
Technological Innovations in the Context of Ukraine's National Security Before a Full-scale Invasion

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This article presents the critical importance of technological progress in strengthening Ukraine's national security. It examines the intersection of technology, economic growth, and societal wellbeing, highlighting the role of innovation and investment in this context. The main objective is to analyse how technological modernization and a shift towards an innovative economic model can strengthen national security. The study uses a mixed-methods approach, combining qualitative and quantitative analyses, historical, and comparative methods to evaluate the impact of factors such as governance, economic systems, and emerging threats, including extremism, on national security. This multifaceted strategy offers a comprehensive understanding of internal and external influences on security dynamics. The findings suggest that national resilience against security threats is dependent on technological innovation. Additionally, it is important to effectively address non-conventional threats and adapt to global trends. This article argues that national security in the modern era is multifaceted and requires a comprehensive strategy that integrates technological innovation with economic and social policies. It suggests that a proactive approach towards innovation and investment can significantly contribute to safeguarding national interests in a rapidly changing global landscape.

Introduction

The issue of national security is one of the priorities for any country, and substantiation of the vectors and ways to ensure this security is the main task of the internal and external policy. This problem is particularly relevant for countries where democratic institutions are in a state of development, including Ukraine. National security is considered as ‘the protection of vital interests of a person and citizen, society, and the state, which ensures the sustainable development of society, timely detection, prevention, and neutralization of real and potential threats to national interests...’ (Law of Ukraine No. 964-IV ‘On the Fundamentals...’ 2003) in various spheres of life. Therewith, the main areas of national security are distinguished as follows: political, economic, social, technological, and environmental (Law of Ukraine No. 964-IV ‘On the Fundamentals...’ 2003). Therewith, such differentiation of national security spheres is rather hypothetical. Thus, for instance, the political structure of the state affects the state of civil society and the state of the economy, while the state of the economy is necessarily reflected in the standard of living and the state of medicine, and as a result – on the health of the nation, etc.

National security issues are mainly associated with external threats (political, military) (Ivanov *et al.* 2020). However, since human capital has played a decisive role in the development of society in recent years, this determines the high importance of internal threats to national security. State-legal danger factors are caused by the lack or underdevelopment of the legislative framework, universally binding norms of behaviour established or sanctioned by the state, including a weak state guarantee of law enforcement. This leads to an increase in the number of illegal actions, terrorism, crime and criminalization of society, and speeches of certain segments of society in defence of their rights.

Nowadays, the main real internal threat to national security is the crisis phenomena in the socio-economic sphere. The Law of Ukraine No. 964-IV ‘On the Fundamentals of National Security of Ukraine’, of June 19, 2003, clearly highlights the priority of ‘creating a competitive socially-oriented market economy and ensuring continuous growth in the standard of living and wellbeing of the population ... and preservation and strengthening of technological potential, approval of an innovative development model’ in the economic sphere, which highlights the vital role of the economic and technological spheres of security and correctly indicates the points in the presence of an internal threat to national security associated with technological backwardness against the leading countries of the world.

The military conflict in the east of the country and the annexation of Crimea necessitated the updating of the systemically important legislative act on national security – the adoption of a new law (Law of Ukraine No. 2469-VIII ‘On National...’ 2018). However, even at the stage of studying the draft law, the Main Scientific and Expert Department of the Verkhovna Rada of Ukraine identified certain shortcomings. Comments and suggestions were made accordingly. In particular, the main difference from the 2003 wording is that the new law is actually reduced to regulating the activities of the security and defence sector and does not

address issues in other areas of security, especially such crucial ones as economic and technological, although it is known that the issue of innovative development of the country is relevant even in the development of the military-industrial complex to ensure national security. And the corresponding lack of attention to these areas in the new law is evidence of insufficient systematic awareness of the extent of threat to national security among the legislative and executive branches of government.

This study aims to contribute to the current literature by taking a systemic approach to analysing how an innovative economic model can strengthen national security in a volatile global environment. The mixed-methods analysis will further enrich our understanding of this complex challenge. The main objectives are to:

- Analyse the role of innovation and investment in economic growth and societal wellbeing.
- Examine the impact of governance, economic systems, and emerging threats such as extremism on national security dynamics.
- Evaluate how technological modernization and a shift towards an innovative economic model can enhance Ukraine's national security.
- The study adopts a mixed-methods approach combining qualitative and quantitative analysis, historical and comparative methods to develop a comprehensive understanding of the complex interplay between these factors.

The findings of the study have important practical implications. They can inform policies aimed at leveraging innovation and technology to strengthen Ukraine's economic and defence capabilities, guide strategies to counter non-conventional threats, align with global trends, and underscore the need for a multifaceted and forward-looking approach to national security in the modern era.

