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Convergent Technological and Hyperconvergent Forms of Productivity Improvement in the Extractive Sector of Economy

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Abstract. The advancement of the extractive sector is affected by a combination of external and internal factors, such as the volatility of world prices with demand for raw materials and the peak of productivity due to technological limitations. In this context, the global demand for raw materials may lead to different issues and an increase in productivity is dependent on the widespread adoption of technologies, which form the essence of Industry 4.0. Therefore, this research aimed to identify the influence of convergent technologies on productivity in the extractive sector of the economy and determine the role of national technological platforms in facilitating the process. The research methodology was formed by the works of Russian and foreign economists in the field of raw materials markets analysis, mineral sector productivity, perspectives and conditions of Industry 4.0 development, technological convergence, as well as regulation of innovation interaction between science and production. The results showed that a recurring cycle of long-term developmental challenges, "productivity stagnation - slowdown of investments inflow - further productivity stagnation" was identified by analyzing prices in the global raw materials market, investment patterns, incomes, and productivity trends within the Russian extractive sector. In addition, this cycle was supported by reliance on equipment imports and the replication of outdated technologies. Due to the advancements of Industry 4.0, a convergent technological approach to modernization was proposed to increase productivity. In this context, a platform was developed for the diffusion of convergent technologies based on the analysis of international practices of using NBIC-convergence in the activities of mineral complex enterprises. Hyperconvergent technologies were particularly considered to mediate the transition from the "Internet of Things" to the "Internet of Everything", facilitating the evolution of automated to fully unmanned production processes. The results could be used in the formation of strategic programs for the modernization of the extractive sector.

Keywords: Extractive sector; Labor productivity; Technological convergence; Technological platform

1. Introduction

Currently, the extractive sector of both global and national economies is facing a significant obstacle to development, which may have a negative impact on mining in the

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context of growing global demand for minerals. This obstacle consists of the intersection and further divergence of the trends of demand for raw materials and productivity in the industries of the mining sector. At the current stage of development, investment in raw materials extraction is losing its appeal worldwide for different objective reasons. Apart from market factors, there are fundamental prerequisites associated with the specifics of the economies. The World Bank experts reported significant technological risks that lack a strong correlation with investments, extractive companies facing restricted opportunities to enhance the level of raw material processing and probabilistic assessment of indicators with high reliance on supply and tariffs set by natural monopolies for profitability (The World Bank, 2021).

This specificity of production in the extractive sector directly restrains productivity growth since a vicious circle of "lower investments - lower productivity - lower investments" is formed in the conditions of growing volatility of prices for raw materials. Therefore, productivity in the sector is the "key" to increased reproduction as a new modernization which is a radical technological renewal under the achievements of the Fourth Technological Revolution (Industry 4.0).

Increased global demand for raw materials in 2022-2040 is associated with the growth of world population at the expense of countries, such as India, China, and Brazil subjected to "new industrialization" (UN, 2021). According to the experts of the European Commission, total digitalization of production and consumption, as well as the development of electric transport increase demand for natural gas and rare-earth metals (European Commission, 2022). In contrast, K. Trenberth argues that exogenous factors, such as climate change increase the demand for raw materials - energy, building materials, and metals (Trenberth, Fasullo, and Kiehl, 2009). This is specifically important for the Russian economy, where mineral resources and processed products account for 70% of exports (ROSSTAT, 2021).

Over the past decade, there has been a decline in productivity in the extractive sector of the main producers and exporters of raw materials. The reasons include short- and medium-term fluctuations in world raw material prices, multidirectional forecasts of alternative energy development, reaching the limits of mining technologies and equipment capacity, closing of raw material use chains within existing production capabilities, and increased competition in the global raw material market. The use of more powerful equipment by mining companies results in the growth of capital and operational costs to reduce the investors' interest in the mass replacement of production facilities of the same technological level. Therefore, the reproduction processes in the extractive sector of the producing countries are slowing down, which leads to a decrease in productivity.

The background of this research is related to the analysis of problems related to increasing productivity in the context of the widespread expansion of Industry 4.0. The slower spread of modern convergent technologies in the extraction of mineral resources, in comparison with the production of final goods and services, considers the experience of earlier research. As a result, the knowledge about the diffusion of convergent technologies should be supplemented in the industry with provisions for the creation of specific technological platforms in the mining sector.

