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FINANCING OF RESEARCH AND DEVELOPMENT (R&D): GLOBAL TRENDS, PERSPECTIVES, AND CHALLENGES

Introduction. In the modern world, the strength of states is measured not only by their natural resources or military potential but also by the quality of their intellectual capital and the pace of scientific and technological progress. In the global economic order of the 21st century, Research and Development (R&D) is not merely an academic activity; it is the most significant strategic resource ensuring the competitiveness of nations. The process of transitioning to a knowledge economy necessitates a radical change in science financing mechanisms and the implementation of more flexible, performance-based models.

Analysis of global trends shows that leading states no longer view science financing as an "expense" but as an "investment" directed toward future development. The dominance of the state budget in this field is gradually diminishing, giving way to multi-source financing models that include the private sector, venture funds, and international grants. In particular, large-scale funds directed toward fields such as artificial intelligence, biotechnology, and green energy are reshaping the global scientific landscape [8].

In the modern innovation economy, investments directed toward R&D have become one of the primary indicators of a country's long-term competitiveness. Global experience demonstrates that funds invested in strategic areas such as high technologies, artificial intelligence, biotechnology, and green energy determine not only economic growth but also national security and geopolitical influence [7]. From this perspective, it is of great importance for Azerbaijan to strengthen its scientific potential and form multi-source, sustainable financing mechanisms to transition to an innovation-based development model.

The issue of science financing is particularly relevant for the Republic of Azerbaijan. At the center of the strategy for developing the non-oil sector and diversifying the economy lies "human capital." Within the framework of Azerbaijan's national development priorities, modernizing the infrastructure of scientific institutions, stimulating innovative activity, and commercializing scientific results are among the primary tasks. At the current stage, the main goal of this research is to deeply study international experience and adapt it to national realities to increase the efficiency of R&D work in our republic. The relevance of the topic also lies in the fact that it is impossible to create a sustainable innovation ecosystem without ensuring the financial stability of scientific activity [2, p. 152].

Historically, scientific research has primarily been under state patronage. Especially after World War II, within the framework of the "linear innovation model," the state allocated funds to basic sciences with the expectation that the resulting knowledge would eventually leak into applied fields. However, since the end of the 20th century, this approach has lost its effectiveness. In the modern era, financing is directed more toward market demands and real needs.

The most striking point in global trends is the relative decrease in the share of the state budget and the sharp increase in the share of the private sector (business). For example, in countries such as the USA, Japan, and Germany, more than 70% of R&D expenditures are accounted for by private corporations (Apple, Samsung, Siemens, Volkswagen, etc.). These companies view scientific research not as a cost, but as a primary condition for future profit.

In the modern era, traditional bank loans and budget subsidies in science financing are giving way to more flexible tools:

- **Venture Capital:** These are investments in projects that carry high risk but promise great revolutionary changes (e.g., biotechnology or space research). This financial tool lies behind the success of the Silicon Valley model.
- **International Grant Programs:** Massive programs like "Horizon Europe" serve to consolidate resources by financing scientific cooperation between countries.

The World Bank assesses the financing of R&D as the foundation of sustainable economic growth and "human capital" development in the modern era. Statistical indicators released by the organization demonstrate the unequal distribution of financial resources in the global innovation ecosystem and the direct correlation between this distribution and the GDP growth rates of countries. According to the World Bank's official database, while the share of R&D expenditures in GDP ranges between 2.5% and 4.5% in developed countries, the low figure in developing countries is identified as a major factor increasing the technological dependence of the economy.

The methodology presented by the Bank within the framework of the "Knowledge Economy Index" (KEI) shows that the financing of science should not be limited only to budget allocations but should also be supported by a favorable institutional environment and mechanisms for the commercialization of innovations. The World Bank's recommendations regarding the modernization of scientific infrastructure and personnel training in Azerbaijan consider it necessary to implement tax-credit instruments that stimulate private sector investment in the research and development field alongside state financing.

