

РОЗДІЛ 4

Вища технічна освіта в умовах глобальної нестабільності



концепції економічної безпеки; ризики і загрози, що впливають на економічну безпеку; механізми забезпечення економічної безпеки у кризових умовах; механізми взаємодії соціальних і правових аспектів у забезпеченні економічної безпеки; стратегії та механізми для підвищення економічної безпеки в умовах нестабільності

KERNASIUK Yurii,

Candidate of Economic Sciences,

Head of the Laboratory of Economic Research and Analysis of Scientific Innovative Potential Institute of Steppe Agriculture of the NAAS

Associate Professor at the Department of

Economics, Entrepreneurship and Hotel and

Restaurant Business Central Ukrainian National

Technical University

HIGHER TECHNICAL EDUCATION IN THE CONTEXT OF GLOBAL INSTABILITY

4.1. Concepts of Economic Security in the Context of Global Technological and Climate Transformation.

Global instability caused by climate change, the energy transition to low-carbon technologies, the rapid spread of clean technologies, as well as the rapid development of artificial intelligence and robotics, poses qualitatively new challenges to society and the economy. Higher technical education is a key factor in ensuring sustainable development: it forms professional communities capable of developing, implementing and supporting the technologies necessary for decarbonization, adaptation to climate risks and digital transformation of industries.

However, traditional models of training engineers and technical specialists, focused mainly on university disciplines and industry standards of past decades, no longer meet the modern requirements of accelerating changes. The combination of multidisciplinary global challenges related to the need to integrate renewable energy sources and energy-efficient systems, the development of autonomous and intelligent infrastructures requires the training of new competencies. In particular, interdisciplinary training, systems thinking, skills in working with big data and AI models, designing sustainable and scalable clean technologies, as well as flexibility in the face of uncertainty and threats to economic security.

Historically, innovation, education, and R&D policies have been closely linked to national security. Today, however, discussions about innovation policy are rarely conducted through the lens of security and take into account problems in education. Innovation policy should predict the side effects of technological transitions, new requirements for education, as well as take into account their multiplier impact and promptly respond to geopolitical shifts, as well as establish a close dialogue between relevant government agencies and scientists of different disciplines [1]. Climate change and environmental degradation remain among the most complex challenges for present and future generations and give rise to a number of security risks that are not sufficiently addressed in the literature [2].

In the context of global technological and climate transformation, the concept of economic security acquires a new content and becomes one of the key guidelines for higher technical education. Economic security in this context implies the ability of the national and regional economy to maintain technological independence, sustainability of production chains, energy stability and competitiveness in the face of extreme climate risks and rapid technological shifts. Vulnerabilities in global supply chains, a shortage of qualified personnel for clean tech and digital infrastructures, as well as dependence on imported critical materials and technologies create systemic risks that directly depend on the quality of engineering training and the scientific and technical potential of universities.

The transition to net-zero energy emissions, which is necessary to combat climate change, is already underway in many countries. Therefore, socio-technical systems are also forced to become environmentally and sustainable. Such transitions have both positive and negative security implications in a variety of ways that deserve attention, but are rarely addressed in research. There is a need to improve interdisciplinary communication and coordination, as well as to expand research using foresight methods to more specifically assess forecast expectations and scenarios [3].

European Union countries have committed to tackling climate change, aiming for climate neutrality and net-zero greenhouse gas emissions by 2050. In December 2019, this goal was reaffirmed by leaders at a European Council summit, after which the European Commission presented the EU's Green Deal. This direction stems from the obligations under the Paris Agreement, which has been ratified by all members of the European Union. The transition to a zero-emission economy in response to the climate crisis offers significant prospects for economic growth, market development and job creation, and technology advancement. The green transformation is designed to strengthen the competitiveness of the EU, provided that the principles of social justice and balanced distribution of benefits are respected [4].

The integration of economic security tasks into higher technical education programs means a focus on competencies that ensure technological sovereignty in the development and adaptation of critical technologies within the country. It is also important to ensure the training of specialists who are able to design sustainable and fault-tolerant infrastructure systems (power grids, transport, production) that will be able to function in response to climate shocks. It is necessary to develop skills in risk analysis in global supply chains and their management using digital tools (data analytics, AI). The formation of abilities for rapid technological retraining and localization of production in response to external crises is the key to successful adaptation.

