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5.2.2. Математические,
статистические и инструментальные методы
экономики (физико-математические науки,
экономические науки)

ИМПОРТОЗАМЕЩЕНИЕ ВЫСОКОТЕХНОЛОГИЧНЫХ КОМПОНЕНТОВ КАК ВАЖНЫЙ ФАКТОР НАЦИОНАЛЬНОЙ БЕЗОПАСНОСТИ

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Долгосрочный характер трансформационных кризисных процессов, вызванных ускоренным научно-техническим прогрессом, эпидемией коронавируса, политическими конфликтами, увеличивает неопределенность и в разы повышает необходимость организации отечественного производства высокотехнологичных компонентов. В статье рассматривается, как дефицит полупроводников, возникший из-за пандемии и территориальных споров, повлиял на функционирование отраслей, в которых он используется. На примере автомобилестроения показано насколько автономность важна для успешного и непрерывного функционирования высокотехнологичной промышленности. Сложная структура иерархии в процессе производства чипов и полупроводников и другие особенности организации

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5.2.2. Mathematical, statistical and instrumental methods of economics (physical and mathematical sciences, economic sciences)

HIGH-TECH COMPONENT IMPORT SUBSTITUTION AS AN IMPORTANT FACTOR IN NATIONAL SECURITY

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The long-term nature of transformational crisis processes caused by accelerated scientific and technological progress, the coronavirus epidemic, and political conflicts increases significantly uncertainty and the need to organize domestic production of high-tech components. The research investigates how the shortage of semiconductors due to the epidemic and territorial issues has affected sectors that depend on semiconductors. The importance of autonomy for the successful and ongoing functioning of the high-tech industry is demonstrated by the example of the automotive industry. The article discusses aspects of the semiconductor industry's production organization, including the complex hierarchical structure that proves how increasing import substitution is crucial to improving Russia's competitiveness and national

производства в полупроводниковой промышленности, рассмотренные в статье, доказывают, насколько важно наращивание импортозамещения для повышения общей конкурентоспособности и национальной безопасности России, а также снижения рычагов давления на неё. Ряд рекомендаций, разработанный для отечественной полупроводниковой отрасли, позволит форсировать процесс импортозамещения, развивать наукоёмкие и высокотехнологичные отрасли в России, повысить конкурентоспособность на глобальном рынке

security and removing external pressure points on the country. A number of recommendations for the domestic semiconductor industry will help to boost the process of import substitution, develop science-intensive and high-tech industries in Russia, and increase competitiveness in the global market

Ключевые слова: НАУКОЕМКАЯ ПРОМЫШЛЕННОСТЬ, САНКЦИИ, ИМПОРТОЗАМЕЩЕНИЕ, ПОЛУПРОВОДНИКОВАЯ ПРОМЫШЛЕННОСТЬ

Keywords: SCIENCE-INTENSIVE INDUSTRY, SANCTIONS, IMPORT SUBSTITUTION, SEMICONDUCTORS INDUSTRY

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Introduction. The pandemic, geopolitical and energy conflicts have hastened the economic environment's transformation, which makes the creation of domestic high-tech and science-intensive enterprises even more necessary. This is especially true for electronic industry, which is considered as the most cutting-edge area of modern mechanical engineering. Government must pay special attention to expanding the capacity of the electronics market and integrating it into a wide range of industries due to the direct impact of this industry on the nation's independence from the imports of high-tech components.

The semiconductor industry was very painfully affected by the pandemic due to the features of its production organization, and it was turned out to be in a precarious position because of geopolitical tensions surrounding Taiwan. The concentration of suppliers of the key electronics industry components in the Asian region, which is exposed to climatic, epidemiological and political risks, carries risks for the national security of the country. This makes the issue of establishing technology sovereignty more urgent.