Research on factors and sources of productivity growth in the extractive sector are based on the reconstruction models of mining enterprises (Prokopenko *et al.*, 2020; Tyurin and Stoianov, 2019; Bak, 2018), the efficiency of inter-sectoral and inter-sectoral interrelationships in the economy (Hyranek *et al.*, 2021; Tsounis and Steedman, 2021; Jonek-Kowalska and Turek, 2017), determination of investment efficiency (Kim, Kim, and Yoo, 2020; Wellmer and Scholz, 2018), optimization of individual production processes

(Gackowiec *et al.*, 2019), effects of innovation on productivity (Woodhead and Berawi, 2020; Varlamova and Larionova, 2020; Wiratmadja, Govindaraju, and Handayani, 2016).

The impact of Industry 4. 0 and more recent breakthrough innovations on industrial production are analyzed from the perspective of individual technological processes (Akundi *et al.*, 2022; Zhang *et al.*, 2022; Maresova *et al.*, 2018) to improve labor safety (Malomane, Musonda, and Okoro, 2022; Osunsanmi, Oke, and Aigbavboa, 2019). Similarly, there are theoretical gaps in the analysis of Industry 4.0 technologies on productivity due to the lack of research on convergent technologies in the modernization of individual processes and the entire sector.

Several research devoted to the analysis of Industry 4.0 technologies in the mining sector can be considered. However, the entire range of convergent technologies is not adequately addressed (Zhironkin and Dotsenko, 2023; Zhironkin and Ezdina, 2023; Zhironkina and Zhironkin, 2023).

The mining industry has the greatest use of big data collection, processing, and analysis technologies at 21.8%. Approximately 19% of every fifth organization also uses cloud services and 18.8% of geographic information systems (GIS). Considering the high level of GIS utilization, the spatial data produced are necessary for the design, development, and management of industrial facilities. A relatively modest penetration of IoT (14.6%) is associated with the complexity of interoperability of physical assets and software solutions. (Gowida, Gamal, and Elkatatny, 2023).

The next step is the transition to Industry 5.0 to introduce advanced technologies into production processes while focusing on sustainable development and human-centric technologies. After Japan announced the transition to the 5.0 Society in 2016, this model was considered (Qi-Zhang *et al.*, 2023).

In all branches of industry, there are great prospects for solutions at the intersection of several directions. These include systems based on "digital doubles", including elements of IA, the Internet of Things, wireless communication technologies, and sensors. The market is expected to grow at an annual rate of more than 50% by 2026 (Yousef *et al.*, 2023). In the manufacturing industry, digital technologies are introduced more actively and the industry ranks second after the financial services sector in terms of the cost of implementing digital technologies (9.2%). However, only 12% of manufacturing organizations conform to modern digital production. This is because the effects of investments have been delayed and are felt as companies move from pilot launches to full-scale implementation of digital solutions (Qi-Zhang *et al.*, 2023).

The reserves of productivity growth are indispensable for the extractive sector in effectively adapting to the evolving structure of global demand. This necessity is evidenced in the proliferation of convergent technologies, which shows the Fourth Industrial Revolution (Yousef *et al.*, 2023; Ghazinoory, Hoshdar, and Nozari, 2022).

Technological convergence represents the stage of development of science and production combined into new types of technologies under the influence. Conversely, in inter-branch integration of research activities, there is a response to the increasing demand for production and goods characterized by new properties. (Lin, Wu, and Song, 2019) Initially, technological convergence was the object of socio-economic research in the 1990s as a reflection of information technologies with various types of material production (Castells, 2009). M.C. Roco, W.S. Bainbridge connected the concept to the synergy of technological development in the following four industries (Roco and Bainbridge, 2003):

- Nanotechnology in materials engineering, chemistry, and robotics,
- Information-computing technologies as a unified digital technological platform for the development of all sectors of the economy,

- Genetic engineering as a general basis for the development of biological sciences and medicine,

- Neural engineering and cognitive technologies, combine human and machine intelligence into complex systems of "intelligent" robots. The data analysis and learning capabilities are far beyond the existing automated systems.