Therefore, it is important to develop a conceptual framework and practical recommendations for the transformation of higher technical education in the context of global instability, taking into account the challenges of climate change, low-carbon transition, clean tech, AI and robotics. This is the most important goal, for the achievement of which it is necessary to solve individual problems.

First, to analyze the requirements of the labor market and the key competencies in demand in the low-carbon and clean tech sectors. Secondly, to assess the current structure of curricula of technical universities and identify gaps in the training of specialists. Thirdly, to propose a model of competencies and educational trajectories that integrates technical, digital and climatic disciplines. In addition, it is necessary to develop methodological recommendations for the implementation of project-oriented, interdisciplinary and modular learning using AI and robotics tools. To propose mechanisms for interaction between universities and industry and government agencies to accelerate the transfer of technologies and practices.

Thus, the transformation of higher technical education towards climate and technological resilience directly serves to strengthen economic security: universities are becoming not only a source of innovation, but also strategic nodes for the reproduction of national technological potential.

4.2. Modern risks and threats affecting economic security

Higher technical education is on the verge of a profound transformation dictated by a set of global climatic, energy, technological, and geo-economic challenges. Climate change and the frequency of extreme weather events require engineers to be able to design resilient and adaptive infrastructure systems that can function in conditions of heightened uncertainty. In parallel, the low-carbon transition is creating a new demand for competencies in the field of renewable energy, energy efficiency and energy storage systems. The development of innovative clean tech technologies necessitates a combination of materials science, chemistry, electronic engineering and system integration to create competitive solutions. Artificial intelligence and robotics are changing the way technical systems are designed, operated, and maintained, requiring graduates to master algorithms, data, and cyber-physical interfaces. Traditional disciplinary boundaries no longer reflect the nature and complexity of the tasks facing modern engineers and specialists. And this calls into question the relevance of existing curricula and educational programs.

Human-induced climate change is often seen as a threat to human security. At the same time, the extent and conditions under which climate impacts and their associated impacts can lead to serious risks to the world are still not sufficiently systematically studied [5,6]. New technologies based on artificial intelligence, big data, blockchain, and cloud computing are driving digital transformation. However, at the same time, they also increase the risks to cybersecurity for companies in the process of using these technologies [7].

Modern risks and threats affecting economic security can be classified into the following levels of influence:

- climate extremes and systemic climate risks – the frequency and intensification of storms, floods, droughts and fires disrupts production chains, infrastructure and logistics, increasing the cost of recovery and reducing the investment attractiveness of the regions.

- energy vulnerability – dependence on fossil fuels, centralized and volatile energy supplies, and a lack of energy storage systems make the economy vulnerable to disruptions and price shocks during the transition to low-carbon models.

- talent gap and skills deficit – a shortage of specialists in clean tech, AI, robotics, and sustainable design limits the ability to quickly adopt and scale low-carbon and adaptive technologies.

- dependence on global supply chains and critical materials – the concentration of production of rare earth elements, semiconductors and other critical components in certain regions creates the risk of technological blockage and price manipulation.

- cybersecurity and digital infrastructure vulnerability – the increasing number of attacks on industrial and energy facilities threatens the operational resilience and security of the data needed to manage critical infrastructure.

- technological backwardness and loss of competitiveness – the inability to develop or adapt key clean and digital technologies leads to the leakage of added value and a decrease in export potential.

- financial risks and reallocation of investment directions – the transition to a low-carbon economy causes a redistribution of capital, and therefore poorly prepared sectors and regions face a lack of investment and increased borrowing costs.

- political and regulatory instability – Unpredictable or inconsistent climate, industry, and trade policies increase risks to long-term investment and technological development planning.

- social and migration shocks – climate migration, rising inequality, and job losses in traditional industries create social tensions, undermining the domestic labor market and the stability of public institutions.

- ethical and regulatory risks of AI and automation – the rapid adoption of AI and robots without proper standards/ethics can cause technological and societal divides that undermine trust in technology and its legitimacy in critical sectors.