As an illustrative example of how industries can fail when are cut off demonstrates the significance of increasing domestic component production in the context of the technological gap of Russian industry. Additionally, under the

current circumstances, Russia depends on countries in terms of components and technology may use it as a tool for manipulation by limiting the supply of equipment and parts. Thus, the primary goal of any local enterprise should be the significantly reducing dependence on imported components and technologies. Import substitution in the field of high-tech and science-intensive components allows not only to increase independence and national security, but also have a positive impact on the gross value added of the industry.

Methodology and Literature Review. The research methodology is based on works of scientists 2020–2022. Particular attention is paid to recent articles. The article was prepared using a significant body of relevant information, statistical and factual data.

Since the 1980s, the relevance topic of import substitution has not decreased among economists both in Russia (e.g., Volchkova N.A., Turdyeva N.A. [1], Khrustalev E.Yu., Slavyanov A.S. [2], Seliverstov Y. I., Chizhova E.N. [3], etc.), and foringers (e.g., Burton H. [4], Silva E. [5], Alavi R. [6]). Foreign experience received a lot of study attention (e.g., Kleiner G.B. [7], Vtolkina N.Sh., Gorbunova N.V. [8], Skvortsova V.A. [9]). Numerous economists have noted that increasing sanctions pressure leads to forced import substitution (e.g., Skvortsova V.A. [9], Seliverstov Y. I., Chizhova E.N. [3], Stroganov A.O., Zhilina L.N. [10]). This should be used to establish domestic technological and component base, as the removal of restrictions on the export of technology to Russia is not expected due to the escalation of the situation.

A number of domestic enterprises, in response to the permit, are actively looking for alternative choices of goods, using the possibilities of alternative imports. But there are other types of companies that are private R&D entrepreneurs. This way is seen as more promising, both for the companies and for the domestic economy [3].

The manufacturing of high-tech components, the majority of which call for semiconductors, should receive special consideration. Despite being one of

the best-selling goods in the world semiconductors, the features of this industry have not been in the focus of the economist for a long time. The digital transformation attracted researchers' interest, but the COVID-19 pandemic was the impulse for researchers, as supply chains crumbled due to rising demand and a halt in chip and board production because of quarantines. The COVID pandemic-related issue in semiconductor manufacturing was made worse by the trade conflict between the US and China [11]. According to studies, the quest for economic efficiency has resulted in the creation of "dependent" production chains. The absence of an independent entire cycle of semiconductor production, even within one location, is the industry's fundamental issue [12]. Some experts believe that a complete closed cycle of semiconductor production within one country is impossible. This is due to the expensive equipment and qualified employers. Nevertheless, it is feasible to minimize imports. Reducing dependence on imports of high-tech components in order to increase the competitiveness and independence of the domestic industry is still a relevant topic for further research.

Results. The events over the past five years have shown that the situation regarding production semiconductors and chips cannot be ignored. First of all, it is dangerous for national sovereignty. A modern company must periodically review its management and development strategies and continuously adapt them to ever-changing environmental conditions. Naturally, there are involved risks with creating long-term strategies, but not all risks can be predicted. There are the risks of uncertainty associated with a pandemic or military conflict which difficult to predict and to adopt emergency steps minimize their impact [13]. Enterprises that embrace prompt and accurate response to the current global crises and transform their business, will not only be able to hold onto their positions, but also discover growth potential [14].

The rapid spread of the COVID-19 virus, which led to a 2021 semiconductor shortage, is an example of strategic breakdown. Lockdowns, the

distant work and study, the digital transformation of consumer goods and services, and the growth of online trade led to an increase in demand for high-performance computers and entertainment equipment (game consoles, TVs, smartphones, and tablets), their shortage and rising prices. However, chips are needed not only for the production of computers and computer technology, they are widely used in other industries. It is almost impossible to imagine a production that does not require semiconductors: from smartphones and cloud storage to automotive technology, industrial equipment, infrastructure, security and protection systems. Many sectors have suffered as a result of interruption of the supply chain.

