Technology Modernization Opportunities in the Russian Economy

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Abstract—Opportunities for socio-economic development are discussed, taking into account the contribution to GDP from the various sectors of the economy. It is noted that a high share of GDP comes from the mining sector of the economy while the contribution of the manufacturing sector remains relatively small. Constraints that limit the growth of processing industries, including the insufficient use of this sector's potential are discussed. Conditions and constraints that hinder coordinated development of the various sectors, and ways to overcome these limitations are outlined.

Keywords: economic sector, manufacturing sector, development potential, development constraints, project management, strategy

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Introduction. This paper looks into the role of companies in the development of the Russian economy as a whole and its individual sectors. The difficulties and obstacles to economic recovery that have emerged since 2014 are diverse and interrelated. The inefficiency of the country's financial system, which has withdrawn itself from supporting the production sector of the economy and has allowed the national currency to fall, has been further exacerbated by external restrictions (pandemic, sanctions), faulty and uncoordinated actions of regional authorities, and challenges with mastering project management methods and project financing.

It is safe to say that our country is successfully coping with these challenging times, gathering strength, and preparing for a leap into a new space of opportunities [1–3]. This opinion is shared by many scholars, experts, and practitioners.¹ However, one should not abandon the previously manifested yet still, for many reasons, unfinished steps in the right directions. Here, we should highlight, first of all, the transition to a knowledge economy based on innovations and new technology, which was set as an intention in 2010, as well as the science and technology development strategy for the Russian economy, which identifies six major challenges [4].

The role of companies in economic development. A crucial condition for the development of Russian companies in recent years has been the increased emphasis on import substitution and the development

of the national economy through the use of its own innovative and technological potential [5, 6].

This approach is a forced measure, which is due, firstly, to the sanctions on the part of the United States and the EU countries on the supply of dual-use high technology to Russia and, secondly, to the need to recover the innovative potential of Russian state-owned companies and the Russian Academy of Sciences and universities so that they could design domestic technologies that would be competitive both in the international and domestic markets.

One of the main features of science as well as the entire realm of innovations, including the stages of transition from fundamental research to practical developments and technology solutions, is the time- and space-distributed nature of the process of transition from innovative ideas to their practical implementation into complex technology [3, 7, 8], which ensures transformation of extracted resources into machines, equipment, end products, and full-cycle services [8–10]. In this context, complex technologies, as means of converting resources and intermediate products into end products, stand out in that they imply the use of professional knowledge and accumulated work-organization skills. In turn, conceptualizing, developing, and creating complex technology not only implies interdisciplinary research but also involves joint participation of designers, technologists, and engineers. The outcomes of their work ensure consistent generation of knowledge on new complex technologies to replace obsolete and uncompetitive ones.

One of the critical conditions for the consistent accumulation of knowledge about technologies is the

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transfer of results obtained to the customer in a finished form to ensure no need for adjustments after launch. As applied to new technologies, this practice is called *turnkey transfer*. Importing companies that supply technologies and equipment to Russian companies strive to comply strictly with this practice since a failure to do so may lead to production losses for the company that purchases the technology, and the importer may have to pay fines for violating the terms of turnkey delivery.

A combination of difficulties (the fall in world prices for hydrocarbons) and objective reasons (covid-19) led to a prolonged stagnation of the Russian economy, which began in 2014 and continues to this day. Many economists believe that Russia possesses sufficient potential to overcome the economic downturn and envisage good market prospects. In order to overcome the crisis inertia, in our opinion, the Russian economy needs a concentration of intellectual, financial, administrative, and technological resources to make a leap into a space of new opportunities that can be created by reforming several ministries and financial institutions in order to move to strategic planning and management based on a project-oriented approach.

After the imposition of sanctions by the United States and the EU countries in 2014, the previous (almost zero) rates of economic growth gradually turned into a protracted economic crisis, during which the investment in the country's economy almost halved, and the population incomes decreased since 2014 by 7% compared to 2009. The leading Russian economists—A.G. Aganbegyan, V.V. Ivanter, S.Yu. Glaz'ev, A.A. Shirov, and others—argue that the low growth rates were due to many factors including the erroneous policy of financial authorities, the lack of a positive outlook in the government strategy, and the low potential for the export of nonprimary goods. Even the successes of the oil and gas sector, the revival of the agricultural sector, and the consistently high potential of Rostec and Rosatom failed to reverse the negative trends.