Each of these risks directly correlates with the personnel training system: reducing the vulnerability of the economy requires targeted updating of educational programs, the formation of interdisciplinary competencies and strengthening the interaction of universities with industry and the state. At the same time, technical universities should become centers of interdisciplinary education, where technical knowledge is complemented by skills of systems thinking and risk management. Economic security in the new conditions is determined not only by resource reserves, but also by the availability of qualified personnel capable of localizing and adapting key technologies. Dependence on imported critical materials and complex components makes countries vulnerable if their universities cannot provide the appropriate scientific and technical base and training.

Integrating economic security into educational programs involves a focus on technological sovereignty, sustainable systems, and supply chain management. In the context of global instability, the ability to quickly retrain personnel and transfer technology is becoming a strategic advantage. Educational trajectories should include project internships, internships in industry, and solving real-world problems so that students gain experience in integrating scientific knowledge and applied skills. This requires close interaction between universities and business and government institutions, as well as the creation of laboratories and clusters for joint development.

The modularity of programs and flexible educational routes will allow you to quickly adapt to changes in the labor market and technological changes. An important element is the formation of competencies for working with data and AI, since analytics and forecasting are becoming key tools for managing complex engineering systems. Skills in designing robots and autonomous systems are in demand in construction, energy, agriculture, and other sectors where automation increases resilience and reduces human risk. Competence centers at universities can serve as platforms for panel research that brings together engineers, environmentalists, economists, and policy specialists. Education programs should reflect the real challenges of decarbonisation, including an understanding of the economic, regulatory and social aspects of the transition. This involves the introduction of courses on technology life cycle assessment, sustainable design and climate risk management.

The development of soft skills – communication, leadership, project management – is becoming critically important for the implementation of complex projects in a multitasking environment. Ethical training of specialists in AI and robotics is also important so that new technologies do not increase social inequality and do not violate basic rights. In modern higher education, it is necessary to stimulate entrepreneurial innovative competencies so that graduates can not only implement other people's solutions, but also create their own clean technologies and startups. Funding for educational and research programs should be focused on long-term strategic objectives related to climate resilience and technological autonomy. Public policy in education and science plays a key role in setting priorities and creating incentives for universities and industry.

International cooperation remains important, but it must be based on the principles of diversification and reducing critical dependence on limited sources of technology and materials. The digital transformation of the educational process involves the use of online laboratories, virtual simulations and collaborative platforms. This will accelerate the transfer of skills and increase access to specialized competencies. Assessing the effectiveness of programs requires new metrics that take into account the contribution of education to national technological independence and the adaptability of the economy. Predictive analytics and scenario modeling tools can help universities shape courses that match possible industry development trajectories.

A risk-based approach to education will allow graduates to better understand the vulnerabilities of systems and make decisions taking into account unforeseen events. Training should include an understanding of the political and economic context of decarbonization and transition financing mechanisms so that engineers can work within real-world projects and business models.

Retraining and continuing education programs will become the norm in the face of rapidly obsolescence of skills. It is necessary to develop competency standards for a new generation of technical specialists who combine climate literacy, digital skills and systems engineering. In addition, universities should actively participate in the formation of regional innovation ecosystems, linking research, industrial partnerships and educational programs.

Supporting interdisciplinary doctoral and postdoctoral programs strengthens scientific capacity and accelerates the transfer of knowledge to industry. Cleantech Testing Labs and Autonomous AI Testing Sites Enhance Students' Hands-on Training and Bolster Investor Confidence.

In the face of climate shocks and geopolitical tensions, a local production base and an expert talent pool are the key to maintaining economic stability. The system of higher technical education should provide not only technological training, but also the ability to adapt to political, economic and environmental changes. This requires reforms in university governance, flexible financial models and mechanisms for the rapid introduction of educational innovations.

The openness of scientific data and collaborative research platforms increase the speed of innovation and reduce duplication of effort. The role of universities in public policy and resilience advice is increasing, as they have the expertise needed to assess risks and develop adaptation strategies. Ultimately, the stability of the economy in the era of climate and technological transformation will be determined by the degree of integration of education, science and industry, as well as the willingness of society to invest in human capital and technological independence.

