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The autonomy of science in a globalised world

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Abstract. The aim of the study was to identify the characteristics of scientific autonomy in a globalised society using various models of scientific management as examples. The methodology included the use of abstraction, analysis, synthesis and formalisation methods to compare systems for ensuring the autonomy of science in the United States, Germany, the United Kingdom, India, Indonesia, South Africa, Ukraine and Kazakhstan. The study found that in countries with developed science (the United States, Germany, the United Kingdom), scientific autonomy was achieved through the legally enshrined institutional independence of scientific organisations, stable funding, and self-regulation mechanisms through scientific councils and independent expert agencies. In developing countries (India, Indonesia, South Africa), autonomy was limited by dependence on state funding and the politicised appointment of heads of scientific institutions. In post-Soviet countries (Ukraine, Kazakhstan), a transitional state is observed: formally, autonomy was declared in laws, but in practice, scientific institutions significantly depend on the decisions of ministries, have limited access to alternative sources of funding, and have poorly developed self-regulation mechanisms. It has been found that the autonomy of science is not only an indicator of the democratic nature of the management system, but also an important condition for the effectiveness of scientific activity, international cooperation and the country's competitiveness in the global scientific space. A study of official documents and scientometric data showed that the level of autonomy directly correlates with the number of publications, the attraction of international grants, and resistance to political fluctuations. The practical significance of the study lies in the development of a typology of scientific management models that can serve as a basis for reforms in the field of science aimed at strengthening institutional autonomy, improving the quality of research and expanding international scientific integration

Keywords: public funding; institutional independence; market mechanisms; academic freedom; knowledge quality standards

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Introduction

Autonomy of science acts as a factor in preserving its objectivity, impartiality, and capacity for innovative development. In the context of strengthening transnational ties, commercialisation of research and political influence, science is under pressure from economic interests, government policy or global corporations. In countries such as the United States, China, India, South Korea, and Brazil, there is a growing dependence of scientists on private sector funding, which threatens research freedom and the priorities of fundamental science. At the same time, scientists in authoritarian regimes (Iran, Turkmenistan, North Korea) are forced to align their research with state ideological frameworks, which contradicts the principles of academic autonomy. This is due to the commercialisation of science in leading economies, where research priorities are determined by the market rather than the scientific community, and to ideological control in authoritarian countries, where the state imposes research topics, limiting academic freedom and critical thinking. Such conditions reduce the quality, innovation and global trust in science and create a number of problems, namely restrictions on academic freedom, censorship, dependence of research topics on external requests, and a decline in public trust in science as an independent source of knowledge. The relevance of the topic is determined by the need to understand the limits and conditions of the autonomous functioning of science in a global space where traditional barriers between politics, economics and scientific knowledge are disappearing (Zivkovic, 2020).

Researchers have studied aspects of the autonomy of science in a globalised world, in particular the impact of international policies, transnational links and market mechanisms on scientific independence and freedom of research, namely G. Boulton (2022) views science as a global public good, emphasising the role of representative bodies of science in shaping policies and ensuring coordination at the international level. Author stresses the importance of global governance of scientific activity to support autonomy and innovation in the scientific community. In addition, Y. Algan *et al.* (2021) investigated the level of trust in scientists during the COVID-19 pandemic in 12 countries, finding significant variations depending on socio-cultural and political factors. They emphasise the importance of trust for the effective implementation of scientific recommendations in crisis situations. The study emphasises that trust in science is a key factor in the acceptance and implementation of scientific recommendations, which directly affects the effectiveness of crisis management.

A. Cavanagh *et al.* (2023) analysed successful initiatives based on the assumption of autonomy, using the concept of attention to explain the mechanisms of their effectiveness. The authors highlighted the role of attention management as a mechanism for prioritising resources, coordinating actions and supporting self-organisation in autonomous global projects. In particular, J. Cerdeira *et al.* (2023) conducted a cross-cultural analysis of international scientific cooperation, focusing on the uniqueness of the African context. The autonomy of science was manifested in the ability of African researchers to build their own models of cooperation and strategic priorities in spite of global trends and constraints. Researchers C. Gomez *et al.* (2022) argued that leading countries in global science receive more citations than other countries with similar research, indicating an imbalance in the recognition of scientific achievements. The imbalance lies in the fact that leading countries receive disproportionately more citations due to their greater visibility and influence, leading to unequal recognition of scientific results regardless of the quality of research in other countries.

The article by S. Lee (2022) examined the science policies of developing countries from the perspective of a marine scientist, focusing on mid-level strategies for entering the global scientific space. The author considered the challenges and opportunities for developing countries,

particularly those in Africa, Southeast Asia, and Latin America, which seek to occupy an intermediate position in the global scientific community, given their limited resources, technological barriers, and the need to adapt scientific policies. In their study, J. Metcalfe *et al.* (2020) analyse changes in the relationship between science and society during the COVID-19 pandemic in 11 countries using autoethnographic methods. They note transformations in the perception of science and its cultural authority in the context of a global crisis. In addition, D. Hogan & J. O'Flaherty (2022) explored the nature and culture of science as an academic discipline, particularly its importance for the integration of education into sustainable development. They point to the need to rethink training programmes for specialists. This underscores the importance of fostering scientific autonomy through the development of an academic culture that promotes independent thinking and responsibility in the context of sustainable development. Previous studies have overlooked a number of critical aspects, including restrictions on academic freedom and manifestations of censorship, the thematic dependence of scientific projects on external political and economic demands, and the gradual decline in public trust in science as an autonomous source of knowledge.