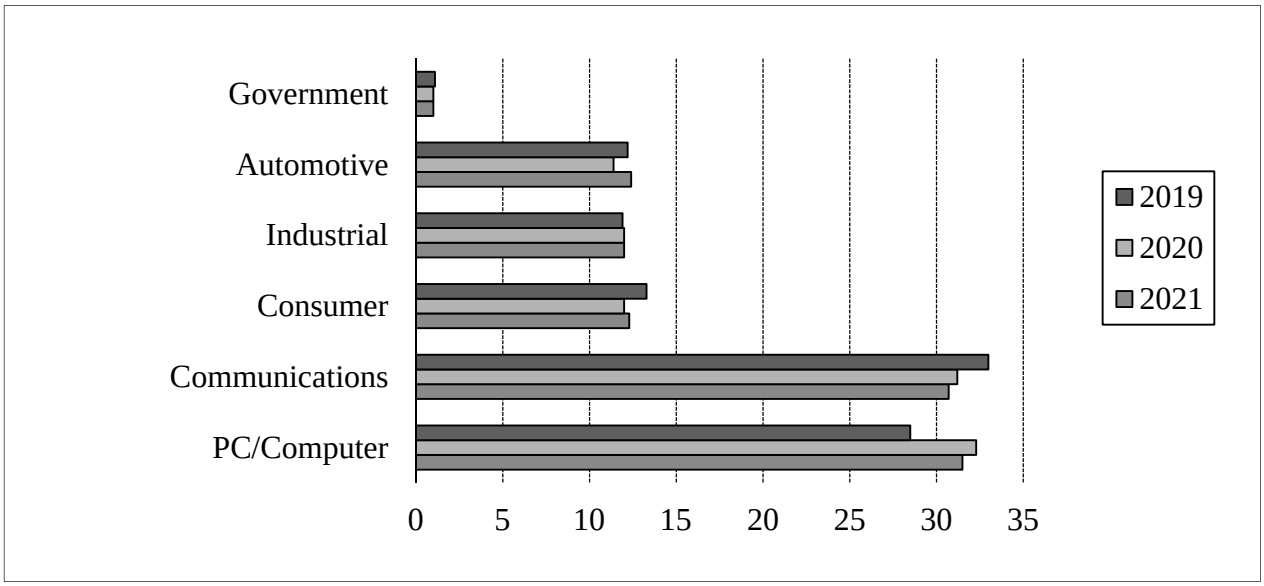

Figure1. Change in semiconductor sales structure, %
Source: Semiconductors Industrial Association. Industry report 2021, 2022[1]

Figure 1 shows that the demand for computing equipment has increased and the consumption of consumer electronics and cars has decreased due to a shortage of chips, supply disruptions and the establishment of queues for products. While chains were successfully restored in the automotive industry, but it is completely different in the consumer market. On the one hand, chip

[1] https://www.semiconductors.org/wp-content/uploads/2021/09/2021-SIA-State-of-the-Industry-Report.pdf
https://www.semiconductors.org/wp-content/uploads/2022/11/SIA_State-of-Industry-Report_Nov-2022.pdf

producers are profitable, on the other hand, equipment producers without a chip manufacturing facility have faced problems with semiconductor supply.

As an example, the automotive industry serves the impact of the chip shortage. Globally, the automobile companies stopped the production line as a result losing of multibillion dollars. This situation has developed due to the fact that auto components, according to the strategies, are purchased exactly at the time of assembly and stocks are not provided. However, the lack of one chip does not allow the car to be fully assembled, and the delay of even a small batch stops the production line of a large factory. GM, Ford, Mazda, Volkswagen, Honda, Volvo, Nissan, Mitsubishi and other manufacturers announced suspension of production in 2021. Due to the shortage of semiconductors, motorists faced a sharp increase in car prices and long queues to buy a vehicle. According to news reports, in the US, for instance, new car prices have increased by 17% while sales have declined by almost 22% since the beginning of the pandemic. In 2021, passenger vehicle prices in Russia have risen by 30%, new car sales in Europe are much below pre-crisis levels. There is a shift in demand for the secondary market. The state of the semiconductor industry alone cannot explain fluctuations in pricing and sales volumes, of course. Inflation and growing energy costs were also contributing factors. Among other automakers, Toyota has managed to avoid production suspension thanks to well-established strategic planning and future purchases, which indicates an effective development strategy and a promptly response to crisis events.