4.3. Mechanisms for ensuring economic security in crisis conditions of global challenges and transformations.

The transformation of economic systems is considered as a necessary condition for overcoming interrelated global crises and problems. Unconventional economic concepts focused on the sustainable well-being of people and ecosystems have the potential for profound transformation. However, their spread is hindered by established interests in society and intellectual stereotypes [8]. A fundamental change in the relationship between people and nature is needed to ensure a transition to more sustainable development trajectories at the local, national and global levels. Crises can trigger transformation and learning in both the short and long term. However, new mechanisms for economic security often reinforce existing unsustainable practices, thereby increasing vulnerability and inequality instead of moving towards a sustainable path [9].

Effective mechanisms for ensuring economic security in the crisis conditions of global challenges and transformations are based on a set of measures aimed at increasing the resilience of production and service systems to external shocks and internal shifts. A key element is the diversification of supply and value chains, which reduces dependence on narrow geographical sources of critical materials and components. Localization of strategically important industries and support for national industrial potential can reduce vulnerability to disruptions in international logistics and sanctions risks.

The formation of reserves of critical materials and components, together with a developed system of recycling and reuse, reduces the consequences of disruptions in imports and contributes to a circular economy. State support for scientific and technological development and financing of applied research creates a platform for maintaining technological sovereignty and accelerates the introduction of clean technologies. Investments in education and the continuous retraining of the workforce and new training ensure the professional skills needed to implement low-carbon and digital transformations.

The development of clusters and industrial hubs that bring together universities, research centers, and enterprises accelerates technology transfer and lowers barriers to entry for startups and small innovative enterprises. The creation of flexible production facilities and the use of additive technologies increase the ability to quickly readjust to market needs and crisis demands. The implementation of early warning systems and risk analytics based on big data and AI makes it

possible to identify vulnerabilities in supply chains, energy and infrastructure in a timely manner. Therefore, new curricula should be developed on the basis of these technologies for education and training of specialists.

Another important area is the development of distributed energy sources, networks and energy storage systems, reduces the risk of mass outages and increases the resilience of critical infrastructure. Strategic energy transition planning and long-term investments in renewable energy provide a basis for reducing dependence on volatile fossil resource prices.

Another strategic direction is to strengthen the cybersecurity of industrial systems and critical infrastructure, preventing scenarios in which technological attacks lead to long-term economic losses. Implementation of standards and certifications for clean technologies increases investor confidence and accelerates the scaling of solutions that meet high environmental and safety requirements.

Support for the diversification of financial sources and the development of green financial instruments ensure the inflow of capital into adaptation and decarbonization projects. The creation of mechanisms for insuring climate risks and developing risk transfer markets reduces the fiscal burden of the state during extreme events. Innovative industrial cooperation policies and international agreements to ensure sustainable supplies of critical materials contribute to collective resilience and reduce geopolitical tensions.

It is important to develop modern transport and digital infrastructure, taking into account resistance to climatic loads. This reduces potential logistics risks and ensures the preservation of trade turnover in extreme weather conditions. Adapting urban and regional development plans to climate scenarios increases the resilience of the economy at the local level and minimizes losses from infrastructure destruction.

Control and transparency mechanisms in supply chains increase the ability of companies and states to respond quickly to disruptions and manage inventories. The development of new digital technologies for critical infrastructure and predictive maintenance technologies reduces the share of unexpected failures and downtime extensions. Promoting technology neutrality and open standards reduces barriers to the adoption of alternative solutions and increases competition for innovation. Government R&D subsidy programs and tax incentives for investment in clean technologies accelerate the transition to a low-carbon economy. The establishment of inter-agency strategies and crisis management focal points ensures coherence and responsiveness.

The strategic objective is to develop institutions for long-term forecasting and scenario modeling, helping to shape sustainable policies and investment strategies. Supporting entrepreneurship in the field of clean technologies and digital services stimulates the growth of local opportunities and reduces technological dependence. Migration. The creation of regulatory mechanisms to assess and minimize the carbon footprint of industrial processes contributes to competitiveness in international markets, where emission requirements are increasing.

As part of the circular economy concept, improving the financing of infrastructure projects for waste management and recycling reduces the risks of material shortages and pollution, which undermine long-term economic sustainability. The introduction of educational standards and programs aimed at interdisciplinary training of engineers, economists and ecologists in this area forms a talent pool for systematic transformation management.