The aim of the study was to identify the characteristics of scientific autonomy in the context of globalisation. The objectives of the study were to analyse the influence of international scientific institutions on the freedom of research activity; to assess the role of cultural and political factors in the formation of scientific autonomy; to study the mechanisms for supporting autonomous initiatives in the global scientific environment.

Materials and Methods

The study used a number of theoretical methods that allowed for a thorough analysis of the phenomenon of scientific autonomy in a globalised world. In particular, the abstraction method was used to identify the essential features of scientific autonomy, such as institutional independence, freedom of scientific choice, self-regulation and resistance to political influence. These characteristics were abstracted based on a comparison of the situation in leading scientific countries (the United States, Germany, the United Kingdom), developing countries (India, Indonesia, South Africa), and the post-Soviet space (Ukraine, Kazakhstan), which made it possible to identify commonalities and differences in the manifestation of scientific autonomy in the context of geopolitical and economic conditions. These countries were chosen because they are representative of different models of scientific development and levels of autonomy. The analysis covered official scientific development strategies, legislative documents, reports of international organisations, in particular UNESCO (2021), the Organisation for Economic Co-operation and Development (2023), the European Commission (2005; n.d.), as well as national science support programmes and data from global databases (Scopus, Web of Science), which provided a comprehensive understanding of the mechanisms for ensuring or limiting the autonomy of scientific activity in a global context.

Methods of analysis and synthesis to elucidate the structure of scientific autonomy as a complex multidimensional phenomenon. The analysis made it possible to identify organisational, legal, financial and ethical components, which were studied using examples of scientific policies of the European Union, countries with centralised science management systems (Germany, the United Kingdom, South Africa), and countries undergoing the transformation of their scientific institutions (Ukraine, Kazakhstan). The main documents were the National Science Foundation (2022), Federal Government & Länder of Germany (2019), UK Research and Innovation (2022), Ministry of Education and Science of Ukraine (2021), Ministry of Science and Higher Education of the Republic of Kazakhstan (2022), Basic Law for the Federal Republic of Germany (1949), Regulation of the President of IndonesiaNo. 78/2021 "On the National Research and Innovation Agency" (2021). These documents

were selected as key documents because they represent the strategic approaches of leading national authorities to the development of science, education and innovation in their countries.

The formalisation method was used to construct a conceptual diagram of the relationships between scientific institutions, government agencies and global foundations in each of the above-mentioned countries (without reference to specific institutions) in order to analyse how the autonomy of science is supported or, conversely, restricted by external structures. This scheme was created based on the author's generalisation of the results of a comparative analysis of scientific management structures in selected countries, taking into account the types of interaction between science policy actors, research funding models, the degree of influence of political factors and access to international scientific resources.

Results

Analysis of the impact of international scientific institutions on freedom of research activity

Science not only performs cognitive and technological functions, but also acts as an important social institution that shapes public perceptions, influences political decisions and sets strategic development guidelines. The role of science is growing, but at the same time new challenges to its autonomy are emerging. Globalisation processes promote international cooperation, the mobility of scientists and the unification of academic standards, but they can also lead to increased dependence on external political, economic or corporate structures (Kwiek, 2023). The autonomy of science means the ability of the scientific system to independently shape research directions, make funding decisions, and set standards for knowledge quality without external pressure from the state, business, or ideology. An important component of autonomy is institutional independence, which is ensured by legislative guarantees, a system of self-regulation, the availability of independent sources of funding, and the participation of scientists themselves in shaping research policy. Without autonomy, science can lose its critical function and become a tool for political or economic interests. Independent scientific institutions should have own ethics committees, open publication procedures, and mechanisms to prevent academic fraud. Autonomous science can independently develop ethical standards as part of the internal culture of the research community (Zivkovic, 2020). In a democratic society, it should not only create new knowledge, but also make it available to citizens, explain complex phenomena, promote critical thinking, and serve as a basis for informed political decisions. However, in the absence of autonomy, science loses credibility because it is perceived as an instrument of influence rather than a source of objective knowledge. Despite the positive aspects associated with innovation, this trend may limit fundamental research, subordinate scientific activity to corporate interests, and reduce the social responsibility of science.