It can be challenging for businesses involved in the semiconductor sector to develop "crisis" plans since the industry's manufacturing is organized in such a way that it is impossible to create a fully closed production chain within one country. This is a rather complicated and expensive process. If we consider the process of creating a computer chip, we can see that it includes more than one thousand procedures (depending on the complexity of the process) and about 80 state border crossings [12]. The manufacturing of the chip may take 12 to 26

weeks [15]. To make a chip, in addition to the actual production process, it is necessary to develop the chip, release and set up production equipment, and train personnel to operate it. Chip production also includes the chip-developing phase, the release and installation of production machinery, and the training of employers to operate it.

Microchip manufacturing is regarded as a science- and capital-intensive process, and the creation of production requires enormous investments. That is why outsourcing is widely used in the industry. It allows for a significant reduction in costs.

The industry is also characterized by a high concentration in the Asian region, narrow global specialization, and a high degree of division of labor. For example, there is the Netherlands-based company ASML and it is considered the only producer of photolithographic scanners in the world. The organization of such a production is exceedingly expensive, and hight quality is difficult. ASML competitors have frequently received complaints about high defect rates or other specifications of their products. The processor cannot be manufactured without a lithograph.

However over 70% of the semiconductor manufacturing facilities (Foundry), including suppliers of key materials such as silicon wafers, photoresist, and other specialty chemicals, are concentrated in East Asia and China (see Figure 2). In addition, over 90% of advanced semiconductor manufacturing facilities are currently located in Taiwan. If something happens in Taiwan (a pandemic, a natural disaster, an international conflict, or a strike) that lead to infrastructure and manufacturing to collapse, it will result in significant interruptions in chip supply and an increase in the deficit.

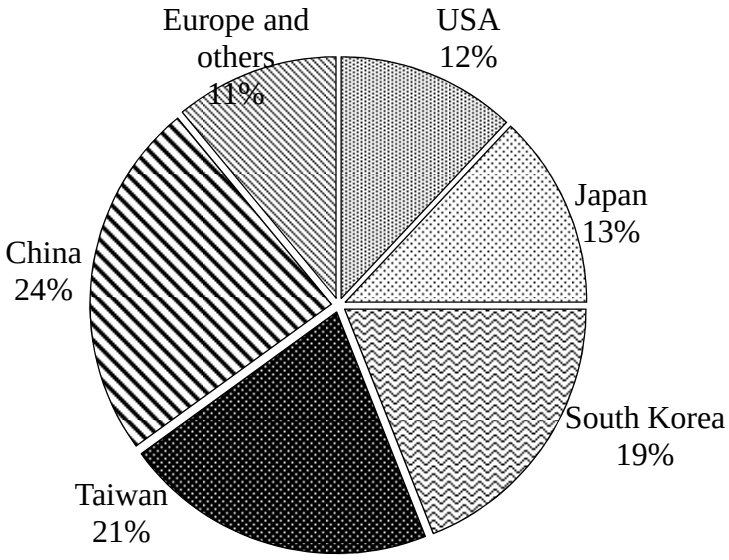

Figure 2. The structure of world capacities for the production of semiconductors

Source: BCG [16]

It was due to geographical and economic features, the cost-cutting principle and the American market management. Moreover, the United States represses all attempts by other countries to develop the semiconductor industry. This explains the political and economic interests of the United States and China in Taiwan.