The creation of platforms for the exchange of knowledge between universities, business and the state increase the speed of implementation of effective practices and technologies. Public-private partnership mechanisms allow for more effective mobilization of private capital and management expertise for the implementation of large adaptation and transition projects. The development of regional value chains reduces transport costs and increases the resilience of local economies. The creation of digital infrastructure and its protection ensure the continuity of services and support for new types of business in crisis situations.

Integrating sustainability principles into production standards reduces the vulnerability of infrastructure to climate impacts. The introduction of transparent mechanisms for accounting and

monitoring climate risks in corporate reporting increases the manageability and confidence of investors. The creation of mobile and adaptive production and logistics solutions, including temporary capacities and container production, strengthens the rapid response to local crises. The development of local financing and business support tools increases economic flexibility and reduces the dependence of regions on large external suppliers. The inclusion of economic security objectives in national sustainable development strategies ensures the coordination of actions and priorities in the long term. The establishment of mechanisms for rapid mobilization of human resources, including volunteering and retraining programs, increases the ability of societies to recover from crises.

A promising area is the development of international networks of cooperation on scientific and technological projects, helps to share resources and reduce single vulnerabilities. Strengthening risk management systems at the enterprise level includes the implementation of corporate business continuity plans and stress testing for climate and technological shocks. Supporting the development of standards and protocols for the safe implementation of AI and robotics reduces the likelihood of systemic failures and social conflicts. Investments in research to replace critical materials and develop alternative technologies reduce long-term risks of shortages.

Creating an enabling environment for infrastructure investment, taking into account the project life cycle, ensures that investments are cost-effective and sustainable. The development of targeted subsidy mechanisms for regions with high vulnerability helps to reduce inequality and increase overall resilience. Support for social programs and security systems reduces social instability, which can exacerbate economic crises. The introduction of programs to improve financial literacy and the availability of financial instruments strengthens the ability of small businesses and households to withstand shocks. The creation of a transparent and predictable regulatory framework stimulates long-term investment and reduces uncertainty for business. Supporting projects to develop sustainable agricultural practices improves food security and reduces the risks of food crises. It is also important to strengthen the logistics resilience system, including alternate routes and multimodal solutions, to reduce the risk of supply disruptions. Promoting the circular economy and designing for recycling creates additional sources of materials and reduces environmental costs.

The formation of national strategies for critical technologies and materials with targeted funding provides priority opportunities for development. The introduction of flexible tax and credit mechanisms to support innovation reduces barriers to the commercialization of clean technologies. The creation of mechanisms for assessing the effectiveness of state programs and their adjustment based on data increases the adaptability of strategies. Finally, a coordinated combination of these mechanisms, including education and R&D, as well as increased infrastructure investment and the development of international cooperation, forms a stable platform for economic security that can withstand systemic risks and ensure long-term stability in the face of global challenges and transformations.

4.4. Innovative Directions of Interaction of Social and Legal Aspects in Ensuring Economic Security.

Innovative areas of interaction between social and legal aspects in ensuring economic security are based on a set of measures aimed at increasing the resilience of societies and institutions in the context of climatic, technological and geo-economic transformations. It is crucial to develop legal mechanisms that support social cohesion and trust, as the legitimacy of government measures directly affects the ability to implement economic security strategies.

Transformational, rather than incremental, adaptation is necessary to meet the rapidly changing socio-ecological systems of the Anthropocene. At the same time as the urgency of such transformations is growing, there is a growing understanding that sustainable transformation cannot be achieved without taking into account security and justice issues. Therefore, in the research and practice of transformations, the intersection of three dimensions is increasingly considered: security,

fairness and sustainability [5]. Therefore, further research on the application of artificial intelligence and machine learning to improve energy efficiency requires an integrated approach aimed at developing technical solutions, improving the sustainability of energy systems and taking into account socio-economic factors [10].

The development of flexible legal frameworks for the rapid implementation of technological and climate measures reduces institutional delays and facilitates rapid resource mobilization. The integration of social indicators into legal risk assessments makes it possible to take into account inequality, the vulnerability of certain groups and potential social conflicts when making regulatory decisions. The creation of mechanisms for public participation in the formation of sustainable development strategies increases transparency and reduces resistance to change, which strengthens the sustainability of political decisions.