The long-term sustainable development of such an economy as Russia, with its vast territory and huge resource stock, could not continue if it had to follow the resource exporting strategy that took shape at the beginning of the 21st century. The possibilities and necessity of a transition to a knowledge economy, based on innovations and new technology, were assessed within the resource innovation development strategy [6–8]. It had been expected that in the 21st century, after the transition from a planned economy to a market economy, the shock therapy, the drop in GDP by 50%, and the default of 1998, the Russian economy would move to a sustainable development trajectory. This development was supposed to arise from the accumulation of funds earned by exporting raw materials, which were in demand at that time in

world markets, and possible redistribution of these financial resources between other sectors of the economy with the subsequent recovery of these sectors' capacity on the basis of innovation and technology. After the change in the country's political organization and the adoption of the Constitution of the Russian Federation, the ownership of the funds received from the export of raw materials at world prices went to companies rather than ministries, agencies, and the government as a whole. The status of monopolies and state-owned companies did not allow for direct redistribution of funds between sectors of the economy. Therefore, the main means of redistributing finances was taxes, including their concentration in the national budget and subsequent redistribution in compliance with the budget code.

Depending on market conditions, development opportunities for each sector of the economy could be assessed within the constraints adopted in the budget code. Moreover, in the 2000s, i.e., the time viewed by many economists as “fat years,” government officials showed no intention to restructure and further diversify the economy. The steady GDP growth in the early 2000s, with a rate close to 7% per year, and the resource stock sufficient for long-term development allowed the government to partly overlook potential risks and confine itself to the accumulation of foreign currency resources in the reserve fund. The global economic crisis, which began in 2008, adversely affected the world economic system and led to a tangible decrease in the growth rate of Russia's GDP (in 2009, it fell by almost 10%) [11].

Analysis of opportunities to quickly harness the potential of knowledge economy through massive support of venture capital structures and small innovative companies uncovered the fact that Russian companies were not ready for innovative development on the basis of the domestic innovative potential. The substantial imports of machinery, equipment, and food (in 2010, despite the 10% drop in GDP in the previous year, the imports of these goods were more than \$180 billion) [11] led government authorities and companies to hope that the changes in the global economy would not last long and the world market would quickly return to high prices for resources. The decline in world prices for resources, primarily hydrocarbons, compelled government officials to use a strategy of economic diversification and consider the possibility of increasing the exports of nonprimary goods. However, the low GDP share of the processing and manufacturing sectors and the low technological level of companies in these sectors hindered the expansion of these exports.

The development of the country's economy as a major component of its socio-economic system (SES) also depends on the interaction between the economy and the other parts of the system: the social sector; the science, innovation, and technology sector; and the

Table 1. Distribution of GDP shares, %, by stage in the full process cycle*

Year	Mining sector	Processing sector	Manufacturing sector	End production sector
2010	35	30	5	30
2020	25	35	5	40
2030 (forecast)	20	30	10	35

* The distribution of types of economic activities (TEA) by sector is given in [3]; 5% of GDP cannot be distributed across different sectors because some TEA belong to several sectors simultaneously. For example, additive technologies belong to both processing and manufacturing, and some technologies for the production of building materials belong to both processing and end production.

Source: Rosstat data [11].

ecological environment. Combining these parts together ensures the *emergence*, or synergy, of the SES [12].

Therefore, identification within the full process cycle of its four successively interconnected components—mining, processing, manufacturing, and end products and infrastructure—may also reveal synergies that contribute to their mutual development. A study of the interaction dynamics between the main economic sectors (mining, processing, manufacturing, and end production) within the full process cycle can assess the existing level of technology and identify promising opportunities for its improvement. To analyze the distribution of the economic contributions of the sectors forming the full cycle, we used output estimates by types of economic activities (by the OKVED classification). Table 1 shows the distribution of the GDP shares by economic sectors in 2010 and 2020, as well as a forecast until 2030.

Analysis of the distribution dynamics of the GDP shares in the mining sector shows a decrease in the share of raw materials in the total GDP. Over the ten years from 2010 to 2020, this share decreased by 10%. The raw materials component of GDP is expected to decrease by 2030, which primarily indicates a possible increase in the output of processing and manufacturing industries. The increase in the share of processing and manufacturing industries and the decrease in the output of mining industries is associated, on the one hand, with a possible decrease in the production of unprocessed resources (crude oil, untreated natural gas, round timber, rough diamonds, etc.) and, on the other hand, with an increase in technological capacity of the processing and manufacturing sectors and an increase in the synergy potential of the entire economy. The growth of processing industries based on innovative technologies can create conditions for the production of modern high-tech machinery and equipment [13].