Of course, the parent companies, and highly qualified personnel engaged in innovative activities and conducting development and testing, are concentrated mainly in the USA (see Figure 3). Most of the equipment is manufactured in Europe (only ASML accounts for 32%). Besides the aspects of production, development, and equipment, there is also resource provision and commerce, which are also concentrated in different regions. Only a small proportion of corporations, such as Intel (USA) and Samsung (South Korea), have a full production chain. Other companies such as Nvidia and AMD (USA) focus solely on R&D and design, and outsource production to TSMC (Taiwan) or Samsung.

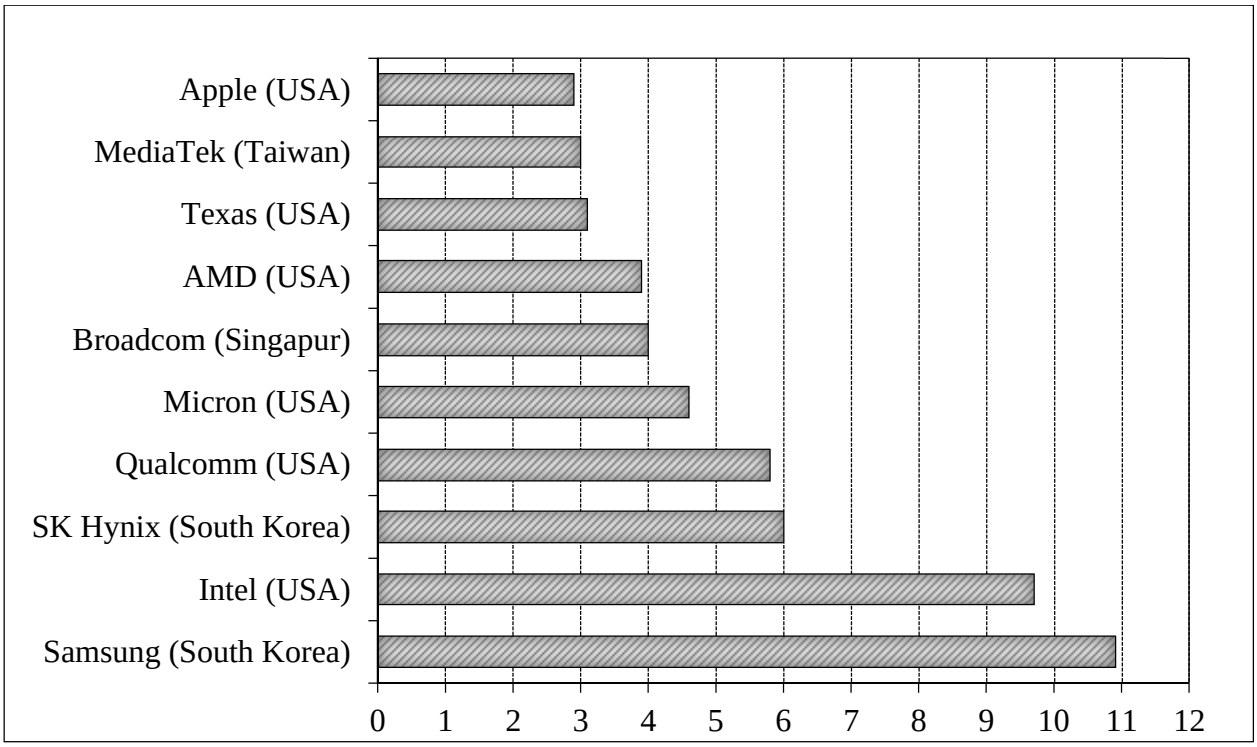

Figure 3. Market share of Top-10 semiconductor manufacturers, %

Source: Author's compilation based on Gartner data

These industry features make the semiconductor manufacturing industry quite unstable. The coronavirus pandemic that emerged in 2020 could destabilize the industry for a long time. Lockdowns broke logistics chains, and the industry did not actually provide for stocks. Due to problems with the semiconductor supply, all electronics, from household appliances to drones, are becoming increasingly expensive, inaccessible, and manufacturers are losing money.