The interest in convergent technology has focused on the analysis of the end-to-end nature, transforming high-tech industries (Palazzani, 2019; Rao, Bojkovic, and Milovanovic, 2009), the macroeconomic potential (Avdeychik, 2021; Park, 2017), the formation of a new quality of human well-being (Ballesta, 2021; Marriwala *et al.*, 2021). Similarly, the lack of research on modernization is reported through convergent technologies, serving as a cross-cutting for many manufacturing industries.

According to Kovalchuk, the primary demand for convergent technologies is from industries functioning to enhance labor productivity, mitigate non-productive expenses, and reduce the risks of hazardous production processes, minimizing direct human participation in operations (Kovalchuk, 2011). Therefore, (Taran, 2019) positioned the extractive sector as the main recipient of convergent technologies due to the increasing demand for modernization in the next decade, as well as public pressure on labor and environmentally hazardous mining operations.

The mining sector cannot underestimate the latest trend in the development of convergent technologies, particularly the development of hyperconvergence, which includes modular and scalable information and cognitive systems (Hewlett Packard Enterprise, 2020). Hyperconvergence may take the form of a future technological transition from an "Internet of Things" closely connecting different types of equipment and remote human operators to an "Internet of Everything" to replace human operators. In this context, the basis of the theoretical analysis of the prospects improves productivity in the long term at the expense of the opportunities related to convergent technologies. The research motivation is to form theoretical provisions to justify the regulation of innovative development in the extractive sector.

The majority of previous publications have an ambivalent position in summarizing the review of the literature on the research problem. On the contrary, the analysis of the advanced end-to-end technologies on productivity is associated with Industry 4.0 and the role in optimizing production, as well as the capabilities of convergent technologies. The research of technological convergence affect the development of the extractive sector to the least extent, showing the diffusion in the manufacturing and high-tech sectors. Therefore, this research aims to determine the influence of convergent technologies on productivity in the extractive sector. The achievement necessitates several tasks, such as analyzing the international dissemination of convergent technologies, stating the technological intricacies of the contribution to productivity, and stating the importance of establishing a national technological platform.

2. Methods

2.1. Initial data

This research considers the possibilities of long-term productivity improvement within the convergent technologies of the extractive sector. The methodology is the analysis of prices, investments, productivity, economies, and foreign experience. The results are used to form theoretical provisions for the regulation of convergent-technological modernization of the extractive sector. Concerning the hypothesis, the diffusion of convergent technologies can have a significant impact on productivity within a specialized national technological platform connecting the interests of extractive companies with research and development entities.

The materials used are the data of Russian and international official statistics, including The World Bank (2021), the reports, and publications of mining companies for the period 2008-2022. The criteria of the analysis are relevance (relevance to the needs of the extractive sector in the new technological basis of modernization), interpretability (presentation of the results in a form understandable to stakeholders), usefulness (indication of the necessary specific actions), and timeliness (accessibility for operational decision-making).

2.2. Research methodology

The research is based on a convergent method for the interdisciplinary boundaries of knowledge through the mutual penetration and influence of various subject areas and information technologies. Convergence is described as an increasing and transformative interaction between scientific disciplines, technologies, communities, and spheres of human activity to achieve compatibility and integration. This variable is important for the information society, and the analysis of the social consequences can solve problems. New technologies and knowledge are based on the following principles, interdependence in nature and society, as well as enhanced creativity and innovation. Convergence or divergence processes depend on a holistic system deductive approach, the development of interdisciplinary high-level languages for new solutions and transmission of new knowledge, and ideological concepts of modern basic research. This is largely due to the combination of natural science and information technology to develop methods and technologies for creating “nature-like objects”, based on the formed technological convergence. The embodiment in the economy is structural convergence, when the principle of macro- and macroeconomic proportions changes from sectoral to technological.

The basis of the approach was the method of structural convergence (Beck, 2021; Scharpf, 2020; Aiginger, 2015) to show interconnections between the merging of innovative technologies, the convergence of different branches and sectors, as well as the convergence of countries with a prevalence of extractive and manufacturing economy on macroeconomic indicators. Meanwhile, the main provisions include the following:

- convergent technologies (AI, digital tweens, machine learning, "smart" robots and co-bots, as well as nano-biochemistry), as the core of Industry 4.0, equally cause radical productivity growth in high-tech and extractive sectors.
- structural changes in the industry under the influence of convergent technologies are universal (Zhironkin *et al.*, 2021) and can solve the problem of long-term stagnation of investment and productivity.
- convergence of productivity in the resource and manufacturing sectors of the economy is more typical of countries where the intellectual rent exceeds the natural rent (Zhironkin, Zhironkina and Cehlar, 2021).