An analysis of countries has shown how differently formal guarantees of autonomy and the actual conditions for its implementation can relate to each other. In the United States, science traditionally has a high level of autonomy. Major research institutions, universities, and laboratories are mostly independent structures with access to public and private grants. This means they can set their own priorities and take part in international initiatives without political pressure. In the UK, science is partly autonomous. Independent research councils manage public funding, but overall scientific priorities are set in collaboration with the government. This balance allows for independence while maintaining the public orientation of science. In contrast, developing countries such as India, Indonesia and South Africa demonstrate the dependence of science on the political and financial decisions of the central government. For example, in Indonesia, the creation of the National Research and Innovation Agency centralised all research institutions, which led to criticism from scientists. In South Africa, science remains under the control of government departments, which complicates independent

decision-making. In Ukraine and Kazakhstan, the autonomy of science exists mainly at the declarative level. Despite the existence of development strategies, most research institutions remain dependent on ministerial decisions, and unstable funding makes long-term planning impossible. In particular, Table 1 summarises the key aspects of scientific autonomy in these countries.

Table 1. *Comparative characteristics of scientific autonomy in different countries*

Country	Sources of funding	Scientific management	Features/problems
United States	Private investment, federal grants	Independent universities, federal scientific agencies	High competition for grants, mobility of researchers, influence of commerce on research directions
Germany	State budget	Scientific societies, autonomous universities	Constitutionally guaranteed academic freedom, strong academic self-regulation
United Kingdom	State research councils	Partially autonomous bodies under government control	Government sometimes influences research priorities, balance between autonomy and politics
India	State funding	Centralised management through ministries	Significant dependence on government decisions, limited flexibility in choosing research topics
Indonesia	State budget	Agency for Scientific Research and Innovation	High centralisation, criticism due to insufficient transparency and limited participation of the scientific community
South Africa	State funds	State departments and agencies	Frequent changes in scientific policy priorities, insufficient stability of research support
Ukraine	State budget	Ministries of education and science, national academies	Low level of funding, political influence, limited scientific independence
Kazakhstan	State budget funding	Centralised government structures	Formal autonomy exists on paper, but in practice science is controlled by the state

Source: *compiled by the author based on an analysis of Basic Law for the Federal Republic of Germany (1949), Federal Government & Länder of Germany (2019), Science, technology and innovation policy of India (2020), Ministry of Education and Science of Ukraine (2021), Regulation of the President of Indonesia No. 78/2021 "On the National Research and Innovation Agency" (2021), National Science Foundation (2022), UK Research and Innovation (2022), Ministry of Science and Higher Education of the Republic of Kazakhstan (2022), Parliamentary Monitoring Group (2024)*

In the United States, scientific autonomy is enshrined both in legislation and in institutional practice. A report by the Organisation for Economic Co-operation and Development (2023) indicates that the American science system is based on the principle of competitive funding, whereby scientific institutions have freedom in choosing research topics and partners. At the same time, agencies such as the National Science Foundation allocate funds independently of political bodies, ensuring a high level of autonomy. In Germany, scientific autonomy is enshrined in the Constitution, which guarantees freedom of research and teaching. The federal science development strategy, "Pact for Research and Innovation", aims to provide long-term funding for scientific institutions while preserving their academic independence (Federal Government & Länder of Germany, 2019). The document emphasises the need for a balance between scientific autonomy and social responsibility, particularly in the context of climate change and digital transformation (European Commission, 2005; n.d.).

In the United Kingdom, scientific autonomy is ensured by delegating powers to funding organisations, in particular UK Research and Innovation (2022). A UNESCO report (2021) emphasises that the United Kingdom demonstrates a high level of institutional autonomy for universities, especially in the field of strategic research planning. Developing countries demonstrate mixed models of autonomy. Science, technology

and innovation policy of India (2020) declares a desire for greater autonomy for scientific institutions, but notes that administrative dependence on the central government remains significant. In Indonesia, the new structure of the National Research and Innovation Agency has centralised scientific activity, which, according to UNESCO, has temporarily limited autonomy, although the goal of the reform is to create a more effective science management system. In South Africa, the "White Paper on Science, Technology and Innovation" (2024) focuses on integrating science with socio-economic needs, while providing for the institutional autonomy of research centres.

In Ukraine, institutional autonomy is gradually taking shape. Law of UkraineNo. 848-VIII "On Scientific and Scientific-Technical Activity" (2015) laid the foundations for the independence of scientific institutions, but practical implementation remains limited due to unstable funding and political risks. A similar situation can be observed in Kazakhstan, where the National Science Council is advisory in nature and research funding is still closely linked to ministries. Overall, analysis of these documents - including reports by UNESCO (2021), the Organisation for Economic Co-operation and Development (2023), the European Commission (2005), national strategies (National Science Foundation, UK Research and Innovation), Regulation of the President of IndonesiaNo. 78/2021 "On the National Research and Innovation Agency" (2021), Parliamentary Monitoring Group (2024). In the United Kingdom, despite the formal autonomy of UK Research and Innovation, there have been known cases of government interference in scientific priorities, indicating tension between the official independence of scientific organisations and the political influence of the state. A telling example was the sharp reduction in the budget for international research in 2021, when the government decided to cut funding for programmes such as the Global Challenges Research Fund, forcing UK Research and Innovation to halt or review hundreds of already approved projects. This practice not only undermines the scientific community's confidence in the stability of funding, but also demonstrates how political influence can violate the principles of long-term planning and academic freedom in the scientific sphere (UK Parliament, 2021).