However, if foreign companies have the opportunity to restore broken chains with some alternative options, the Russian Federation has an almost impossible task under unprecedented sanctions. Large corporations such as Intel, AMD, Nvidia, Samsung, and TSMC have cut ties with Russia. The rupture of relations with Taiwan had the most negative impact, since domestic processors' manufacturing was organized on their capacities. Dependence on foreign equipment also has a negative influence on the domestic industry [17]. Because of sanctions, already installed equipment is not subject to maintenance. Buying

new equipment is difficult for the same reason. Almost half of the equipment is made in Europe, 27% in the United States, and the same number in Japan. All of these countries have blocked Russia's access to technologies and equipment.

But the domestic electronic industry, which has been under sanctions pressure since 2012, is well accustomed to functioning under them. Nevertheless, Russia also has several advantages in this area. First, there is the resource advantage in the supply of some rare earth metals such as palladium (45% of the world's supply) and neon. Second, Russia produces 80% of sapphire substrates, without them it is impossible to make a processor. In addition, domestic substrates had a price edge over Chinese ones in this market because arranging any production process in this industry is an expensive operation.

The semiconductor sector is not the only high-tech industry that has been under sanctions pressure. Many Russian enterprises and industries base their production on Western technologies because of simplicity and profitability, although scientists and economists constantly talk about the dangers of such dependence. In addition, the availability of imports reduces the incentives to conduct their own R&D and the demand for innovation. Many studies and reports focused on the necessity of import substitution for strategically significant components and conducting their R&D to close the technological gap. Many scientists pay attention to the trap of technological dependency.

Machines, equipment, and vehicles take half of the structure of Russian imports. The import rate for software is 90%. These areas also require counterparts with their own analogs. The development of the IT sector in modern conditions can take place similarly to the scenario of *Silicon Valley*, whose active growth began with the obtaining of state defense orders [9].

As indicators of innovation activity usually use research costs, the number of organizations, and the number of personnel employed in R&D. Despite the active discussion around the reducing the technological gap, the number of researchers in Russia is constantly decreasing (see Figure 4). In 1992, there were

1,532.6 thousand employees working in R&D. The number of research organizations has also been declining, but it is worth noting that since 2014 the number of research organizations has increased to the level of 2000 and now stands at just over 4,000 (in the 1990s, according to the collection Russia in Figures 2020, the number of such enterprises was at the level of 4,500) [2]. A positive moment was the growing importance of educational organizations engaged in research. The number of such organizations has increased almost 2.5 times in 20 years, from 390 to 951 units, which makes it possible to use the potential of young engineers and researchers [18].

Even though there are fewer researchers and organizations, the figures on the number of technologies developed show that the dynamics are growing, which may point to an improvement in the standard of human capital and staff training.