2.3. Research limitations

The limitations adopted in this research are associated with unequal rates of diffusion of convergent technologies in the basic sectors, depending on the level of innovation infrastructure and financing of the sector. This causes difficulties in predicting the growth rate of productivity during the diffusion of convergent technologies. However, the platform system of innovation development is recognized as equally effective for the sectors of the economy.

2.4. The research Flow

This research was carried out in three stages and covered the period of 2017-2022. In the first stage (2017-2018), an analysis of the state of research related to the problem of productivity growth in the national and global mineral resource sector was conducted in line with the expansion of convergent technologies. In the second stage (2019-2020), an analysis of the influence of Industry 4.0 convergent technologies on the mining industry was carried out to consider the main component of the subsystem, namely Mining 4.0. In the third stage (2021-2022), the provisions were developed for a national convergent technology platform in Russia to increase the radical modernization of the extractive sector to the level of Industry 4.0, with access to a higher level of productivity.

3. Results and Discussion

World prices on basic resources for iron ore and steam coal industries since 2008 and 2016 are under pressure from volatile demand, as shown in Figure 1. In the short term, decreasing raw material prices have squeezed the cash flows of major commodity companies by 25-40%. This has affected investment in technological upgrades, resulting in a global decline in productivity over the past 15 years.

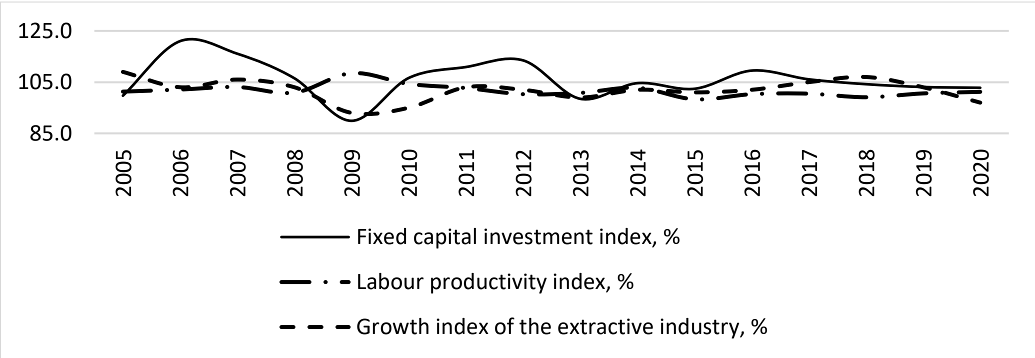

Figure 1 Index of world prices for certain types of minerals and productivity in the mineral complex (2008 - 100%), Author's interpretation based on reporting data Price Waterhouse and Coopers (2020)

According to the data in Figure 1, fluctuations in the price of basic extractive sector products (coal and iron ore) cannot drive productivity growth on a global scale despite the periods of recovery in 2012 and 2018. In 2012, productivity decreased by 22% compared to 2008 due to a significant decline in investment, which amounted to a 10% reduction in 2010 as shown in Figure 2 Subsequently, the trend of reduction in investment since 2014 led to a decline in productivity in 2016-2018. In 2020, the productivity in the global extractive sector reached the mark of 90% compared to 2008.

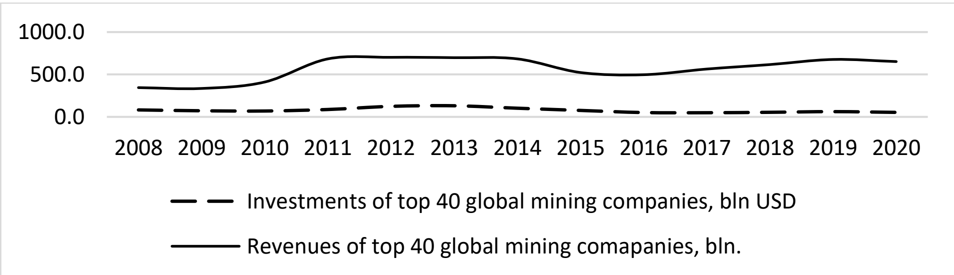

Figure 2 Dynamics of investments and revenues of the world's 40 largest mining companies. Author's interpretation based on reporting data Price Waterhouse and Coopers (2020)