Legal support for the protection of workers' rights in the process of digitalization and automation contributes to mitigating the social impact of technological shifts and maintaining the social functions of the economy. Innovative approaches to social protection include flexible retraining programs, supported by legal instruments that guarantee access to training and temporary income during the transition period. The development of legal norms to stimulate corporate social responsibility and take into account external social effects increases private interest in investments that strengthen economic security. Implementing standards and norms for the ethical use of AI and robotics reduces legal uncertainty and protects civil liberties, while preserving the potential for technological development.

The creation of legal mechanisms to support local communities and businesses strengthens regional resilience and flexible diversification of the economic base. The combination of social contracts and legal frameworks for risk sharing in the climate and economic crises contributes to a more equitable redistribution of the burden of recovery. The integration of gender equality and inclusion norms into economic security programs increases the overall adaptability of society and expands human resources. The development of legal incentives for social innovation, including the creation of social enterprises, cooperatives and sharing platforms, contributes to the creation of sustainable local ecosystems.

The introduction of legal recognition and support mechanisms for the informal sector reduces the vulnerability of groups dependent on precarious incomes and increases the tax base for financing security measures. Establishing transparent legal procedures for compensation and recovery from climate disasters builds trust and accelerates the recovery of economic activity. Innovative approaches to international law and agreements can incorporate social safeguards into mechanisms for technology exchange and access to critical materials, reducing geopolitical risks. The systematic integration of digital legal registers and platforms for monitoring compliance with regulations increases the efficiency of control and accountability of actors. Institutional mechanisms for the protection of critical infrastructure should be combined with social programs to support dependent communities in order to minimize the consequences of potential failures. Introduction of social risk and impact disclosure obligations in corporate reporting raises awareness and encourages preventive measures.

Supporting scientific and legal expertise in the field of technology ethics helps to shape standards that are compatible with human rights principles and economic efficiency. The integration of law and social science into education increases the willingness of lawyers, managers, and engineers to work in hybrid teams in the development of economic security policies. The creation of mechanisms for alternative resolution of social conflicts and the restoration of trust after crises reduces the duration and depth of economic shocks. Developing legal frameworks for the use of public resources in emergency situations ensures equitable access and reduces the risk of conflicts over resources.

The development of special social assistance systems, supported by legal obligations, is important, which increases the speed of measures to protect vulnerable groups of the population. Stimulating civic participation through legal mechanisms, public councils, consultations, and digital

platforms increases the legitimacy of decisions and the quality of policies. The development of standards for the protection of digital rights and privacy when using AI in risk management ensures a balance between efficiency and citizens' rights. Legal instruments to stimulate investment in social infrastructure, health, education, and housing contribute to long-term stability and economic sustainability. Implementation of programs for the social integration of migrants and displaced persons on a legal basis reduces social tension and contributes to the preservation of labor resources.

Effectively supporting energy transitions requires a synthesis of knowledge from disciplines that study economic development, technological innovation, and policy and legal change. In the literature, there is a lack of a common understanding of which disciplines should be involved and how to integrate them. Considering national energy transitions as a joint evolution of three interconnected systems based on energy flows and markets, energy technologies and energy-oriented policies, it is important to understand the essence and prospects for their development [11].

The creation of legal mechanisms to regulate labor markets during periods of transformation helps to manage the more efficient distribution of labor resources between sectors and reduce unemployment. Also, support for additional training programs and the integration of new professions of the initiative reduces the risk of mass unemployment in the context of structural changes. The inclusion of the social consequences of climate and technology policies in the assessment of management decisions increases the sustainability and fairness of measures to reduce negative impacts. Legal encouragement of long-term investments in human capital, including tax incentives and training grants, strengthens the ability of the economy to adapt to global challenges and transformations.

Adapting institutional mechanisms of legal responsibility for violations of sustainability standards encourages companies to comply with the rules and reduces systemic risks. The development of partnerships between the state, NGOs and the private sector on a legal basis improves the coordination and effectiveness of social programs. The inclusion of local communities in project impact assessment procedures based on legal requirements increases the consideration of local interests and the sustainability of solutions. The development of international legal standards on climate risk management and social protection contributes to the coordination of actions and the exchange of best practices. The implementation of legal measures to ensure access to information and educational resources strengthens public awareness and readiness for change.