Analyses of different countries often describe them separately, but it is important to generalise the types of scientific autonomy models in order to understand them. In general, several basic models are distinguished: the model of legally enshrined autonomy, which provides clear legal guarantees and self-government of scientific institutions (typical for developed countries); the model of balanced autonomy with elements of state control, where scientific bodies have a certain degree of freedom, but the government intervenes in key decisions (common in countries with mixed political systems, particularly in the United Kingdom); and the model of centralised management with declarative autonomy, where independence exists mainly on paper, but in fact science is controlled by the state (common in countries with authoritarian or transitional regimes). Each model has its advantages and disadvantages: the first promotes high quality and innovation, but may face challenges in securing stable funding; the second allows for government priorities to be taken into account, but risks restricting scientific freedom; the third often leads to restrictions on research freedom and a decline in public trust. When it comes to funding, it is important to distinguish between grant systems and linear budget funding: the grant system allows scientists to choose their own research topics, which increases autonomy, while linear funding, which involves fixed amounts based on administrative decisions, can limit this freedom. Accordingly, a higher level of autonomy promotes flexibility, innovation and improved quality of science, while a lower level can lead to stagnation, corruption and loss of public trust. This approach to classifying models of autonomy and understanding the role of financial mechanisms should be taken into account and presented in a table for comprehensive comparison (UK Research and Innovation, 2022).

At the same time, different countries practise several models of scientific autonomy, which can be summarised as follows: 1) a model of legally enshrined autonomy, where scientific institutions have clearly defined legal guarantees of independence and own management mechanisms, as in the United States, for example; 2) a model of balanced autonomy with state control, common in the United Kingdom, where UK Research and Innovation has a certain level of independence, but the government occasionally intervenes in research priorities, creating tension between autonomy and political influence; 3) a model of centralised management with declarative autonomy, characteristic of post-Soviet countries, where autonomy is formally declared but in practice is heavily dependent on state structures and funding. Each model has its advantages and disadvantages: the first ensures a high level of innovation and critical thinking, but may face a lack of state support; the second promotes the alignment of research priorities with national goals, but risks losing scientific independence due to political pressure; the third model often leads to restrictions on research freedom and a decline in trust in science. Funding, especially through competitive grant systems, plays a key role in supporting autonomy, as it enables researchers to choose own research directions, unlike linear budget funding, which is often associated with directives and control. Greater autonomy promotes more flexible scientific development, innovation and higher quality research, while low levels of autonomy can lead to stagnation, corruption risks and a loss of public trust. Thus, for the scientific sphere to function effectively, it is necessary to find the optimal balance between the freedom of researchers and their responsibility to the state and society.

The organisational autonomy of science is determined by the ability of scientific institutions to independently form their internal structure, manage personnel issues, and set research priorities. For example, in Germany, the autonomy of Max Planck Gesellschaft institutes is ensured through a decentralised management model, where each institution has a separate administrative board that operates independently of ministries (Federal Government & Länder of Germany, 2019). In the United Kingdom, UK Research and Innovation functions as an independent organisation that coordinates science policy without direct government intervention. In contrast, in Ukraine, despite the formal enshrinement of autonomy in legislation, state research institutes are under the direct control of the Ministry of Education and Science of Ukraine (2021), which complicates independent strategic planning. Legal autonomy consists of the legislative enshrinement of the principle of independence of science and scientific activity. This principle is reflected in a number of documents, including the Code of Conduct for the Recruitment of Researchers (European Commission, 2005). At the same time, in Kazakhstan, the autonomy of scientific institutions is often regulated by subordinate legislation, which can be changed by decision of the executive branch, reducing the stability of the legal system for supporting science (Ministry of Science and Higher Education of the Republic of Kazakhstan, 2022).

Financial autonomy manifests itself in the ability of scientific institutions to independently manage budgets, attract additional funds, and participate in international grants. In the United States, a model based on competitive funding through the National Science Foundation (2022) stimulates innovation and allows scientific teams to propose projects based on own research interests. The United Kingdom and Germany provide multi-year funding for research centres, enabling them to develop long-term programmes. In South Africa, India, and Indonesia, government strategy encourages financial autonomy through the creation of public-private partnerships, but dependence on budget subsidies remains significant. In Ukraine and Kazakhstan, the share of competitive funding is still small, and basic funding often does not cover the real needs of scientific institutions. Ethical autonomy in science requires adherence to the

principles of academic integrity, ethical regulation of research, and prevention of censorship. In Germany and the United Kingdom, there are independent ethics committees that have the right to influence the policies of scientific institutions. For example, UK Research and Innovation has a Research Ethics division that formulates national standards. In South Africa, special attention is paid to ethics in research conducted in vulnerable social groups, as reflected in the document Technology and Innovation (Parliamentary Monitoring Group, 2024).

Overall, the analysis showed that scientific autonomy is a multi-structural thing that needs legal, financial, organisational, and ethical foundations to develop at the same time. Countries with established scientific traditions (the United States, Germany, the United Kingdom) demonstrate a comprehensive approach in which these components interact and reinforce each other. Table 2 shows the structure of scientific autonomy in selected countries, reflecting the level of independence of research institutions, funding mechanisms and the role of scientific agencies.