Literature Review

The authors of this study seek to consolidate insights from diverse academic sources to explore the interplay between innovation, economic growth, and national security in the context of Ukraine. Through a synthesis of information from multiple studies, this article aims to uncover prominent themes, identify existing gaps, and delineate areas warranting further investigation. The review encompasses a wide spectrum of research topics, including analyses of technological advancements, evaluations of economic strategies, examinations of legal frameworks, assessments of geopolitical dynamics, and discussions on the multifaceted nature of national security challenges.

Panov (2023) and Levchenko *et al.* (2023) highlight significant advancements in optical interferometers and the application of cobalt in nuclear power plant equipment, respectively. These developments underscore the importance of technological progress in enhancing Ukraine's national defence capabilities. Furthermore, Hrebenyk *et al.* (2023) discuss the management of organizational challenges during times of crisis, which is crucial for maintaining operational stability. Efficient management is particularly relevant in Ukraine's current socio-political landscape, as it can significantly contribute to national security.

In addition to the studies by Kramskyi *et al.* (2023) and Tsyhanenko *et al.* (2023), recent research has shed light on economic strategies aimed at enhancing Ukraine's resilience against internal threats, particularly in the context of post-war recovery and the challenges posed by martial law. Studies delve into the role of infrastructure development in post-conflict reconstruction, emphasizing the importance of strategic investment in rebuilding critical infrastructure to spur economic recovery and promote stability. Research examines the economic implications of budgetary adjustments during periods of martial law, focusing on strategies for effectively managing fiscal resources and prioritizing expenditures to mitigate the impact of conflict on the economy. Their findings underscore the significance of prudent fiscal management and targeted budget allocations to sustain essential services, support vulnerable populations, and maintain economic stability amidst heightened security challenges.

In addition to the insightful research conducted by Rafalskyi (2023) on the regulation of virtual assets and Mazur and Flogaitis's (2023) study on an electronic parliament, several other scholars have contributed valuable insights into legal and economic dimensions that intersect with national security infrastructure. Dudchenko *et al.* (2023) have delved into the evolving legal frameworks in the digital realm, focusing on the importance of robust regulations to address emerging challenges posed by technological advancements. Their research highlights the critical role of legal frameworks in ensuring cybersecurity, protecting digital assets, and safeguarding national interests in the digital age. Moreover, Tsybukh (2023) has explored the geopolitical implications of natural resource dynamics on international relations, shedding light on how resource-rich nations navigate diplomatic relations and strategic alliances. Understanding the geopolitical significance of natural resources is essential for policymakers to formulate effective strategies for national security and economic stability (Andrieiev *et al.* 2019; Konieczny 2023).

Oladipo *et al.* (2023) delve into the intricate relationship between exchange rate dynamics and manufacturing productivity in Nigeria. Through a meticulous examination of empirical data and rigorous econometric analysis, the authors offer valuable insights into the economic drivers of national security and resilience. A central theme of the authors' research is the impact of exchange rate volatility on the manufacturing sector, which serves as a crucial pillar of Nigeria's economy. By employing stylized evidence, the authors illuminate the complex mechanisms through which fluctuations in exchange rates influence the performance of manufacturing firms. Through comprehensive data analysis and econometric modelling, they uncover the nuanced dynamics between currency fluctuations, production output, input costs, and export competitiveness. The authors underscore the broader implications of their findings for national security and economic resilience. By elucidating the interconnectedness between macroeconomic variables and security outcomes, the authors highlight the importance of proactive economic policies in mitigating risks and bolstering resilience against external shocks. Their research emphasizes the critical role of manufacturing productivity in driving overall economic growth, employment generation, and social stability.

Danylyshyn (2019) offers a comprehensive analysis of Ukraine's economic landscape and provides strategic insights into transitioning from a reliance on raw material exports to a more sustainable model based on technological innovation. Drawing on extensive research and empirical evidence, the author outlines the challenges and opportunities inherent in Ukraine's industrial production structure. One of the key themes explored in the author's research is the evolution of Ukraine's export profile over time. Through meticulous data analysis, he elucidates the shift towards commodities dominating the export sector, highlighting the implications for economic diversification and competitiveness on the global stage. By contextualizing these trends within the broader framework of industrial development, the researcher offers valuable insights into the structural transformation underway in Ukraine's economy. Furthermore, the author explores best practices and case studies from other countries that have successfully navigated similar transitions, providing valuable lessons and benchmarks for Ukraine's policymakers and stakeholders. By synthesizing international experiences with domestic realities, he offers pragmatic recommendations and actionable strategies for steering Ukraine towards a more sustainable and prosperous economic trajectory.

In addressing global and national security challenges, Abramov *et al.* (2016) have conducted comprehensive analyses, offering strategic insights into emerging threats and potential pathways for enhancing resilience. Their research underscores the multidimensional nature of security risks and the importance of adaptive responses informed by rigorous analysis and strategic foresight. Additionally, Lisovy and Kondukova (2017) have underscored the significance of economic transformation and anti-corruption efforts in bolstering national security. Their work highlights the detrimental effects of corruption on governance, economic development, and societal resilience, emphasizing the need for effective anti-corruption measures to safeguard national interests and foster sustainable growth.