The formation of special legal regimes and temporary measures for areas of high vulnerability allows for faster mobilization of resources and adaptation of policies. Investing in legal infrastructure, including courts and sustainability ombudsmen, increases access to justice and the protection of civil interests. Support for research on the socio-legal aspects of economic security helps to build adequate norms and practices. The inclusion of norms to protect the rights of indigenous and local communities in the implementation of projects reduces the risk of conflicts and preserves social capital. Programs to develop leadership and citizenship on a legal basis strengthen the local ability to organize self-organization in a crisis. The development of mechanisms of legal support for social innovations and experimental economic regimes stimulates the search for adaptive solutions.

Standards for ensuring inclusion and non-discrimination in access to support programs increase the effectiveness of measures and reduce social tensions. The combination of legal and social financing mechanisms, including microloans and guarantees, expands opportunities for sustainable development of small businesses. Legal regulation of transparency in the management of restoration funds increases trust and improves the allocation of resources. The creation of institutions for monitoring and reporting on the social and legal aspects of economic security strengthens policy feedback and adjustments. Finally, the systemic interaction of social and legal measures, built on the principles of fairness, transparency and adaptability, creates a solid foundation for economic security, allowing societies to more effectively withstand global challenges and transformations.

4.5. Strategies and Mechanisms for Improving Economic Security in the Context of Instability Caused by Technological and Climate Change

Strategies and mechanisms for improving economic security in the context of instability caused by technological and climate change are based on a combination of preventive, adaptation, and transformational measures aimed at reducing the vulnerability of the economy and increasing its ability to recover quickly. The most important strategy is to diversify the economic base and supply chains, including the development of local and regional production of critical components, which reduces dependence on geopolitically vulnerable sources. At the same time, an active policy of import substitution in strategic sectors is required, taking into account economic feasibility and environmental restrictions.

Investments in research and innovation infrastructure create a technological reserve that promotes technological sovereignty and reduces risks from external shocks. The key mechanism is the development of human capital through education, retraining and lifelong learning programs focused on skills in clean tech, AI and robotics. Innovations based on a flexible and modular production base, including additive technologies and platform manufacturing, increase the speed of adjustment to new market requirements and crisis needs.

Artificial intelligence, resource management, big data analytics, blockchain, and the Internet of Things are helping firms improve supply chain efficiency and adapt to changing environmental regulations and sustainable decision-making requirements. With the help of digital technologies, companies are able to ensure transparency of supplies, implement the principles of a circular economy and conduct production taking into account social justice and environmental friendliness. In addition, smart governance practices improve decision-making and resilience, which contributes to regulatory compliance and ensures long-term legal profitability. Integrating business innovation and digital solutions into organizations' legal structures improves economic efficiency, reduces operational costs, reduces resource use, and reduces carbon footprint, creating a dual-benefit model for long-term sustainability [12].

Strengthening energy security through diversification of energy sources, scaling up renewable capacities and developing storage systems helps to reduce vulnerability to price and supply shocks. The implementation of early warning systems for risks based on big data, AI and predictive analytics makes it possible to detect threats in a timely manner and plan responses. The development of infrastructure for recycling and the circular economy reduces dependence on primary resources and creates reserve flows of materials. The formation of green financial instruments, insurance mechanisms and the stimulation of investments in adaptation and decarbonization ensure long-term financing of sustainable projects.

A major problem in recent decades has been the conflict between rapid technological progress and the slower creation of regulatory and ethical norms, as well as the question of the distribution of responsibilities between the state and the private sector. The solution is an innovative networked regulatory model that brings together government institutions and industry experts to develop adaptive "dynamic" rules that can evolve with technology [13].

Public-private partnerships and clusters that bring together universities, R&D centers and industry accelerate technology transfer and commercialization of innovations. The development and implementation of sustainability standards and certifications for technologies and products is important, which increases market confidence and facilitates access to international supply chains. The policy of long-term planning and scenario modeling helps to form adaptive development roadmaps taking into account climate and technological scenarios. Strategies to strengthen the cybersecurity of critical infrastructure reduce the risks of technological attacks and protect the data needed to manage systems.