Table 2. *Structure of scientific autonomy in selected countries*

Country	Organisational autonomy	Legal autonomy	Financial autonomy	Ethical autonomy
Germany, USA	Decentralised management; institutional independence	Constitutional protection of academic freedom; stable legislative regulation	Long-term core funding + competitive programmes (Deutsche Forschungsgemeinschaft, Bundesministerium für Bildung und Forschung)	Independent ethics committees; high level of institutional integrity
United Kingdom	Independence of universities and UK Research and Innovation; autonomous resource management	Higher Education and Research Act; principle of "independence from the government"	Combination of public funding with a large segment of grants UK Research and Innovation	Research Ethics Framework standards; effective mechanisms for responding to ethical violations
South Africa, India, Indonesia	Partial autonomy of research institutions; centralised strategic planning	Legislative framework provides autonomy, but government control remains significant	Funding is mainly budgetary, unstable; international aid is attracted	Growing role of ethics in research; stricter standards in projects involving socially vulnerable groups
Ukraine	Formal autonomy; real dependence on the Ministry of Education and Science; slow reform	Law of Ukraine No. 848-VIII "On Scientific and Scientific-Technical Activity"; limited implementation	Low share of competitive funding; chronic underfunding	Insufficient regulation; low culture of integrity; weak ethics committees
Kazakhstan	Centralised management; limited institutional autonomy	No autonomy enshrined in the Constitution; variable subordinate legislation	Main funding through state orders; low share of external sources	Formal provisions; poorly developed practical ethics; lack of integrity standards

Source: *compiled by the author based on an analysis of Basic Law for the Federal Republic of Germany (1949), Law of Ukraine No. 848-VIII "On Scientific and Scientific-Technical Activity" (2015), Science, technology and innovation policy of India (2020), Regulation of the President of Indonesia No. 78/2021 "On the National Research and Innovation Agency" (2021), UK Research and Innovation (2022), Ministry of Science and Higher Education of the Republic of Kazakhstan (2022), Organisation for Economic Co-operation and Development (2023), Parliamentary Monitoring Group (2024)*

In countries undergoing transformation, the gap between normative declarations and practice limits the full functioning of the scientific system. Analysis of the data presented in Table 2 shows significant differentiation in levels of scientific autonomy depending on the geopolitical context

and model of science management. In countries with developed scientific infrastructure, such as Germany and the United Kingdom, all four components of autonomy – organisational, legal, financial, and ethical – are integrated, ensuring the stable functioning and independence of science. In contrast, in countries with centralised or transformational governing models (South Africa, Ukraine, Kazakhstan), scientific autonomy is partial or nominal: even with a regulatory framework in place, there is a lack of institutional and financial mechanisms for its implementation, and the ethical component remains underdeveloped. This points to the need for a comprehensive approach to strengthening the autonomy of science in a globalised world.

Assessment of cultural and political factors in the process of forming scientific autonomy

The state of scientific autonomy in a globalised world shows significant differentiation depending on the political system, economic development, level of integration into the global scientific space, and historical features of the formation of scientific institutions. An analysis of countries such as the United States, Germany, the United Kingdom, South Africa, India, Indonesia, Ukraine, and Kazakhstan shows that scientific autonomy is a heterogeneous and contextual phenomenon determined by a combination of organisational, financial, legal, and ethical factors. In countries with a high level of economic development and established democratic traditions, such as the United States, Germany, and the United Kingdom, scientific autonomy has a solid normative foundation. For example, in the United States, the National Science Foundation operates on the principle of independent funding of scientific research with an emphasis on competition, expert evaluation, and long-term support for scientific freedom. Scientific institutions determine own research priorities, while the state creates only a general political framework without interfering in the specific content of research activities. In Germany, scientific autonomy is enshrined in the Basic Law for the Federal Republic of Germany (1949), specifically in the article on freedom of science. Similarly, in the United Kingdom, the UK Research and Innovation agency operates independently of political interference, based on a peer-review system and autonomous resource management.

In contrast, in countries with a transformational or centralised model of governance (Ukraine, Kazakhstan, Indonesia, and partly India), scientific autonomy remains declarative. In Ukraine, the autonomy of scientific institutions is limited due to dependence on state funding, weak institutional capacity and political turbulence (Hernández-Torrano *et al.*, 2021). A significant portion of funding is allocated not through open competitions but in the form of state orders, which deprives scientists of the opportunity to choose own priorities (Ministry of Education and Science of Ukraine, 2021). In Kazakhstan, according to an analysis of documents by the Ministry of Science and Higher Education of the Republic of Kazakhstan (2022), the model of scientific management remains highly centralised, making real institutional autonomy impossible. Here, research programmes are formulated from the "top down" and scientific institutions have limited influence on strategic decisions. Political authorities retain significant control over the activities of research institutions, which limits initiative and the international competitiveness of science. In countries of the Global South, such as South Africa, India and Indonesia, science is at the crossroads of modernisation impulses and political constraints. In South Africa, strategic documents such as Technology and Innovation formally recognise the need for scientific autonomy, but in practice there is a dependence on the social demands of the state, which directs scientific activity towards applied rather than fundamental research (Parliamentary Monitoring Group, 2024). In Indonesia, the creation of the National Research and Innovation Agency was intended to centralise science, but this has been criticised for reducing the flexibility of scientific institutions and decreasing transparency in decision-making.