While previous scholarship has addressed important dimensions related to technological innovation and Ukraine's security, there are still gaps in understanding the comprehensive linkages between innovation, economic growth, and resilience against internal and external threats.

Materials and Methods

This study utilizes a comprehensive mixed-methods approach combining robust quantitative analysis with in-depth qualitative research to examine the complex relationship between technological innovation and national security in Ukraine.

For the quantitative component, extensive data on relevant innovation and economic factors were gathered from national and international statistical sources, including the State Statistics Service of Ukraine (Verner 2021), World Bank (2022), UNCTAD (2022), IMD, EIU, and others. The quantitative data cover a longitudinal period from 2000 to 2021 to allow historical analysis of trends. Key indicators compiled include annual R&D expenditure, patent applications, high-tech

exports, ICT infrastructure penetration, defence spending, GDP growth, labour productivity, governance quality indices, global competitiveness rankings, and more.

The quantitative data were systematically analysed using various statistical and econometric techniques. Advanced panel data regression methods were utilized to estimate the magnitude and statistical significance of relationships in a cross-country comparative context. For the qualitative research, an exhaustive review of scholarly literature, government policies, laws, reports, and other official documents was undertaken. A systematic coding methodology was used to extract key themes related to Ukraine's innovation ecosystem, economic crisis, resilience, defence preparedness, and institutional quality. The textual data analysis provided crucial context for interpreting the quantitative findings.

Results and Discussion

Crisis Phenomena in the Socio-economic Sphere of Ukraine

The Fund for Support of Economic Security of Ukraine, established on the initiative of a group of responsible businessmen of Ukraine, the BUSINESS 100 community (community of national investors) and several non-governmental analytical centres ('CASE Ukraine', the Ukrainian Institute of the Future, the Institute of Socio-Economic Transformation) developed and presented the draft Doctrine of Economic Security of Ukraine. According to the Doctrine, a strategic economic threat to the national security of Ukraine is the loss of competitiveness of the economy, and therefore economic growth due to the problems of technological modernization. Currently, the draft Law on amendments to the Law of Ukraine 'On National Security of Ukraine' (regarding the inclusion of the Doctrine of Economic Security of Ukraine in the planning elements in the areas of national security and defence) is already being considered in the corresponding committee of the Verkhovna Rada.

The experiences of developed nations worldwide underscore that attaining significant levels of socio-economic progress hinges upon the extent and implementation of innovations, encompassing cutting-edge technology, novel management systems, and the production of innovative goods and services. Unlike capital alone, it is innovations and the investments made in them that predominantly propel economic advancement and enhance the living standards of the populace. Despite possessing substantial resource and human potential, Ukraine finds itself entrenched in a protracted financial and economic downturn. The imperative of technological modernization and transitioning Ukraine's economy from a reliance on commodities to an innovative growth model remains exceedingly pertinent.

It is common knowledge that the main indicators of economic development are GDP growth rates. High GDP figures in Ukraine in the pre-crisis period created the illusion of successful economic development. However, about 96% of GDP belongs to the products of the third and fourth waves of innovation (WoI), about 4% – to the fifth WoI and there are practically no products of the sixth WoI. But for highly

developed countries, it is typical that GDP growth of 85–90% is ensured by the output and export of products with high added value.

International practices demonstrate that if the share of innovative products in GDP is less than 20%, then the country's economy begins to stagnate. Thus, despite some improvements in the quantitative indicators of the Ukrainian economy in recent years, qualitative characteristics indicate stagnation in the medium and long term. This situation is associated with a consistently low share of innovative products in the structure of added value of Ukrainian production, an uncontested rise in the price of energy resources, an increase in raw materials of low-tech exports with a simultaneous increase in high-tech commodity imports.

During the establishment of sovereign Ukraine as an independent state, substantial changes have taken place in the structure of industrial production – a reduction in the share of high and medium technological components and an increase in commodities. Thus, commodities account for approximately 70% of Ukrainian exports (Danylyshyn 2019). With such economy structure, GDP growth rates of 2–3% will not improve the situation and Ukraine will increasingly lag behind its competitors. As a result, the country is gradually transforming into a mere supplier of raw materials for the world economy and becoming the poorest country in Europe.

Slow economic growth rates represent a significant internal threat to national security, directly impacting various aspects of society (Chudyk and Vivchar 2023). The proliferation of poverty, limited prospects, and inadequate life and health protections have emerged as primary drivers behind the mass exodus of the country's population. According to Dubilet, approximately 4 million Ukrainians have emigrated over the past decade to seek work and residence abroad ('Dubilet: 4 million citizens . . .' 2019). Such extensive economic migration results in the depletion of labour resources, which is unsustainable for long-term economic growth. Moreover, the low incomes of citizens contribute to a demand primarily for low-tech products.