The data in Figure 2 reports that the world's largest mining companies increase revenues mainly during periods of high prices for raw materials. In this context, the long-term trend of investments and productivity shows stagnation. According to previous results, the extractive sector of mineral exporting countries was effective only within the existing structure of prices and demand (Sick, Golembiewski, and Leker, 2013). The change in demand for minerals expected in the next decade may lead to industry crises due to unfolding trends of decarbonization of internal combustion engines with electric motors, and replacement of metals with super-strong composite materials. This applies to the Russian economy due to the volatility in the sector over the last 15 years as well as a long-term downward trend, and stagnation of productivity.

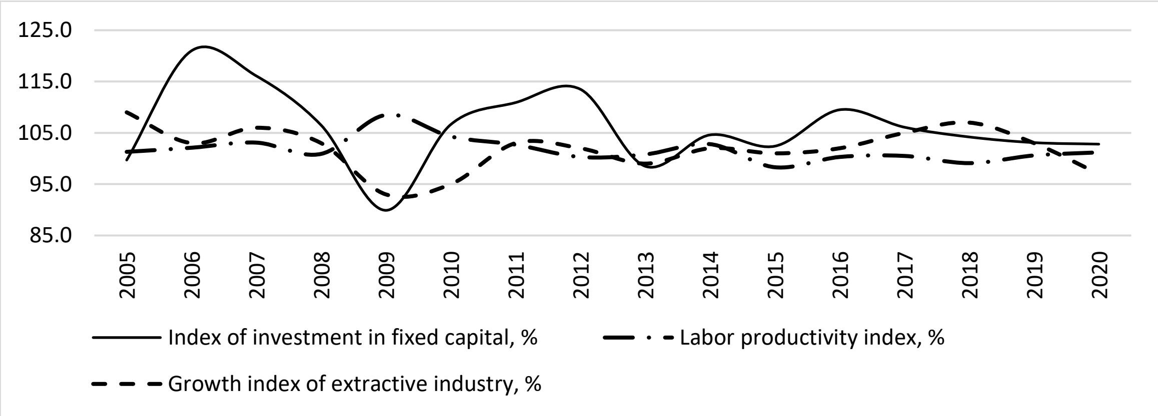

Figure 3 Indices of investment, labor productivity, and growth in the extractive sector in Russia, author's interpretation based on reporting data Price Waterhouse and Coopers (2020)

From the data presented in Figure 3, the growth rate of the extractive industries sector tends to decline below zero and the index of investments in the fixed capital shows a similar dynamics. Therefore, the productivity index fluctuates at 102.5%, showing a "technological stagnation" in the extractive sector of the Russian economy.

Technological stagnation is considered as the long-term persistence of organizational, investment, and technical problems in the commercialization of new technologies. The solution includes using the capabilities of the most advanced technologies to radically increase productivity in all sectors of the economy.

In this context, "technological stagnation" requires the diffusion of convergent technologies in the structure of the extractive sector. The specific risks should be recognized with the breakthrough opportunities described. Factor analysis of convergent technologies used for productivity increase is presented in Table. 1.

The economic basis for the expansion of technological convergence and hyperconvergence includes a radical increase in labor productivity and the formation of new forms of attracting investment. Radical increases in labor productivity include the changes within the generations of production due to the extensive use of AI and cyber-physical systems in equipment, process control, design planning, investment, sales, and logistics. In addition, nano-bio-convergent technologies are capable of developing new methods of mineral extraction with significantly lower costs, up to the abandonment of modern mines and quarries. This is achieved by dissolving coal in the subsurface, using copper-eating bacteria, and running underground robots-geodes. The reproductive - component of the convergent-technological modernization is related to the creation of a technological platform.