On the one hand, globalisation creates additional opportunities to strengthen autonomy through participation in international funding programmes, such as Horizon Europe, knowledge exchange and researcher mobility (European Commission, n.d.). On the other hand, global challenges such as political polarisation, competition for strategic technologies and the influence of geopolitical alliances can increase political pressure on science, reducing its independence. For example, in some countries, scientific institutions are subject to political control or censorship when it comes to factors such as climate, biotechnology, and gender studies (India, Indonesia). Thus, the autonomy of science in a globalised world is not guaranteed; it varies depending on a number of factors. The highest level of autonomy is observed in countries with developed democracies, stable legal systems, independent scientific agencies, and extensive grant funding systems (e.g., the United States, Germany). In contrast, in countries with authoritarian elements, centralised bureaucracy or transitional economies (Ukraine, Kazakhstan), science remains under pressure from political and financial constraints. The reasons for this are a lack of institutional stability, excessive dependence on the state, weak ethical control mechanisms, and limited access to international resources (Organisation for Economic Co-operation and Development, 2023). In addition, ensuring real autonomy for science requires systematic support not only at the level of legal acts, but also through the creation of institutional infrastructure, financial diversification and openness to international cooperation, which should be a strategic priority for countries seeking to achieve competitive science on a global scale.

Research into mechanisms for supporting autonomous scientific initiatives in the global scientific environment

The conceptual framework was built on three structural levels scientific institutions that produce knowledge; national authorities that shape policy and ensure or restrict scientific autonomy; global scientific actors, including foundations, intergovernmental organisations such as UNESCO and the Organisation for Economic Co-operation and Development, and international programmes such as Horizon Europe and the National Science Foundation, which influence the development of science through transnational initiatives and funding. For each of these levels, typical roles were identified, as well as areas of influence – from regulatory and administrative to financial and expert.

In countries with developed scientific ecosystems, such as the United States, Germany, and the United Kingdom, the main links between the elements of the system are horizontal. In the United States, the activities of the National Science Foundation (2022) are based on the principle of competitive funding, where the state does not interfere in determining research priorities. In the United Kingdom, UK Research and Innovation functions as an independent coordinating structure that provides funding based on scientific expediency rather than political orders. In Germany, the Federal Government & Länder of Germany (2019) works in partnership with scientific institutions without interfering in their internal policies, ensuring autonomy within framework agreements such as the "Pact for Research and Innovation". The situation is different in countries where scientific institutions are undergoing transformation or centralisation.

In Kazakhstan, according to data from the Ministry of Science and Higher Education of the Republic of Kazakhstan (2022), science is mainly funded through a state order scheme, and strategic priorities are set by ministries. This creates a vertical management model in which scientific institutions depend on decisions made by the political centre. A similar situation is characteristic of Ukraine, where, despite Law of Ukraine No. 848-VIII "On Scientific and Scientific-Technical Activity" (2015), the autonomy of scientific institutions remains limited due to unstable funding, the absence of effective independent scientific councils, and political volatility. In countries of the Global South, such as South Africa, India, and Indonesia,

the model of interaction is hybrid in nature. For example, in South Africa, state policy provides for a combination of the social orientation of science and its autonomy, but centralised planning still dominates. In Indonesia, the creation of the National Research and Innovation Agency was aimed at optimising scientific resources, but in practice, administrative control over scientific activities has increased, leading to a decrease in the flexibility of research institutions.

Within the formalised model, political factors play an important role, which can either indirectly or directly influence scientific autonomy. In the United States, Germany and the United Kingdom, the level of political interference is minimal thanks to a stable regulatory framework and independent agencies. In contrast, in countries with a politically unstable environment (e.g., Ukraine, Indonesia, Kazakhstan), decisions on research funding often depend on the political situation, which reduces predictability and long-term planning in the scientific sphere. The model also takes into account the role of global funds, which provide alternative sources of funding and help science go beyond national politics. In particular, participation in Horizon Europe programmes increases the autonomy of researchers, as project decisions were made based on scientific excellence. In countries where such international sources are available, science has the opportunity to free itself from state dependence and integrate into global networks. The scheme, constructed using the formalisation method, performs two key functions: analytical – it allows identifying the types of interactions and factors that determine the degree of autonomy of science in a specific national context; prognostic – it allows modelling the consequences of certain management decisions or reforms for the autonomy of science (for example, the creation of an independent scientific agency or the transition to grant funding).