An increase in the diversity and properties of manufactured products is closely related to the quantity of consistently realized *technological conversions*, i.e., combinations of interrelated technologies focused on the manufacture of products of a certain quality with given properties.

The principle of technological convergence [7, 8, 14], which emerged and took hold at the beginning of

the 21st century, suggests that future technologies will be designed through the combination and interaction of the various processes within the framework of nano—info—cogno—bio technology. This implies the development of technologies at the nanoscale; the ability to interact with related technologies on the basis of information processing; and the ability to adapt to and tune into the interaction with other processes and technologies, including with the processes of living (biologically active) systems. Such technologies exist already, e.g., sensor technologies for network interactions of robots and drones, face recognition technologies in group settings, etc.

The famous Russian philosopher Ivan Il'in defined, as early as at the beginning of the 19th century, the role of quality as follows: "We believe and we know that the time will come and Russia will rise from decay and humiliation and will enter an era of new greatness, but it will revive and flourish only when the Russian people understand that salvation must be sought in quality" [15].

Efficient organization of the science and technology space and the processes of translating innovative ideas and solutions into new technology can help to replace the morally and physically obsolete technologies used by companies in the production of goods and services. This replacement of outdated technologies with new ones defines the process of technological development in modern conditions. Its pace, especially for information technology, has been increasing rapidly in recent years. The saturation of the production base with new technologies largely depends on the stance of the company's management when they choose a development strategy. Much depends on the location and economic sector of the company within the full process cycle. Companies in the mining sector show a high level of competitiveness, which is primarily due to environmental factors and, to a lesser extent, to the level of production costs. Therefore, such companies spend less money on acquiring new technologies and innovative solutions than companies in the processing and manufacturing sectors.

The transition to the market largely affected the role and scale of centralized management of the economy—the plan-based and directive management of companies by government bodies and ministries gave

way to coordination of companies' activities, and companies became the owners of tangible and intangible assets. Therefore, companies have to overcome the challenges of development on their own, focusing on internal resources, i.e., mainly profits and bank loans. The new development conditions slowed down the renewal of fixed assets and largely differentiated this process by sectors of the economy.

Interaction between the key sectors of the economy. A structurally balanced state of an economic system, i.e., a coherence of flows and resources between its key sectors, shows its resilience to external disturbances and challenges. Such a balance can be achieved both by consistently coordinating the output volumes and the quality of products manufactured by the mining sector with the output of the processing sector, and then coordinating this output with that of the manufacturing sector. The consumer properties achieved in the previous sector largely determine the quality of output in the subsequent sector. Therefore, the output of the mining sector cannot provide, as a rule, sufficient added value for the economy as a whole if the latter has no advanced processing and manufacturing sectors [16].

The greatest added value in the world economy comes from the manufacturing industry, which is capable of producing machinery and equipment for the implementation of technologies used in all the other sectors of economy. Thus, the global output of the electronics industry, including computers, communication facilities, devices, microprocessors, etc., vastly exceeds the sales of hydrocarbons and refined products.

The modern concept of industrial production organization has changed our understanding of the role of machines and technology. Previously, technology was viewed as a way of organizing production at the micro level, including individual production processes, but in the early 1990s, these views shifted to looking at technology at the macro level as a generalized way of transforming products from one state to another, more finished state within the full process cycle.

Analysis of domestic and foreign experience in searching for innovative ideas and their transformation into innovative solutions reveals qualitative changes in the transition to new technologies. The latter are able to combine the process as a method of transitioning from the previous state to the next one and to equip this method with the necessary machines and tools, trained personnel, and an effective management system.

The key condition for development: a recovery of the innovative reproduction cycle. An initial stage in exploring the need to recover the capacity for implementing the technology reproduction cycle for a company (Fig. 1) is to analyze and forecast the market development. It is important to identify the life cycle of each product sold in the market and to investigate the

impact of competing products on the competitive potential of a given product. A decrease in the product's market potential leads to a decrease in sales and, hence, a decrease in the profitability of its output. Low profitability (e.g., below the average for the company) can initiate a search for causes and ways to address them. These include replacing or modernizing a current technology with a more advanced one in order to reduce costs or improve the product quality.

This search is based on information from forecasting and analytical centers that perform predictive research within forecast- or foresight-type prognoses. The leading role in the process of harmonizing companies' interests and their development opportunities belongs to production companies that concentrate market development potential and ways to realize it on the basis of new technologies. In this case, the role of forecasting structures, albeit auxiliary, is far from the last.