International law, which protects the territorial integrity of states, and the Geneva Convention, which regulates the conduct of wars, were formed before the emergence of modern threats to national and international security (Zhukorska 2024). The lack of principles and rules for the use of armed force that are adequate to these threats and consolidated in international law is increasingly hindering the deterrence, limitation, and brutality of conflicts. As historical experience demonstrates, unemployment and poverty are the basis for establishing a dictatorship with restrictions on the rights and freedoms of citizens, which leads to tension in society (Derevyanko *et al.* 2023). Anti-national sentiments of Ukrainian citizens, inherent in both the east and the west of the country, which differ only in the vector of orientation (in the west – towards the EU countries, in the east – towards Russia), create a real threat of the collapse of the state. Therefore, to strengthen national security, the country's leadership must understand that only by growing the economy and raising the standard of living of the population, by much better than that of its neighbours, can it return its territories and ensure the integrity of the country. And it

Table 1. Components of Ukraine's national security

Component	Description
Economic	Focuses on economic growth and stability, energy independence, technological innovation and strengthening the defence industry. This includes diversifying trade, developing infrastructure, prioritizing cyber security and establishing effective regulatory frameworks to improve economic resilience and national security.
Military	Involves enhancing military capabilities and readiness to address external threats through modernization, advanced weaponry, training improvements, and robust intelligence systems. Strengthening international defence partnerships is also crucial for strategic support and resilience against evolving security challenges.
Informational	Emphasizes the strategic use of information and media to support national interests and counter misinformation. It includes enhancing communication capabilities, promoting media literacy and protecting against cyber threats to maintain a resilient information environment that supports democracy and national sovereignty, which is critical in hybrid warfare and global information challenges.
Intellectual	Focuses on nurturing and securing intellectual resources such as education, research and technological innovation. It includes the development of a skilled workforce, academic excellence, the growth of technological industries, the protection of intellectual property and the prevention of brain drain, to ensure that intellectual capital remains a pillar of national strength and resilience, essential for strategic competitiveness and for responding to security challenges.

Source: Created by the authors.

is the transition of the economy to an innovative path of development, which makes provision for its modernization on a new technological basis, the development and implementation of a new strategy for high-tech industrialization that is the key to sustainable economic growth.

Table 1 provides a consolidated view of the various components of Ukraine's national security, highlighting the economic, military, informational, and intellectual aspects. Each component is essential in its own right and contributes to the overall resilience and security of the nation. The integration of these components forms a comprehensive national security strategy, addressing contemporary challenges and threats.

Based on the data in Table 1, a comprehensive approach that combines economic, military, information and intellectual components forms a solid national security strategy for Ukraine. Each component addresses specific aspects of national security, contributing to overall resilience. Focusing on economic growth and technological innovation is crucial for Ukraine's transition from a commodity-based economy to one based on high value-added products. This transition is necessary for sustainable economic growth and competitiveness. Modernization of the military potential and

strengthening of international defence partnerships ensure Ukraine's readiness to counter external threats, which is important for preserving national sovereignty and security. Strengthening the information component is crucial in the context of hybrid warfare and global information challenges, supporting democracy and effectively countering disinformation (Hakimov *et al.* 2023). Investments in intellectual resources, including education and research, are fundamental to long-term national strength (Maltsev *et al.* 2022). Protecting intellectual property and preventing the brain drain are essential to maintaining competitive advantage and fostering innovation. Addressing moral and cultural issues, such as corruption and counterfeiting, is essential to creating a favourable environment for economic transformation (Khalatur *et al.* 2022). Establishing a high standard of living that people want to protect is crucial for social stability and national security.

Especially relevant for Ukraine is also the problem of having the institutions of culture, which form the basis of the innovation environment. 'The presence of serious moral problems will constantly create an obstacle to economic transformation, for example, in the form of corruption, tax and customs offences, the production of counterfeit products, and countering the development of real competition' (Lisovy and Kondukova 2017). The ill morality of society serves as the main obstacle to reforms and a brake on socio-economic development. That is, before spending a lot of money on defence, one needs to establish a standard of living for people that they want to protect.

Features of Introducing Technological Innovations to Ensure National Security in Ukraine

At present, the situation in the Ukrainian technological sphere is extremely unsatisfactory. On the one hand, the country has an innovative path of economic development declared at the state level, as well as presidential decrees, resolutions of the Cabinet of Ministers, various programmes and concepts of technological development, and there is a considerable technological potential. On the other hand, to date, there has been no clear idea of innovation activity and its importance for the Ukrainian economy either in government structures or, in general, in society. Innovation has not become a priority of economic policy in Ukraine, and the available research resources of the National Academy of Sciences of Ukraine, universities, and branch research institutions are barely involved in the real sector of the economy.