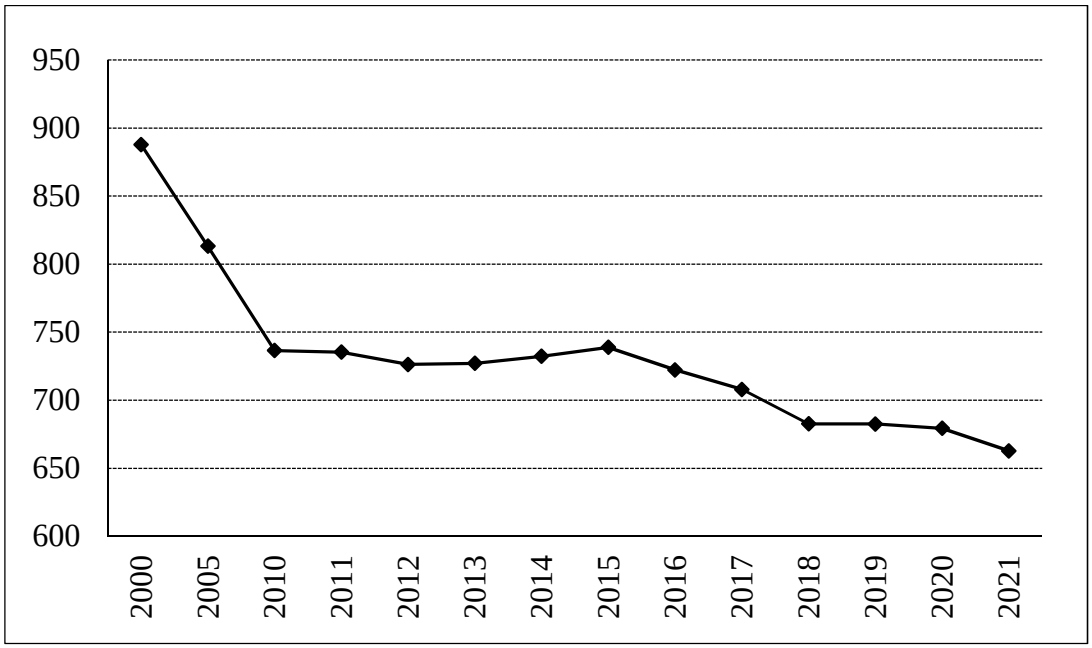

Figure 4. Number of personnel engaged in research and development in the Russian Federation, thousand people

Source: Rosstat[3]

[2] https://rosstat.gov.ru/storage/mediabank/GOyirKPV/Rus_2020.pdf
[3] https://rosstat.gov.ru/mediabank/nauka_2(1)

Among the barriers to Russia's innovative development is a lack of strong linkages between science and industry. The necessity for innovations or research findings frequently does not match the demand.

Overcoming barriers to innovative development will help speed up the progress of import substitution programs in Russia, the need for which has increased significantly due to the prevailing foreign economic and political conditions. It is clear that the national economy is at risk when the export consists of only raw commodities. The import substitution program is currently being successfully implemented in the agricultural and defense industries. Especially revealing is the agriculture sector, which strengthened after introducing sanctions on food supply in 2014. The nation has almost completely met the requirements for food security. Russia could become a leader in grain production, and fertilizer companies also saw significant growth [19].

Because of the forced refusal of imports, the country must design its own strategies for innovation development and economic and industrial policy that are adapted to the current circumstances without concentrating on the views and support of other nations or organizations. The Ukrainian crisis has shown that any dependence between nations can turn into a conflict, even if it was a solid alliance [20].

Discussion. Western sanctions have long been a key element in global competition as well as a political tool. The sanctions attack affects both industries that are competitive, such as the oil and gas sector and metallurgy and those that are the most vulnerable, as microelectronics and mechanical engineering.

The Russian electronics market comprises 95% foreign components. Of course, Russia imports components not only from the USA. Semiconductor manufacturing is mainly concentrated in Asia. The government understood the necessity increase its own semiconductor production before the pandemic and the escalation of the conflict with Ukraine in order to strengthen its level of

industry autonomy. The growth of the semiconductor industry will influence the indicators for other sectors where electronic components are used. As chips are also used in military products, this is a significant issue that impacts the economic sovereignty of the country [21].

Russia has its own semiconductor production facilities, such as *Micron Group, NIIPP, El Silicon Group (Kremny EL Ltd), and GS Nanotech*, but it is not enough for the ever-growing demand. Russia's electronics market has not yet developed into an open one, producers are forced to compete in an artificially limited market. Due to the small size and specialized nature of chips and other microelectronic devices, concentrating only on the military market will not be successful. Additionally, there are no successful commercialization examples, and the level of government involvement in the sector's management is significant [22]. The fact that all the equipment is foreign and cannot be quickly replaced just makes the matter worse.