Mechanisms for stimulating local entrepreneurial activity and startups in the field of clean tech create an additional source of innovation and jobs. The development of transport and logistics resilience through multimodal routes and strategic reserves reduces the risk of supply disruptions. It is also important to put in place social protection mechanisms and retraining programs to mitigate

the impact on workers in the automation and transition of industries. Creating financial and fiscal incentives for investment in low-carbon infrastructure accelerates the transition and reduces market barriers.

Developing legal and institutional frameworks for the rapid deployment of critical energy infrastructure and production projects reduces delays and improves response efficiency. The formation of national reserves and strategic funds to finance emergency recovery work ensures promptness and resilience in crisis situations. The development of monitoring and assessment of the life cycle of technologies helps to choose the most sustainable and economically viable solutions. A focus on regional sustainable development strategies helps reduce unevenness and increases the overall resilience of the economy.

Putting into practice the principles of sustainable development and adaptation of infrastructure to climate risks reduces potential losses from extreme events. Stimulating international cooperation in the field of technology and resource security, while diversifying partners, reduces the risk of technological blackmail and shortages of key materials. Financing mechanisms through green bonds, infrastructure funds and targeted grants provide capital flows for large-scale adaptation and decarbonization projects. The development of platforms for data exchange between the state, business and scientific communities improves decision-making and coordination of measures. An important strategy is to promote the principles of a circular economy and environmentally friendly solutions to reduce waste and improve material efficiency.

Support for initiatives to localise value chains, taking into account the specialisation of the regions, contributes to the creation of sustainable jobs and the reduction of logistics risks. Implementing climate risk and resilience disclosure commitments for companies increases transparency and encourages the adaptation of corporate strategies. The development of standards for the safe and ethical use of AI and robotics provides a combination of efficiency and the protection of social rights. The availability of flexible lending mechanisms and guarantees for businesses facilitates their adaptation to new economic conditions and market requirements. Strategies include the development of mechanisms for the substitution and recycling of critical materials, which reduces long-term risks of shortages.

The establishment of institutions to coordinate crisis response at the national and regional levels increases responsiveness and coherence. Investments in educational programs and research networks on sustainable technologies support the constant updating of knowledge and practices. Climate-smart infrastructure investment incentives help reduce the vulnerability of long-term assets. The inclusion of social dialogue and consultative mechanisms involving trade unions, business and civil society organizations improves the acceptance and legitimacy of reforms. The creation of flexible regulatory tools and pilot legal regimes allows for faster testing of innovations without the need for complex legal support that hinders adoption.

The development and implementation of innovative educational programs for the development of regional food security reduces the risks of food crises. The strategies include mechanisms for the rapid mobilization of resources and human resources for emergency response. Supporting sustainable water management initiatives reduces risks to industry and agriculture. Strengthening corporate governance institutions for sustainable development is an important mechanism.

At the global level, a comprehensive approach is needed that combines policy change, investment in climate-smart rural practices, technological innovation, and infrastructure upgrades. At the same time, efforts to increase food production must take into account the needs and living conditions of the population, prioritizing sustainable land management and proven methods to increase crop yields. With the right decisions and investments, it is possible to create a more risk-resilient and equitable food sector by 2050 [14]. Promoting sustainable agricultural practices is vital to achieving food security in the world. Sustainable agriculture refers to the set of practices, policies and technologies that contribute to these outcomes [15-20].

Driving innovation in materials and energy efficiency reduces transition costs and increases competitiveness. The development of climate and technology risk insurance systems reduces fiscal pressure on the state in times of crisis. The creation of sustainable financial instruments for adaptation investments ensures long-term planning and implementation of projects. Supporting international mechanisms for the exchange of technology and knowledge contributes to collective resilience and reduces individual vulnerabilities.

Finally, the comprehensive implementation of these strategies and mechanisms, based on the general coordination of efforts between the government, scientific and educational institutions on the one hand, and business on the other, forms a reliable platform for economic security that can withstand the challenges caused by technological and climate change. The adaptation of technical and economic education is especially important: updating curricula for interdisciplinary training, introducing practice-oriented modules on clean tech, AI and sustainable management, developing continuing education programs and continuous retraining throughout a person's working life, strengthening ties between universities and industry and clusters, as well as creating flexible educational trajectories and new standards of competence – all this increases the economy's ability to generate qualified personnel for the implementation of security strategies and accelerates technological and social adaptation in crisis conditions.

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