An analysis of the experience of using the designed technologies, including the study of their competitive advantages, is carried out both by companies that use the technologies and by specialists, experts, and consultants working in the relevant fields of knowledge. Summarizing this experience, companies formulate requirements for improving the technologies, including their operational properties, in order to increase the quality of products and (or) reduce their cost. As a rule, company specialists participate in the various science and technology forecast studies, where their assessments allow one to correct the forecasts by taking into account the experience of best practices. The assessments performed by company specialists allow one to correct the forecasts, formulate technical specifications for new technology design projects, and explain the benefits of the company's participation in such projects.

Thus, the level of innovative activity of companies engaged in the extraction of mineral resources was 7.9% (by the three criteria in the new edition of the Oslo Manual), and that of processing industries was 23.2%. In 2018, the technology innovation cost and the share of this cost in mining industries were, respectively, 156.7 billion rubles and 0.9, while in processing industries, these figures were 665.0 billion rubles and 1.7, respectively [11].

An important element of the interaction between the science and technology sector and manufacturing companies is the full process cycle (Fig. 1). The main link in the interaction between this sector and companies is the feedback that reflects the companies' interests, risk assessments, and development prospects when they use the forecast proposals prepared by research institutes and centers to place orders for the implementation of research and technological projects to launch or modernize the existing production facilities. The possibilities of multilateral participation of the various organizations in the formation of a full

Fig. 1. Interaction of participants within the innovation cycle.

innovation reproduction cycle were discussed within the forecast of the implementation of the Strategy for Scientific and Technological Development of the Russian Economy [4].

We regard the possible increase in the GDP share of manufacturing industries as a promising structural shift. This dynamic will not only help reduce the imports of machinery, equipment, and vehicles (2018, \$112 719 million; 2019, \$112 545 million) but also ensure their exports to the CIS countries and beyond [11].

The most important goal of modernizing the Russian economy is to recover the capacity of manufacturing industries. Independent technological development of the Russian economy is impossible without domestic production of modern competitive machinery and equipment in the face of external opposition. To achieve this goal, the Government of the Russian Federation should not only provide large-scale support to the core industries of this complex (machine tool building, mechanical engineering, instrument making, robotics, electronics, electrical industry) but also grant preferential taxation to these industries in the initial period.

At the same time, it is necessary to provide ways to create conditions for an effective flow of investment from other sectors. These conditions in the form of investment loans can be created as bonds and shares in the capital of future high-tech industries. It is only joint efforts by the government, banks, and companies purchasing imported equipment and spare parts at high prices that will enable the transition of the manufacturing industry to the import substitution of technology.

Recent years have seen a transformation in the goals and potential of the economic development opportunities laid down in the resource and innovation strategy, the core of which was the export potential of Russian hydrocarbons. Climate change, which is influenced by carbon dioxide emissions, and the growing role of the non-carbon economy have imposed constraints on the potential benefits of hydrocarbons. The restrictions and bans of the EU countries and the United States on the supply of oil and gas technology for the development of hard-to-recover reserves should inevitably compel the government to address the task of import substitution of this equipment as well as consider the technological possibilities of producing equipment for renewable sources and energy-saving technologies in all the sectors of the economy.

The government's orientation towards supporting the resource exporting strategy of socio-economic development in Russia at the beginning of the 21st century was quite utilitarian in nature; i.e., the idea was to export all the available and disposable resources, scrap metal, and semifinished products and to accumulate foreign currency funds for the purchase

of food, machines and mechanisms, computers and their units, mobile communication devices, etc.

An analysis of the changes in imports and exports from 2000 to 2019 for the main commodity groups shows a decrease in imports, primarily for such groups as food (meat, fish, sugar, cereals, oil), and a stable growth in the imports of machinery, equipment and vehicles, medicines, and computers and their component parts. These trends occurred amid a growth in the exports of wheat, coal, trucks and cars, and raw materials [11]. The changes in the export–import ratio show that on the whole, the import substitution strategy was successful for food and was lagging behind in the field of technologies and machinery and equipment. If we compare the ratio of the GDP shares for the main sectors of the economy (see Table 1), we see that the smallest contribution comes from the manufacturing sector (mechanical engineering, electronics, machine tool building, instrument making, electrical engineering), whose share fell to 5% in 2020. These industries have long been known to lag behind not only the world level but also the needs of the domestic industry. Imported technologies and machinery and equipment were substituted for the insufficient domestic mechanical engineering. At the present stage of development, machinery and equipment cannot be separated from technology, i.e., methods of beneficial and effective application of the former and their integration into the general processes of material production.