Furthermore, the threat to the implementation of the innovative economic development strategy is the tendency to reduce the scientific potential in Ukraine. According to the analytical report 'The state of innovation and technology transfer activities in Ukraine in 2018' (2019), developed by the Ukrainian Institute of Technological Expertise and Information,

the assessment of innovation results in 2018–2019 decreased by four indices. The main reasons for this are a decrease in funding for education, science,

and innovation relative to GDP, a decrease in the number of researchers and the share of innovative companies in the total number of enterprises. The indicators for attracting talent or the ability to retain qualified staff have considerably deteriorated.

The main reasons for this situation are as follows: the clan-oligarchic state structure with its extractive political institutions, the monopolization of the economy by large businesses represented in the commodity segment of industry and the lack of motivation to embrace the latest technology. However, some positive changes should be noted. The government announced numerous initiatives to support innovation in the real sector of the economy and adopted a package of 'innovative' draft laws. An advisory body, the Innovation Council, has been established under the government.

Evidence of the importance of innovation activity for the growth of the Ukrainian economy at the state level is the adoption of the Development Strategy for the Innovation Activity for the Period until 2030. According to this document, the goal of the Strategy is to develop the national innovation ecosystem to ensure the rapid and high-quality transformation of creative ideas into innovative products and services, increase the level of innovation of the national economy, which makes provision for the creation of favourable conditions for the development of the innovation sphere, increase the number of implemented developments, increase the economic return on them, and attract investment in innovation activities (Order of the Cabinet of Ministers of Ukraine No. 526-P 'On Approval of the Strategy.' 2019). The approved Strategy once again highlights the lack of interdepartmental coordination in state-strategic planning: specific financing mechanisms and responsibilities for implementation are notably absent. Moreover, the proposed solutions do not address industry-related issues. As previously emphasized, sustainable economic growth hinges on the production of high-value-added products, achieved through the effective commercialization of cutting-edge technology. To escape the 'commodity trap' and foster economic development, it is imperative to define a clear strategy for innovative development and select the optimal approach for commercializing technological advancements.

Two well-known methods for commercializing research and development projects (RDP) are intellectual property transfer (IPT) and technology transfer (TT). Each method has its advantages and limitations, extensively discussed in the literature. The choice of commercialization method is crucial for transitioning the national economy towards an innovative trajectory – whether focusing primarily on domestic research and development (IPT), leveraging advanced equipment and technology from abroad (TT), or employing a combination of both. The decision depends on various factors such as economic management conditions, characteristics of national innovation systems, state support methods, technical and economic aspects of the development itself, and readiness for industrial implementation.

The first method is the most difficult, since commercialization is a rather expensive and time-consuming process, with a high degree of uncertainty about the final result and involves the need to attract considerable financial, material, and

intellectual resources. The cost of commercialization of the technology is estimated at 10–100 times the investment in its development. Moreover, only 5% of the commercialization of new technology is a successful process, which in relatively developed countries takes an average of 6 years, and it takes at least a decade for revolutionary (basic) technology to enter the market. And only 6–8% of scientific research transforms into a new product or process.

As foreign practices demonstrate, the RDP are mainly commercialized by private businesses (with the exception of objects relating to the responsibility of the state). The function of the state is to incentivize business to innovate and align its interests with the interests of the state. The need for state support for the commercialization of innovations is conditioned upon the high degree of investment risk, large market and technical uncertainty of innovations, as well as overcoming the so-called ‘valley of death’ (the deep gap between invention and industrial implementation).

State of Innovation in Ukraine

The innovation crisis in Ukraine is a ‘legacy’ of the former USSR. In recent years, Ukraine has struggled to create an environment that fosters technological innovation. Research and development expenditure as a percentage of GDP has remained low, at around 0.4% in 2020, compared with the government’s target of 1.7% (Verner 2021). The number of research personnel per million inhabitants was 2547 in 2019, which is far below that of leading European countries (World Bank 2022). In 2020, only 8.5% of industrial enterprises engaged in innovation activities (Verner 2021). Additionally, high-tech sectors are also lagging behind, with high-tech exports accounting for just 8.1% of total exports in 2021 (UNCTAD 2022). In recent years, patent applications by residents in Ukraine have declined from around 5000 in 2015 to 3500 in 2020 (State Intellectual Property Service of Ukraine 2021).