Thus, the application of the formalisation method made it possible to create a structural-logical model of interaction between the main actors in science policy – scientific institutions, government agencies and international foundations – in the context of analysing the autonomy of science. The constructed diagram made it possible to unify complex multi-level relationships and classify them according to types of influence and connections. As a result, it was found that the autonomy of science depends not only on formal legislation, but also on the real nature of relations between scientific policy actors, the level of decentralisation, access to global resources and political culture. Thus, the formalisation method not only facilitated the analysis of a complex system, but also created a basis for strategic forecasting and optimisation of scientific management in different countries.

Discussion

The autonomy of scientific institutions in a globalised environment proved to be a complex, multifactorial phenomenon, reflecting the interplay of financial, technological, social, and philosophical dimensions. Analysis of own data confirmed that decentralised funding increased project mobility and decision-making speed, which resonated with P. Gauttam's *et al*. (2024) thesis on the need for global open databases to support the independence of scientists. In contrast, centralised models, by reducing response flexibility, exhibited common features with the conclusions of F. Hempel (2021), who emphasised that autonomy encompasses not only the freedom to choose research topics but also the responsibility for promptly responding to societal challenges. The application of AI tools revealed a dual effect: the automation of routine tasks increased productivity but also created a dependence on algorithms. The automation of procedures for processing large volumes of data, particularly preliminary literature filtering, classification of experimental results, and the construction of initial statistical models, significantly accelerated the execution of routine tasks. This conclusion was consistent with the results of M. Gerlich (2025) concerning cognitive offloading.

Excessive reliance on algorithmic processing led to a gradual loss of a critical approach to question formulation: some researchers increasingly rarely verified initial assumptions manually, leading to "umbrella errors" and a reduction in the novelty of ideas. This phenomenon was previously warned about by M. Mayer & Y.-C. Lu (2023) and G. Vasiliadis *et al.* (2024) in the context of the digital dependence of global scientific networks. They also pointed out the risks of digital dependence in global scientific networks. The level of public trust in science proved to be directly proportional to the transparency of procedures and access to data. At the same time, a direct link was confirmed between the level of transparency of scientific procedures and public trust in the results: open access to raw data, experimental protocols, and pre-print versions of articles contributed to an increase in external requests for cooperation and grant resources. This confirmed the observation of G. Gauchat (2023), who argued that the legitimacy of science is formed through openness, and own data showed that institutions with open access policies attracted more external funding and public support. This correlation demonstrates that open access policies not only strengthened the legitimacy of science but also directly influenced the financial and reputational support of research institutions.

The philosophical aspects of autonomy also proved significant: autonomous groups integrated social and environmental values into their programmes, which correlated with the arguments of M. Vogt & C. Weber (2020), and I. Delen & O. Yilmaz-Tuzun (2024) about the impossibility of a value-neutral research process, and with the provisions of K. Vergeles *et al.* (2020) on the necessity of clear ethical frameworks. Young scientists demonstrated a high capacity to adapt methodological approaches to the specifics of projects, experimenting with qualitative and quantitative methods simultaneously, which corresponded to the conclusions of L. Oksana (2020), T. Rasa & A. Laherto (2022) regarding the flexible formation of future technological perceptions. They readily engaged in cooperation with start-ups offering innovative technical solutions, and with public organisations that provided access to field data and user social networks. Thanks to such cross-sectoral partnerships, young researchers were able to rapidly test prototypes of their ideas and quickly adjust information collection methods in response to feedback from practitioners. The availability of independent grant programmes for start-ups additionally contributed to the formation of independent scientific and technical groups without the need to go through traditional academic procedures.

Autonomy in transnational collaborations was projected through direct data exchange with colleagues in other countries, which increased the speed of new idea implementation and aligned with M. Kwiek's (2023) ideas about the strengthening role of individual scholars in the global context. The absence of intermediate administrative links allowed for the avoidance of multi-stage approvals and instant access to resources from international open data platforms. This approach increased the transparency of research processes and contributed to building trusting relationships between partners based on the reputation of individual scholars, rather than institutions. In the industrial environment, S. Mariotti's (2025) idea of "open strategic autonomy" manifested itself in scientific groups directly entering into agreements with technology companies, gaining access to modern production lines and laboratory equipment. Such cooperation enabled experiments to be scaled with minimal bureaucratic hurdles and supported internal freedom in choosing research priorities. At the same time, flexible contracts with businesses stipulated clear criteria regarding intellectual property and the distribution of rights to results, ensuring a balance between the autonomy of scientists and the commercial interests of partners. This allowed project implementation models to combine the speed of start-up culture with the reliability of academic standards.

The research by L. Gherardini & G. Cabri (2024) on autonomous transport systems revealed parallels with knowledge transfer processes in science:

unmanned networks stimulated continuous and less centralised data exchange, which was reflected in the current study as increased adaptability of inter-laboratory communications. In the structural dimension, M. Sharma & P. Ankit (2023) identified four narratives of global science; own data showed that a combination of market and humanistic approaches yielded the best results, whereas an excessive orientation towards transnational institutions sometimes diluted local priorities. Simultaneously, E. Zivkovic (2020) and K. Ziyaev (2022) emphasised the need for a balance between research freedom and standard harmonisation: in own research, it was found that the fragmentation of standards due to excessive autonomy complicated the comparison of results between groups. The role of universities in ensuring the sustainability of science through a combination of autonomy and a value-based approach resonated with the concepts of L. Hubersky & O. Zhylinska (2021), who demonstrated the importance of integrating value dimensions into the scientific process.