Table 1. Share of R&D expenditures in GDP across various countries in 2024, percentage

Country	R&D expenditures / GDP (%)	Main source of funding
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Israel	6.3%	Private sector and high-tech companies
South Korea	5.0%	Corporate sector and government programs
USA	3.4%	Private corporations and federal funds
Japan	3.4%	Industry and technology companies
Germany	3.1%	Public-private partnership (PPP)
European Union average	2.1-2.2%	Government and business sector
China	2.6%	State-oriented innovation policy
Azerbaijan	Approximately 0.2-0.3%	Primarily state budget

Source: OECD Main Science and Technology Indicators, 2024

Statistical indicators demonstrate that in developed countries, the specific weight of funds allocated to research and development (R&D) as a share of GDP is at a high level. In particular, the fact that this indicator exceeds 5% in countries such as Israel and South Korea proves the formation of an innovation-based economic model. Comparative analysis shows that the share of R&D expenditures in Azerbaijan's GDP remains low for the time being, which necessitates the implementation of new mechanisms in the financing of scientific activities.

In developed countries, the state no longer allocates funds to scientific institutions in an "arbitrary" manner. The primary criterion here is the KPI (Key Performance Indicators) system. If the activity of a scientific institute does not benefit the national economy or lacks a standing in international rankings, its funding is reduced. This creates a competitive environment among institutions and ensures that resources are directed toward the most promising projects.

Table 2. The share of the private sector in the financing of research and development (R&D) across various countries.

Country	Share of the private sector in R&D financing (%)
Israel	80% approximately
South Korea	78%
USA	70–72%
Japan	75%
Germany	66–68%
China	76%
Azerbaijan	Low level

Source: OECD Main Science and Technology Indicators, 2024

The data presented in the table indicates that in developed countries, the primary burden of financing research and development (R&D) falls on the private

sector. Especially in innovation-oriented economies such as Israel, South Korea, and Japan, the share of business structures in R&D expenditures varies between 75–80% [6, p. 22-24]. This tendency demonstrates that scientific activity is closely integrated with market mechanisms and that innovations are valued as direct sources of economic profit.

Over the past 20 years, through a model of public-private cooperation, China has directed billions of dollars in investment into the research field, consequently becoming one of the global leaders in artificial intelligence, 5G, and high technologies.

In the cases of the USA and Germany, the public-private partnership model holds particular importance. The state encourages private sector investment in scientific activity through tax incentives, grant programs, and legal stimulation mechanisms. As a result, the commercialization of scientific results is accelerated, and competitiveness in the high-technology sector increases.

In Azerbaijan, however, the fact that R&D financing is primarily based on the state budget indicates that the level of private sector participation in innovation activity remains limited. From this perspective, developing venture financing mechanisms, expanding university-industry cooperation, and applying tax incentives to entrepreneurial subjects are of particular relevance.

The role of the state is not only to provide funding but also to create conditions for capital to flow into science. In many countries (e.g., France and Canada), companies receive tax deductions for every dollar they allocate to the R&D field. This "tax credit" system is the strongest incentive pushing the private sector toward collaboration with science.

The development of science is one of the priority directions of state policy in the Republic of Azerbaijan. In the "Azerbaijan 2030" National Priorities, establishing an innovative economy is set as a primary goal [1]. At the current stage, the efficiency of research work must be increased to transform revenues from the oil sector into sustainable development.

Science financing in our country still largely depends on the state budget. However, the activity of the Science Fund in recent years and the holding of competitive grant competitions are positive trends. In the long term, the following opportunities exist for Azerbaijan's scientific institutions:

- University-Industry Collaboration: Local plants and factories commissioning scientific institutes to solve technological problems.
- The Role of Technoparks: The application and commercialization of scientific inventions in production through the High Technologies Park (HTP) [1].

As in many developing countries, one of the main problems in Azerbaijan is "dead patents"—that is, scientific inventions exist but do not reach the market.

The creation of national venture funds to support innovative startups and scientific projects in Azerbaijan is the shortest path to keeping pace with global

trends. The state can reduce the risk for private investors by participating in these funds based on the principle of "co-funding."

Deficiencies in the mechanisms of financing R&D activity lead not only to technological stagnation but also to the loss of the country's most strategic resource—"intellectual capital"—through the phenomenon of "brain drain" [5, p. 85]. Weak financial support in the academic environment, low levels of social protection for researchers, and scientific infrastructure that does not meet modern requirements directly affect the career choices of promising young personnel.

International experience shows that the transfer of highly qualified personnel to foreign scientific centers leads to a break in scientific continuity within the country and a weakening of innovation potential. This process constitutes a "double loss" from an economic standpoint: the state loses both the funds spent on training the individual and the future economic value that the person could have generated.

Within the framework of national perspectives, to prevent "brain drain," the science financing strategy should be based on the principle of investing in human capital rather than just equipment provision. Establishing a competitive salary system for young researchers, approving special stimulating grant packages, and increasing the author's share of income from the commercialization of scientific results are important financial levers to prevent intellectual migration. Thus, ensuring financial stability serves as a fundamental guarantee for protecting the scientific potential of the national gene pool and realizing it within the country [5, p. 85].