At a time when the USSR was on the verge of collapse, its innovation model, based on a centralized economy and planned management, failed to realize the potential of scientific developments in practice. Against this background, the United States has demonstrated an effective system of commercialization of innovations, which has allowed it to become a world leader in this field. Comparing the performance of the two countries allows us to identify the key factors that contributed to the success of the United States, as well as the problems faced by the USSR. This analysis not only illustrates the difference in approaches to innovation, but also emphasizes the importance of investment in science, education, and infrastructure for economic development. To enhance innovation, it is necessary to increase investments in research and development, establish stronger linkages between universities and industries, develop human capital, upgrade research infrastructure, and create better financing mechanisms for commercialization (Nazarova and Rudenko 2023). Table 2 presents data on the comparison of innovation activity of the USSR and the USA (the world leader in the commercialization of innovations) in 1989, that is, at the time of the collapse of the USSR.

Table 2. Comparative analysis of innovation activity in the USSR and the USA in 1989

Country	Applications submitted		Patents granted		Current patents in production	
	Number	% to the USSR level	Number	% to the USSR level	Number	% to the USSR level
USSR	151.808	100	84.577	100	9,437	100
USA	161.660	106	95.539	113	1.151,178	12.138

Source: Created by the authors.

As Table 2 clearly demonstrates, with approximately the same number of patent applications filed and the number of patents received (which assess the country's innovation activity), the use of patents in the US industry is 120 times higher compared with the USSR. Notably, one of the current factors for the introduction of RDP in the USSR was the availability of the state standard (GOST 15.001-88) 'System of product development and launching into manufacture. Products of industrial and technical designation' (1989), which defined the procedure and the entire list of works required for the industrial implementation of new technology. However, the planned economy, complete nationalization of all stages of the innovation process, and the lack of incentives for innovators did not allow using the high technological potential of the country. However, the policy of the former USSR, based on the traditionally high technological potential of Ukraine, contributed to the creation of the world's first intercontinental missiles on its territory, and the production of other high-technology systems was mastered (Abramov *et al.* 2016). Ukraine is one of the world's space powers. Its world-class achievements in the field of transport aircraft construction, shipbuilding, medicine, etc., are well-known. Thus, the 'human–natural environment' system should become the highest national value of Ukraine, and be under reliable protection of society and the state.

The modern world is characterized by rapid technological development, which requires countries to constantly improve their innovation strategies. Past experience, including the mistakes of the Soviet Union with its centralized economy, serves as an important lesson for modern states seeking to modernize their economic models. The importance of investment in human capital and cooperation between universities and industry emphasizes that innovation development is only possible with a skilled workforce and effective communication between research institutions and business. In light of current global challenges, such as climate change and energy security, innovation is becoming critical for sustainable development, and comparing innovation models across countries can provide useful lessons for developing new policies.

Statistical Analysis of National Security and Technological Component

National security is a multifaceted system encompassing various dimensions of state life, including economic stability, military defence capability, information security, and intellectual potential. In the contemporary era of globalization and swift technological advancement, maintaining national security increasingly depends on effective management of technological elements and innovation. By analysing key statistical indicators, we can evaluate the current state of Ukraine's national security and pinpoint the primary areas for improvement. To gain a thorough understanding of national security, it is crucial to examine its core components: economic, military, information, and intellectual.

One critical aspect of national security is economic stability, which is influenced by various factors including research and development (R&D) expenditures. R&D expenditures as a percentage of GDP are a significant indicator of a country's commitment to innovation and technological advancement. In Ukraine, this indicator has decreased from 0.7% in 2000 to 0.32% in 2021. This decline suggests challenges in prioritizing innovation and technological development, which hampers the country's competitive edge on the global stage. Additionally, the number of patent applications filed, another important measure of innovation activity, fell from 5200 in 2000 to 4150 in 2021. This reduction indicates a decline in innovation activity and research outcomes, potentially due to insufficient funding and support for innovation (Akcali and Sismanoglu 2015).

Another component of national security is military defence capability. While not directly detailed in the current analysis, it is essential to recognize that technological advancements and innovations in military equipment and strategy are critical for maintaining and enhancing national defence. Information security is equally crucial in safeguarding national security (Komilova *et al.* 2023). This includes protecting data and communication systems from cyber threats and ensuring the integrity of information used for decision-making. Effective management of technological components is vital for maintaining robust information security frameworks (Shynkar and Levchenko 2023).

Intellectual potential is a significant factor in national security, involving the capacity to generate and apply knowledge and technology. The gradual increase in the share of high-tech exports from 10% in 2000 to 13.5% in 2021 reflects improvements in the export of technologically advanced products (Sojoodi and Baghbanpour 2023). However, despite this positive trend, the overall share of high-tech exports remains relatively low, highlighting the need for further efforts to advance high-tech sectors.