It is currently impossible to produce machinery and equipment without analyzing and taking into account the general processes of their application since the advancement of machinery and equipment occurs simultaneously with the advancement of the corresponding technologies. Therefore, now the interests of system engineers are growing closer to those of designers of machines and equipment, and the role of production technologists, who determine the methods of production of equipment, becomes subordinate to the general goal of a company as an integrated organized technology that unites the interests of systems engineers, designers, personnel training specialists, managers, and marketers [7, 8].

Investment for innovative development. The lack of companies' internal funds to finance innovative solutions can be compensated by bank loans. However, A.A. Blokhin argues that Russian companies differ substantially in terms of their access to financial resources [17]. The highest degree of access is observed for several dozen large export companies, which can obtain relatively inexpensive financial resources (from 0 to 5%) to finance their investment projects. These companies include Gazprom, Rosneft, Lukoil, Norilsk Nickel, etc. Stable export supplies of hydrocarbons and metals allowed these companies to earn a high reputation with Western banks and not only receive cheap loans but also keep a part of

their savings in securities and bonds. Blokhin calls this feature of Russian companies the *institutional rent*.

Russian companies are reluctant to participate in innovations for several reasons. A statistical survey conducted in 2001–2017 revealed 13 such obstacles. The most challenging one was the lack of internal funds (26.4%). For many years the level of financial support for research and development in Russia has been about 1.0% of GDP (in the United States, 2.6%; Germany, 2.4%; France, 2.3% (2014)). These data suggest a lag by a factor of 2–2.5 behind the leading world economies. Moreover, we should not forget about the low share of private sector expenditures (0.2–0.25%) on science and technology in Russia.

The alleged lack of funds only partly explains the reluctance of Russian companies to order research and development from domestic organizations. Other obstacles include [18] the high cost of innovation, the fact that the providers are not ready for turnkey deliveries without subsequent adjustments, a high economic risk, and a long payback period for innovations.

Among the other factors hindering innovative development, the statistical survey listed 17 obstacles [18], but some of them were closely related to each other (e.g., obstacle 6 and 15, 7 and 17). It should be emphasized that the recommendations of some experts to solve the problem of insufficient innovation in the Russian science and technology sector only by increasing its funding would be a mistake. Apart from increasing support for the innovation sector by increasing companies' funds, it is necessary to implement a complex of changes, including adjustments in the development strategy of the companies themselves, expansion of the potential of the entire innovation sector, expansion of the potential of the company personnel, and maintaining of strong ties between companies and development institutions.

Determining the prospects for the development of Russian companies involves a choice between the import of technologies and the development of domestic ones. If possible, both of these areas should be combined yet with a stronger focus (than today) on internal strengths by recovering the partially lost potential of the Russian Academy of Sciences and promoting the development of university science together with large companies that develop their technologies in Russian science engineering centers.

Conclusions. Since the early 1990s, the oil and gas complex has been the locomotive of the Russian economy.

The hopes that the export of hydrocarbons would serve as a basis for modernizing the Russian economy have not been realized in full, and the planned transition to a knowledge economy lingers on.

The reasons for the slowdown in the transition to economic modernization on the basis of innovative technology are as follows:

First, the abandonment of the planned economy and the transition to market-based management made it difficult to quickly redistribute the income from hydrocarbon exports between economic sectors.

Second, the government's intentions to move to a diversified economy and increase the share of nonprimary exports did not receive sufficient support in terms of building the capacity of the processing and manufacturing industries.

Third, by placing the bet on the import of technologies without proper support of these measures by the national science and technology complex, the decision-makers overlooked many risks, including international sanctions.

Fourth, the manufacturing industries (mechanical engineering, machine tool building, instrument making, robotics, electronics, etc.) did not receive, for many reasons, due attention from the authorities and the financial sector, which largely complicated import substitution and technological support of the domestic industry in the development of competitive technologies.

Despite the sanctions and the difficulties of import substitution, the domestic industry remains largely competitive (medical industry, nuclear industry, and defense industry). If the activities of the financial sector, tax authorities, and the science and technology sector are responsibly coordinated, it has all the capacity to make a breakthrough in the transition to harmonious development and strategic planning while strengthening the role of project management.

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