Relying on China in this situation makes no sense, as China is already subject to US sanctions in this area. The USA has controlled the semiconductor industry, and the current geopolitical conflict is about "maintaining the required order" (for the USA) in this sector. Three groups of countries can be distinguished based on their trade and economic standing in this market. Leading nations in the design and manufacture of equipment and semiconductors, including Germany, the Netherlands, and Japan, make up the first group. The top semiconductor-producing nations, however, don't always have independent domestic production [17]. The second group includes countries dependent on equipment supplies, such as Taiwan and South Korea. In order to control the market situation, the United States can use the levers of pressure on these countries. A particular interest for the US is Taiwan, so they have battle with China. The third group of countries comprises competitors with a high dependence on imports for raw materials and equipment, like China. The

United States will make every effort to constrain these countries' decreased reliance on imports and their technological advancement.

As a face of significant amount of equipment produced for the semiconductor industry in Europe, it's important to keep in mind that this strength can turn into the reason for the US "attack" on this area in order to preserve complete control over the semiconductor sector. The deindustrialization process starts and the European energy crisis could be the first steps in diminishing Europe's position.

It is unrealistic to expect an immediate normalization of the global semiconductor market. The crisis that occurred during the pandemic, combined with chip scarcity, has shown how strategically important this industry is for preserving leading spot.

In the current environment, Russia should focus on forging economic ties with China and India in order to boost local business activity and the competitiveness of domestic commodities and also look for alternative suppliers. The development of domestic production facilities is required concurrently. The autonomization of the industry is a complex, expensive process that will require a significant amount of additional initial investments and would raise semiconductor prices by 35–65% overall. This will increase the final cost of electronic devices for consumers, and the competitive advantage of a low price will be lost. But the organization of production results in the independence and stability of supplies, which creates another competitive advantage. The existence of domestic high-tech production, supported by internal resources, is a prerequisite for survival as well as progress. For example, it has implemented over 1,500 projects to produce Russian equivalents of previously imported goods during the eight years of sanctions [9].

Russia has competitive scientific and engineering schools capable of training the necessary personnel and conducting research. Increased industry

cooperation will result in intensified innovation activities. These rules apply to all high-tech industries, not just the semiconductor sector.

Establishing local production will accelerate the process of import substitution, increase the competitiveness of both suppliers and finished products. It reduces reliance on foreign partners, avoid downtime brought on by the failure of foreign supplies, and increase the proportion of high-tech and science-intensive products. All this will have a positive impact on Russia's economic growth and national security. Of course, it will be difficult to estimate the effect of import substitution in the short term, but with sufficient investment and an acceleration of the pace of creation and implementation of innovative projects, good results are achievable in the long term.

Conclusion. The development of science-intensive and high-tech industries will be crucial for the sovereignty and economic prosperity of advanced countries. The high-tech industry is based on the IT and microelectronics industries, which depend on the functioning of the semiconductor industry. This further demonstrates the importance of organizing national semiconductor production. Besides, Russia relied on imports from Western and Asian nations for these industries. However, future expectations for international collaboration and foreign investment should be minimal. The import of machine tools, equipment, and components is no longer a viable strategy for Russia. Organizing domestic production of equipment, components, and final goods is important to overcome these stagnant states. On the one hand, it requires funding and human resources, and on the other, import dependency ought to have been eliminated long ago because it prevents industry from becoming globally competitive.

Nevertheless, the sanctions have helped the Russian economy develop its independence. There was a motivation to invent, but not to purchase. In the context of breaking economic ties with international partners and limiting export potential and outflows of investment, the way of forming several groups of large

companies with state participation, as done in the US, France, and China, seems promising. It is critical that these companies work together to accelerate the innovation process. Under the circumstances, competitors should compete against a foreign producer rather than one another.

Russia's economic development will be under extreme circumstances. Speedy high-tech and science-intensive industry growth, particularly in the semiconductor sector, is necessary for global competitiveness as well as for the country's technological security, independence, and defense capacity. High-tech industry's localization will allow Russian economy to move into new, more profitable positions.

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