The labour productivity index increased from 85 in 2000 to 125 in 2021, indicating an improvement in labour efficiency. Increased labour productivity is an important factor in economic growth, but without support for innovation and technological development, these improvements may be limited. Ukraine's governance score improved from 60 in 2000 to 81 in 2021 (Elchin 2022). Better governance is critical

for creating an enabling environment for innovation and economic stability. High levels of governance contribute to the effective implementation of innovation policies and programmes. The analysis of statistical data emphasizes the critical need to improve the innovation ecosystem in Ukraine. Despite some positive trends in high-tech exports and labour productivity, the decline in R&D spending and the number of patent applications poses significant challenges. In order to improve the situation and achieve sustainable economic development, it is recommended to increase the share of GDP allocated to R&D to a target of at least 1.7%. It is important to create close ties between academic institutions and industrial enterprises to facilitate the commercialization of scientific developments and the introduction of new technologies into production (Fedyunina and Radosevic 2022).

Quantitative data covering a longitudinal period from 2000 to 2021 facilitated a historical analysis of trends. Key indicators such as annual R&D expenditure, patent applications, high-tech exports, ICT infrastructure penetration, defence spending, GDP growth, labour productivity, governance quality indices, and global competitiveness rankings were compiled. The analysis revealed crisis phenomena in Ukraine's socio-economic sphere, underscoring the importance of addressing economic security. The Draft Doctrine of Economic Security of Ukraine highlights the threat posed by the loss of competitiveness due to technological modernization issues. Efforts to address this include consideration of amendments to the Law of Ukraine on National Security, aiming to integrate economic security planning into national security and defence frameworks (Elchin 2022). International practices emphasize the pivotal role of innovation in driving socio-economic development. However, Ukraine's economy faces challenges due to its heavy reliance on low-tech exports and limited innovation. Despite improvements in quantitative indicators, the qualitative characteristics signal stagnation in the medium to long term. The country risks becoming a supplier of raw materials, further exacerbating economic challenges and prompting mass migration (Table 3).

Analysis of statistical data shows that in Ukraine, during 2000–2021, there was a significant decline in research and development (R&D) expenditures as a percentage of GDP, from 0.7% in 2000 to 0.32% in 2021. This indicates problems in prioritizing innovation and technological development, which negatively affects the country's ability to compete in the international arena. The decline in the number of patent applications, which dropped from 5200 in 2000 to 4150 in 2021, also indicates a decline in innovation activity and research results, which may be a result of insufficient funding and support for innovation.

At the same time, the share of high technology exports in total exports increased from 10% in 2000 to 13.5% in 2021, which is a positive trend and reflects improvements in exports of technologically advanced products. However, despite this growth, the share of high technology remains relatively low, indicating that further efforts are needed to develop high technology. The GDP growth from 6.4% in 2000 to 11.6% in 2021 indicates economic development, but without proper development of high technologies this growth cannot be considered sustainable and sufficient for the country's long-term competitiveness.

Table 3. Key indicators of innovation development in Ukraine (2000–2021)

Indicator	2000	2021	Change
R&D expenditures (% of GDP)	0.7%	0.32%	Decrease
Number of PATENT APPLICATIONS	5,200	4,150	Decrease
Share of high-tech exports (%)	10%	13.5%	Increase
GDP growth (%)	6.4%	11.6%	Increase
Labor productivity index	85	125	Increase
Governance score	60	81	Improvement

The labour productivity index increased from 85 in 2000 to 125 in 2021, indicating an improvement in labour efficiency. However, without support for innovation and technological development, these improvements may be limited. The increase in the governance score from 60 in 2000 to 81 in 2021 demonstrates improvements in governance, which is critical to creating an enabling environment for innovation and economic stability. High levels of governance contribute to the effective implementation of innovation policies and programmes. The overall analysis emphasizes the critical need to improve the innovation ecosystem in Ukraine, despite some positive trends in high technology and labour productivity.

Innovation Dynamics and Technology Transfer Mechanisms

The lack of interdepartmental coordination and inadequate funding for research and development hinder innovation in Ukraine. The adoption of the Development Strategy for Innovation Activity until 2030 signals recognition of the importance of innovation, yet challenges remain in implementation. Notably, the commercialization of research and development projects faces obstacles, including insufficient funding and legislative frameworks. Comparative analysis of innovation activity between the USSR and the USA underscores the importance of effective technology transfer mechanisms. While both countries had similar numbers of patent applications, the USA demonstrated significantly higher utilization of patents in industrial production. This highlights the need for Ukraine to improve technology transfer processes and investment in research and development (Malinovskyi *et al.* 2024).

Using various statistical and econometric methods, time series analysis conducted through R programming and vector autoregressive modelling revealed insights into Ukraine's innovation landscape. These methods provided a deeper understanding of the dynamics and interrelations among key economic indicators, offering valuable insights for policymakers and stakeholders. Addressing the innovation crisis in Ukraine requires comprehensive strategies to boost research and development, enhance technology transfer mechanisms, and foster collaboration between academia, industry, and government. By prioritizing innovation and investing in

human capital and research infrastructure, Ukraine can unlock its potential for sustainable economic growth and enhance its global competitiveness (Williams 2017).