Table 1 Convergent technologies on productivity in the extractive sector of the economy

Factors affecting productivity in the extractive sector	Ways to solve productivity problems	Role of convergent technologies in increasing productivity
1. Reaching the productivity limits of existing raw material extraction technologies	Full automation of production processes Internet of	Things for digital-physical high-precision production systems
2. Increase in operating costs due to higher cost of resources and higher safety requirements	Optimization of production processes, energy, and resource consumption	Equipment combined with drones, application of "smart sensors
3. Growth of personnel costs Implementation of unmanned production systems	Transition from the Internet of	Things to the Internet of Everything
4. Price volatility on the global commodity market	Introduction of information and analytical complexes based on AI, allowing modular reconfiguration of production processes under the dynamics of markets	Artificial Intelligence (AI) technologies in the management of companies and enterprises
5. Deterioration of minerals due to the gradual depletion of deposits with high availability	Improvement of mining planning and forecasting processes	Transition from information-convergent to hyperconvergent technologies
6. Legislative requirements for full restoration of extractive cluster ecosystems	Development of environmental management based on convergent technologies	Nano-bio-convergent technologies for complex extraction of mineral resources

Convergent technologies of the Fourth Industrial Revolution are represented in the industry by the achievements of digitalization. New means of production created with the use of information-cognitive convergent technologies and supplied to the extractive sector include systems of 3D modeling and design of production processes, wearable environmental scanning devices, unmanned mine dump trucks, excavators and drilling rigs connected through the "Internet of Things", and unmanned mining sites. Convergent information-cognitive technologies in AI provide equipment with the ability to convert data sets into automatic predictions of future events. This increases the possibility of making management decisions without human participation in operational planning, as well as forecasting technical, natural, and man-made incidents. Currently, the technological transition from man-machine systems to "AI-machine" is widely represented by interactive technologies of virtual and augmented reality. Additionally, digital twins are used by mining companies for performing advanced modeling and monitoring of work operations as well as improving the accuracy of operations.

In particular, "smart" protective glasses, which are fitted to the employees of mining enterprises are capable of giving real-time instructions to the personnel based on the online analysis of information from "smart sensors" and video surveillance. In 2017, the implementation of convergent-technology tools by Freeport-McMoran Copper & Gold achieved a remarkable 85% reduction in the frequency of accidents to minimize losses and downtime. Additionally, the adoption enabled the company to save up to $2 million in employee injury payments (Antworp, 2018). The information-cognitive convergent technologies can also be used to provide immersive worker training to prepare for contingencies in hazardous environments and reduce the impact of human error on lost time and property damage in accidents.

Another aspect of convergent technologies in the extractive sector is the digital-physical transformation of production, which opens up new opportunities for using robotics to produce autonomous equipment. Investments in production are projected at $30 billion in 2025, which is explained by the cheapening of industrial robots by 70% over 1990-2010. This is achieved with a simultaneous increase in labor costs for the extractive sector of the U.S. and EU economies (Nadipuram, 2014).

Major mining companies actively implementing digital mining management and design systems, as well as unmanned equipment, in 2018 reported a reduction of operating costs and losses from technogenic risks by 12-15% (Price Waterhouse and Coopers, 2018). Moreover, the global market for AI implementation tools for mining management and design was valued at $6.8 billion, $9 billion, and $30 billion in 2018, 2020 (Price Waterhouse Coopers, 2018), and 2025 (AI Foundations, 2019), respectively. The COVID-19 pandemic has increased the inclination towards automating and digitizing mining operations, thereby reducing reliance on manual processes. Therefore, there is a projected deepening of this trend, with the demand for AI systems within the industry anticipated to potentially double by 2025.

The convergence in mining engineering is associated with the development of new method of production coupled with drones. The use of drones can lead to a significant reduction in labor costs and improve the quality of real-time information on equipment operation and mineral extraction. Additionally, machines connected to drones significantly increase productivity and economic efficiency through the use of autonomous mining and transportation systems (AHS). In the context of AI, mining equipment using "connected" and self-training devices, such as intellectual sensors, can optimize equipment performance and provide preventive maintenance to minimize man-made accidents as well as related production restoration costs reaching 25% of operating costs.

In 2030, new mines in the USA and Australia will be fully equipped with unmanned production facilities connected by the "Internet of Things". The majority of technological processes will be controlled by AI, connecting the components of the value chain in a single system for analyzing huge volumes of data in real time as well as making optimal technical and economic decisions. The capital cost of building an unmanned iron ore mine is estimated at $750 million, with an expected 24% increase in equipment productivity and a 17% reduction in operating costs. Meanwhile, the payback period should be a quarter less than the conventional mines (Durrant-Whyte, 2015).

