1000 meters, which determines significant risks. In order to optimize production processes, the company uses the PRESS 3D URAL software package, whose task is to identify especially dangerous zones prone to rock bursts [31].

If earlier the mining process was regulated mostly by legislative enactments, today the use of digital assets made it possible to increase the accuracy of predictions and, accordingly, the safety of work.

Speaking about the value that complementary assets have, we want to highlight two important features. Firstly, they represent the sources of innovation needed to create a product or service. Secondly, they facilitate or simplify the course of the innovation process, caused by them or without their participation. For example, complementary assets reduce risk, help lower transaction costs, and so on.

Given that complementary assets contribute to the production and transfer of innovation, providing interaction between the company and the external environment, it can be argued that they represent an important component of open innovation.

The concept of open innovation emerged in the early 2000s with the publication of Henry Chesbrough's book "Open Innovation: The New Imperative for Creating and Profiting from Technology" [32]. The concept quickly became popular and discussed among specialists in the field of innovation management [21, 33, 34]. Its essence lies in the fact that for any company the innovation process is difficult if it takes place in isolation from external market participants. Firstly, not every company is able to develop and implement an innovation on its own. This is determined by the industry the company operates in, its specifics, size, etc. Secondly, by closing themselves off from the outside world, companies often duplicate developments. At the same time, the intellectual potential of employees is spent on already known innovative results, instead of uniting with the potential of stakeholders to solve new problems. In addition, there are cases when companies reject the innovations they have developed due to the impossibility of their use at the moment for a number of reasons. And only spreading the innovations outside of the enterprise allows them to find application [34].

The idea of open innovation determines the need for a company to interact with the external environment in order not only to obtain greater efficiency from the ongoing innovation process, but also to have the possibility to implement the concept. Despite this, in the literature there is a noticeable shortage in the number of publications devoted to the consideration of these topics in a comprehensive manner. Complementary assets and open innovation are considered independently of each other, although openness to innovation does not determine a company's success in itself. At the same time, openness is understood as a combination of factors such as the number of alliances of a company, the variety of partners (universities, laboratories, start-up companies, suppliers, consumers), the share of R&D carried out in external organizations, etc.

For the successful implementation of this idea, a necessary condition is just the development of intangible complementary assets. It is their competent combination and application that will ensure the necessary interaction with the external environment.

Taking into account the analysis carried out, we will single out the main features that assets should have to be classified as complementary ones.

Firstly, two or more assets can be considered complementary when they are linked together in their application. The exact number of assets is determined for each specific situation and enterprise.

Secondly, at least one of the complementary assets must be specific. This determines its use at a particular enterprise, the impossibility of copying and, as a result, receiving benefits.

Thirdly, assets are characterized as real options. This means that the company is able to carry out its activities without the use of such assets, however, their implementation and operation brings a greater economic effect than the refusal to use complementary assets.

Fourthly, one of the assets determines the creation, implementation and use of the other. Moreover, the links between assets are not one-way. The development of one asset stimulates the development of the other, which, undergoing changes, influences the first one.

Fifthly, the constant evolution of assets causes their growth, which, as a result, contributes to an increase in their value for the enterprise and, accordingly, cost. Complementary assets, when used optimally,

provide an enterprise with a range of competitive advantages that can improve the efficiency of production processes.

Conclusions

In the course of this study, the following results were obtained:

1. when considering and analyzing the problems arising during the implementation and use of digital assets in the mining industry, it was found that the specific features of the industry do not allow it to be among the leaders in the implementation of digital technologies, however there is already some positive experience, whose development will help companies achieve high results;

2. for the effective functioning of digital assets in the industry, certain conditions must be created, including a developed infrastructure for the implementation of assets and trained personnel;

3. the digitalization of the industry should be considered from the point of view of the concept of complementarity, that is, digital assets should be interconnected with structural and human capital;

4. the assets must have certain characteristics in order to be counted as complementary ones.

A company is not just a complex mechanism, but also a dynamically developing structure; in order to meet the challenges of the environment, it must make a choice in favor of developing its innovative potential. However, the concept of open innovation cannot fully function without the creation of the necessary conditions. The main condition is to support openness with complementary assets. Complementary assets are a combination of mutually influencing intangible assets, they create an environment for the functioning of open innovations and directly affect the growth of their efficiency. The synergistic effect obtained from complementarity allows the company not only to get significant results, but also to state that existing assets, including digital assets that have been actively developing recently, increase their value over time, thereby compensating for the decrease in the cost of mineral assets due to the depletion of the mineral resource base and deterioration in the quality of raw materials.

Directions for further research

The directions of further research are a deeper study of the interrelation of complementary assets at a mining enterprise, the development of a model of their integration, as well as the presentation of a methodology for assessing the complex economic effects of the use of complementary assets in a company.

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Статья поступила в редакцию 28.02.2021.

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