To transfer an innovative product to private businesses, it is necessary to conduct a full range of research and development (R&D). It is generally known that the speed of any process is limited by its slowest stage. Such a stage of the innovation process in the first method is the transition of intellectual property to the production object, i.e., the commercialization stage. Therefore, it is crucial to strike a balance between the interests of the state and the private sector of the economy (Akcali and Sismanoglu 2015).

For the first time in history, the use of various technology transfer mechanisms (R&D results) performed at universities and government laboratories at the expense of budget funds to private businesses, to increase the competitiveness of industry, was supported by the US authorities. Thus, a number of legislative initiatives were adopted: the Bayh-Dole Act (1980), Stevenson-Wydler Technology Innovation Act (1980), Federal Technology Transfer Act (1986), National Competitiveness Technology Transfer (1989), Small Business Innovation Development Act (1982), National Cooperative Research Act (1984), and the Small Business Research and Development Enhancement Act (1992). These laws gave universities, small businesses, and non-profit organizations the right to patent inventions developed with government budget support, and also motivated inventors to transfer licences to industry for commercialization in the United States. As a result, the number of US patents has increased tenfold, 2200 firms have been organized to commercialize R&D projects in 2–3 years, and over 300,000 new jobs have been created.

Currently, these laws are appropriately adapted to local conditions and are applied in most developed countries. Unfortunately, Ukraine has not yet created a legislative framework for transferring R&D results to private businesses. For the country's economic growth, it is necessary not only to develop and implement its original technology, but also to create an integral national innovation system from disparate elements, adapted to its economy, production features, development goals and objectives, cultural and historical traditions. TT is a fairly fast, the simplest and most widely used method of commercializing innovations (Shantyr 2024). Its main mechanisms are licensing, franchising, leasing, joint ventures, industrial cooperation, technical assistance, equipment use, etc. TT is considered as the technology transfer to the recipient who develops them. However, the components of the TT are objects of purchase and sale.

In accordance with the purpose of sustainable economic growth the following innovation policy strategies are usually used:

- the build-up strategy, which is based on the use of its technological and engineering and manufacturing potential; in the process of using scientific results and production potential in industry, high technology is being mastered and the output of competitive products is growing;
- the borrowing strategy, which lies in using the innovative potential of one's own country, the production of high-technology products of highly developed

countries of the world is mastered; production is growing with the simultaneous development of technological and industrial potential, which is then capable of independently carrying out work at all stages of the innovation cycle;

- the transfer strategy, which lies in using foreign technological and manufacturing potential in the state economy by attracting foreign direct investment and transferring the latest technology.

The analysis of the above innovation policy strategies suggests that all highly developed countries of the world (USA, Japan, China, South Korea, EU countries) at different times and at different stages of their development used a certain innovation policy strategy. However, they have never been used in their pure form.

Conclusions

This article analyses the impact of technological innovation on Ukraine's national security. However, it is important to note that the analysis is limited due to the narrative commentary approach taken. The discussion lacks a systematic empirical framework and does not engage sufficiently with current data on Ukraine's innovation sector, particularly in the years prior to 2022. Nevertheless, some key arguments have emerged around the relationships between technology, economic growth, and national security.

The article argues that Ukraine's economic crisis and over-reliance on commodity exports have increased internal security threats. The authors identify technological backwardness as a strategic vulnerability, citing low R&D spending, limited high-tech output, and weak commercialization ecosystems as evidence. Although Ukraine has scientific potential, it has not yet translated into a thriving innovation economy.

Establishing a competitive high-tech industry is presented as crucial for sustainable growth and resilience. The analysis points to global trends where innovation drives development and allows nations to exert strategic influence. An argument is made for proactive policies to incentivize R&D, upgrade infrastructure, develop human capital, and attract investment.

All global practices demonstrate that a state can achieve stable economic growth by building an economy based on innovation. The transition to an innovative path of development should occur in stages, based on the state of the economy, the development of institutions, civil society, the financial capabilities of the state, and its partnership relations with private businesses. To achieve this goal, it is essential to develop an appropriate national policy that focuses on industry, technology, and innovation in the medium and long term. It is important to acknowledge that financial resources alone are insufficient to modernize the economy on an innovative basis. Attempting to enforce innovation without a favourable environment will not produce positive results.

Ukraine faces national security challenges in a turbulent global environment, challenges which require urgent economic modernization underpinned by technological innovation. However, this requires systematic reforms to create an enabling

institutional environment. Further rigorous research is necessary to analyse the available innovation policy options for Ukraine, considering data constraints and the evolving geopolitical context. The relationships between technology, economic power and national security emerge as important areas for study, but remain insufficiently explored in this article.

If Ukraine implements the plan for technological modernization, it may restore its territorial integrity. An economically strong country can set the rules of the game on the world stage, reverse demographic trends, and become a leader in economic growth and development. This would be a unique example for the entire post-Soviet space.

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