An important aspect of convergent technologies in the extractive sector is the protection of intellectual property rights as the basis of Industry 4.0's method of production, and the sharing of revenues from the use. In addition, the use of AI and automated technologies creates the problem of users being responsible for the decisions made without human inclusion. Industry 4.0 is a concept of a new reality in the economy, in which the management of most processes will be fully or partially in a digital format (David, Deepika, and Philip, 2021) and subordinated to AI (Erboz, 2017) to form full-scale cyber-physical systems (Abu-Abed, 2022). The diffusion of Industry 4.0 technologies creates a subsystem of innovative development for Mining 4.0, which is characterized by digital twins of individual processes and clones of equipment (Vitor, 2022), blockchain in mining inspection (Pincheira, Antonini, and Vecchio, 2022), widespread use of smart sensors, machine vision and learning (Kodratoff and Moscatelli, 2021) as well as the expansion of the Internet of Things during the transition to completely unmanned enterprises. There should be mechanisms of transfer and protection of rights on information generated when using licensed technology since the manufacturers of modern mining equipment are connected by contractual relations with producers of information-analytical systems and AI. Furthermore, entitlements regarding data usage must be weighed against the prospective rights to personal privacy of employees after the enactment of data protection legislation featuring expansive definitions of personal data.

In the Russian economy, the diffusion of convergent technologies is constrained by the uncoordinated development of technology platforms. This served as the most important infrastructural element of innovation investment in the European Union in the early 2000s. The main feature of European technology platforms is the participation of universities and research organizations as well as investment companies and banks in the innovation process. In Russia, technological platforms were created in the early 2010s on the initiative of the Government. The following technological platforms operate within the field of information and computing technology, National software coordinated by "Sirius" concern, which is part of state corporation ROSTECH, and unites 65 organizations, including major Russian technical universities (Bauman Moscow State Technical University, MIEM, MIPT), institutes of management problems and system programming of Russian Academy of Science and leading domestic producers of software products (1C, ABBYY, ALT Linux), National supercomputer technology platform coordinated by Institute of Software Systems RAS, and M.V. Lomonosov MSU, which includes 42 participants with 20 independent developers.

The projects belonging to the techno-platforms are mostly remote from the modernization of the mining sector to improve the information infrastructure and security creating supercomputers and computer networks for the needs of public administration and defense. The proposed technological platform should reflect the impact of convergent technologies on productivity in the extractive sector presented in Tab. 1. These include unmanned production systems, "smart sensors" and equipping drones, increasing use of the "Internet of Things" and transition to the "Internet of Everything" in mining.

The discussion section of the research contributes to solving the problem of increasing labor productivity through the introduction of convergent technologies even though most research of Industry 4.0 focus on the expansion of digital technologies. The analysis of the accumulated experience in the implementation of end-to-end digital technologies is related to the manufacturing sector of advanced countries. Furthermore, this research contains provisions for the platform development of convergent cyber-physical, nano-biochemical, and cognitive-management technologies as the main condition for a radical increase in productivity.

Concerning the associated limitations, the mining sector exhibits minimal adoption of convergent technologies, resulting in reduced productivity across mineral extraction operations. Therefore, further research should summarize positive experiences in this field and develop recommendations for the expansion of a national platform of convergent technologies within the mineral resources sector.

4. Conclusions

In conclusion, the necessity to address the decrease in technological convergence and hyperconvergence over the past decade was considered when summarizing the analysis regarding potential opportunities to increase productivity in the extractive sector. The demand for radical technological modernization of the mining sector was created by volatile commodity prices, unstable investment volumes, revenues of mining companies, and the efficiency limits of existing mining technologies. This prevented possible future energy and resource crises caused by structural shifts in consumption. In addition, convergent technologies served as the core of modernization, which manifested as a product of inter-industry diffusion of innovations and the development of new industries.

As the main driving force of the Fourth Industrial Revolution, convergent technologies led to AI and unmanned method of production, as well as the integration of "smart sensors" and the "Internet of Things" into the extractive sector of several countries. In the Russian economy, the diffusion of convergent technologies was restrained by the fragmented functioning of technological platforms, and the productivity in the extraction of raw materials became stagnant. To overcome this problem, a platform was proposed to decrease the development of domestic unmanned systems, introduce AI in the planning and management processes of the enterprise, as well as create modular production based on the "Internet of Everything."

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