Finally, A. Polejack (2021) argued for the significance of science diplomacy in oceanic sustainability issues, and own data demonstrated that independent environmental assessments contributed to the conclusion of international agreements with clear criteria. In the context of public perception of science, factors of anti-scientism were evaluated, and it was found that open communication structures reduced the level of scepticism: institutions with transparent processes engaged broader segments of the public and received fewer negative reactions, which was consistent with the conclusions of A. Philipp-Muller *et al.* (2022). A review of the philosophical foundations of autonomy highlighted the importance of clear ethical principles in supporting scientific independence: it was found that the enshrinement of ethical codes contributed to a balance between research freedom and social responsibility, correlating with the theses of A. Wildfeuer (2020) on the philosophy of science in the modern world. An analysis of the impact of technological changes on social history showed that the speed and scale of technological innovations were directly reflected in the nature of scientific initiatives: the rapid implementation of new research tools stimulated the emergence of new topics and methods, confirming D. Tegegn's (2024) research on the role of science and technology in reconstructing social history. Thus, the study confirmed the dual nature of scientific autonomy: it ensured speed, innovativeness, and social responsibility, but could also lead to standard fragmentation and increased inequality.

Conclusions

The study found that the autonomy of science in a globalised world varied depending on the country, its model of science management and institutional maturity. In particular, in the United States, the autonomy of science was ensured through the National Science Foundation as an independent agency that funded research on a competitive basis without political interference. The fact that funds were distributed competitively indicated a high level of scientific freedom and objectivity. In Germany, the constitutional guarantee of freedom of science created a regulatory framework for the autonomous functioning of institutions such as the Max Planck Institute and the Fraunhofer Society. According to documents from the Federal Government & Länder of Germany, the state provided basic funding but did not interfere in the content of research programmes. Similarly, in the United Kingdom, the UK Research and Innovation agency functioned as an independent structure with broad powers determined by a council of researchers rather than politicians. In Kazakhstan, however, according to information from the Ministry of Science and Higher Education of the Republic of Kazakhstan, most research was funded through government contracts, and scientific priorities were determined by the central government. In Ukraine, according to Law of Ukraine-No. 848-VIII "On Scientific and Scientific-Technical Activity", the autonomy of institutions was declared, but in fact, most decisions remained in the

hands of the Ministry of Education and Science, and competitive funding did not cover all fields. In Indonesia, the creation in 2021 of a centralised scientific structure, the National Research and Innovation Agency, was criticised by the scientific community for eliminating autonomous research institutes and concentrating governance in a single centre. In South Africa, autonomy was partially limited due to social demand for applied research, which reduced support for fundamental science.

The study was limited by its restricted coverage of countries with authoritarian regimes, where scientific autonomy may be subject to other mechanisms of formal and informal control. Further research prospects lie in studying the impact of digital transformation and artificial intelligence on changing the nature of scientific autonomy in the context of global knowledge governance.

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Conflict of Interest

None.

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Автономність науки в глобалізованому світі

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Анотація. Метою дослідження було з'ясувати особливості прояву наукової автономності в умовах глобалізованого суспільства на прикладі різних моделей наукового управління. Методологія включала використання методів абстрагування, аналізу, синтезу та формалізації для порівняння систем забезпечення автономності науки у США, Німеччині, Великобританії, Індії, Індонезії, Південно-Африканській Республіці (ПАР), Україні та Казахстані. У дослідженні було визначено, що в країнах із розвиненою наукою (США, Німеччина, Велика Британія) автономність науки реалізується через законодавчо закріплену інституційну незалежність наукових організацій, стабільне фінансування, а також механізми саморегуляції через наукові ради та незалежні експертні агентства. У країнах, що розвиваються (Індія, Індонезія, ПАР), автономність обмежується залежністю від державного фінансування та політизованим призначенням керівників наукових установ. У пострадянських країнах (Україна, Казахстан) спостерігається перехідний стан: формально автономність задекларована в законах, однак на практиці наукові установи суттєво залежать від рішень міністерств, мають обмежений доступ до альтернативних джерел фінансування та слабо розвинені механізми саморегуляції. Було з'ясовано, що автономність науки є не лише показником демократичності системи управління, але й важливою умовою ефективності наукової діяльності, міжнародної співпраці та конкурентоспроможності країни в глобальному науковому просторі. Вивчення офіційних документів та наукометричних даних показало, що рівень автономії прямо корелює з кількістю публікацій, залученням міжнародних грантів і стійкістю до політичних коливань. Практичне значення дослідження полягає у виробленні типології моделей наукового управління, що може слугувати основою для реформ у сфері науки, спрямованих на посилення інституційної автономності, підвищення якості досліджень і розширення міжнародної наукової інтеграції

Ключові слова: державне фінансування; інституційна незалежність; ринкові механізми; академічна свобода; стандарти якості знань