In the era of digital transformation, R&D financing is shifting from physical infrastructure toward intellectual technologies and cloud-based computing systems. Artificial Intelligence (AI) and digitalization are changing the science financing model in three main directions: cost optimization, acceleration of results, and risk forecasting.

AI-based research platforms and Big Data are reshaping the "cost-benefit" balance of scientific research. Thanks to the processing of Big Data, theoretical research that once took years is now completed in seconds. This means significant savings in researchers' time and project budgets. For funding agencies, AI platforms provide analytical tools that pre-assess the probability of a project's success, thereby preventing "dead investments" [4, p. 118].

Digital laboratories and automated analysis systems radically reduce scientific infrastructure costs. While traditional laboratory conditions require expensive reagents and physical equipment, "digital twins" and simulation systems allow for an infinite number of tests in a virtual environment. This transition causes financial resources to be directed toward software and the training of highly qualified personnel rather than the purchase of expensive equipment.

The application of automated scientific analysis systems opens new opportunities for the "sustainable financing" of science. AI-supported systems

immediately analyze the commercial potential of scientific results, shortening the time for patenting and transition to production. Consequently, the return on investment (ROI) in the R&D field is accelerated. Within Azerbaijan's national development perspectives, building a digital scientific infrastructure should be considered the most flexible strategic move to increase the effectiveness and global competitiveness of scientific activity, especially under limited budget resources [4, p. 118].

Although certain institutional reforms have been implemented in the financing of R&D in the Republic of Azerbaijan in recent years, several problems restricting the efficiency of the existing system remain. These problems negatively affect the competitiveness of scientific activity, the commercialization of innovations, and the country's integration into the global innovation system:

1. High dependence of science on the state budget.
2. Passivity of the private sector.
3. Weak university-industry relations.
4. The outflow of young scientists abroad ("brain drain").
5. Non-commercialization of patents.
6. Weak integration of scientific results into production.
7. Underdevelopment of the venture capital market, etc.

To eliminate these structural problems and elevate scientific potential to a new level of development, the state has put forward a conceptual approach, the main directions of which are reflected in relevant strategic documents. One such document is the "Strategy for Socio-Economic Development of Azerbaijan in 2022-2026." This document is considered the "road map" for Azerbaijan's future economic model. In the relevant sections (pp. 42–45) of this Strategy, the formation of a modern innovation environment was identified as a priority direction to increase the global competitive power of the national economy. One of the main theses noted in the document is that the country's economic sustainability directly depends on an effective financing system for R&D and the quality of highly qualified intellectual resources [3, pp. 42–45].

Within the framework of the Strategy, restoring the interaction between scientific potential and real production and supporting the activities of innovation-oriented entrepreneurial subjects are included among the important tasks of the state. To achieve these goals, specific target indicators such as increasing the share of R&D expenditures in GDP and accelerating personnel training in high-tech fields have been determined. Strategic analysis of the document shows that, along with budget funds, the application of fiscal (tax and customs) incentives to stimulate non-state investments in this field, as well as the development of a venture financing ecosystem, serve as key economic tools [3, pp. 42–45].

Thus, the aforementioned state document confirms that Azerbaijan's strategic development line until 2026 is based on including scientific results in the economic turnover and applying the principles of a "knowledge economy." This

approach serves to form scientific activity not merely as an object of subsidy but as an integral and driving part of the real sector of the economy [3, pp. 42-45].

Conclusion. As a state, we must view science financing not merely as a social expense but as the most profitable investment tool ensuring national security and economic independence. As a result of the research, it can be noted that financing scientific research is not just an economic issue but also a change in management philosophy. The proposed strategic steps for Azerbaijan are as follows:

1. Diversification of financial sources: Reducing dependence on the state budget and increasing the share of the private sector and international grants.

2. Tax incentives: Implementing special tax regimes for entrepreneurs investing in science.

3. Monitoring and Evaluation: Measuring every penny of scientific expenditure based on real results (articles, patents, prototypes).

4. Investment in Human Capital: Providing opportunities for young researchers to intern abroad and establishing modern laboratory conditions.

Only through these complex measures can the research and development field become the locomotive of Azerbaijan's economic progress. Synthesizing global trends with national characteristics is the only way toward a sustainable future.

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