

<https://doi.org/10.31891/2307-5740-2024-328-64>

UDC 330

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THE IMPACT OF NANOTECHNOLOGICAL INNOVATIONS ON THE COMPETITIVENESS OF THE GLOBAL MARKET

In today's global market, the integration of nanotechnological innovations has become a crucial factor affecting competitiveness. This article explores the multifaceted impact of nanotechnology on global market dynamics, emphasising its role in improving industrial efficiency, creating new products and stimulating economic growth. The analysis emphasises that nanotechnology plays a key role in the context of the Fourth Industrial Revolution (Industry 4.0), transforming industries and creating new competitive advantages on a global scale. This article outlines the significant impact of nanotechnological innovations on the global market, highlighting the interconnection between globalisation, technoglobalisation and Industry 4.0.

To provide a broader perspective on the topic, Ukraine was analysed and compared with the following countries: The United States of America, Germany, China, Japan, Israel, and Finland. These countries are interesting for comparison with Ukraine in terms of the development and implementation of nanotechnologies, as well as their impact on competitiveness in the global market. Each of these countries has its own unique achievements and strategies that can provide valuable insights for the study. Comparing Ukraine with these countries will help to identify the strengths and weaknesses of the national nanotechnology industry, as well as to identify potential areas for development and increase of Ukraine's competitiveness in the global market. Globalisation has greatly accelerated the spread of technological innovation across borders, contributing to a more interconnected and competitive global marketplace. In this context, nanotechnology, defined as the manipulation of matter at the atomic and molecular levels, has become a transformative force.

This article analyses the costs of education and business in the countries studied, providing a global overview of important indicators that may affect competitiveness in the global market. The findings of this study allow us to compare the level of investment in education and infrastructure in the countries studied and their impact on competitive positions on a global scale.

Keywords: globalization, technoglobalism, technology, innovative development, nanotechnology, global market, industrial revolutions, Industry 4.0

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ВПЛИВ НАНОТЕХНОЛОГІЧНИХ ІННОВАЦІЙ НА КОНКУРЕНТОСПРОМОЖНІСТЬ ГЛОБАЛЬНОГО РИНКУ

На сучасному глобальному ринку інтеграція нанотехнологічних інновацій стала вирішальним фактором, що впливає на конкурентоспроможність. У цій статті досліджується багатогранний вплив нанотехнологій на динаміку світового ринку, підкреслюється їхня роль у підвищенні промислової ефективності, створенні нових продуктів і стимулюванні економічного зростання. Аналіз підкреслює, що нанотехнології відіграють ключову роль у контексті Четвертої промислової революції (Індустрія 4.0), реформуючи галузі та створюючи нові конкурентні переваги в глобальному масштабі. У цій статті окреслено значний вплив нанотехнологічних інновацій на світовий ринок, підкреслено взаємозв'язок між глобалізацією, техноглобалізмом та Індустрією 4.0. Завдяки підвищенню продуктивності продукції, економічній ефективності та стійкості, нанотехнології створюють конкурентні переваги, формуючи майбутнє промисловості в усьому світі.

Ключові слова: глобалізація, техноглобалізм, технології, інноваційний розвиток, нанотехнології, глобальний ринок, промислові революції, Індустрія 4.0

INTRODUCTION

The rapid development of nanotechnology has ushered in a new era of innovation, significantly impacting various sectors of the global market. As a multidisciplinary field, nanotechnology encompasses the manipulation of matter at the atomic and molecular levels, which has led to revolutionary developments in materials science, electronics, medicine and energy. These innovations have not only improved product performance and functionality, but also redefined industry standards, creating a dynamic and highly competitive global market. The integration of nanotechnology creates both opportunities and challenges. While it offers significant potential for economic growth and sustainable development, it also raises concerns about the regulatory framework, ethical considerations and socio-economic impacts of widespread adoption. The key role of nanotechnology in shaping the future of the global market is emphasised. By identifying key trends and developments, the author substantiates how nanotechnological innovations can be used to increase global competitiveness and stimulate sustainable economic progress.

The purpose of the article is to study the impact of nanotechnological innovations on the competitiveness of the global market. By studying the key industries that have integrated nanotechnology into their production processes, it is necessary to justify how these achievements have contributed to the creation of competitive advantages, market growth and economic development.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Nanotechnology, as an interdisciplinary field of science and technology, has gained significant development and application in various sectors of the economy in recent years, including medicine, agriculture, energy and industry. Their implementation helps to increase the efficiency of production processes, improve the quality of products and services, and create new market opportunities. This literature review examines the impact of nanotechnology innovations on global market competitiveness, based on current research.

The use of nanotechnology in medicine is one of the most dynamic areas of development in this field. Abaszadeh et al. (2023) point to significant advances in the use of nanotechnology in surgery, including the development of new materials for surgical instruments and implants that have improved physical and chemical properties and increased biocompatibility. Such innovations help to reduce the risk of postoperative complications and speed up the recovery process of patients, which ultimately improves the quality of medical services and their competitiveness in the market. Anjum (2024) considers the introduction of nanotechnology in dentistry, noting that the use of nanomaterials in the production of dental fillings, braces and other instruments significantly increases their efficiency and durability. This, in turn, improves the quality of dental treatment and makes it more affordable and effective for patients, which increases the competitiveness of dental clinics.

Nanotechnology is also having a significant impact on the energy sector and industry. Hosny et al. (2023) analyse the use of nanotechnology to improve the efficiency of oil production. In particular, nanoparticles are used to improve the properties of oil emulsions and increase the efficiency of chemical enhanced oil recovery. This reduces production costs and increases the productivity of oil wells, which contributes to the growth of companies' competitiveness in the global market. In industry, nanotechnology contributes to the development of new materials with unique properties, which allows for the creation of more efficient and wear-resistant products. Ifiok et al. (2024) note that the use of nanomaterials in construction contributes to improving the energy efficiency of buildings and reducing their environmental impact, which is an important factor for increasing competitiveness in the field of sustainable development.

Nanotechnology also plays an important role in agriculture. Saikant et al. (2023) discuss the use of nanomaterials to improve soil quality, fertiliser and crop protection efficiency. Such technologies can increase crop yields and reduce the negative impact on the environment, making agricultural products more competitive on global markets. Tian et al. (2021) analyse strategies for developing future crops using nanotechnology, noting that such innovations contribute to the creation of more resistant plants to climate change and disease. This helps to ensure a stable food supply and increase the competitiveness of the agricultural sector in the global market.

International cooperation in the field of nanotechnology is a key factor for increasing competitiveness. Lo et al. (2020) investigate the impact of global R&D collaboration on the quality of nanotechnology patents, noting that international projects facilitate the exchange of knowledge and resources, leading to the creation of high-quality innovative products and technologies. Sun et al. (2019) emphasise the importance of university research and its role in technology transfer, noting that cooperation between universities and industry contributes to the development of new nanotechnology solutions and their commercialisation, which increases the competitiveness of companies in the global market.

In general, the introduction of nanotechnology innovations has a significant impact on the competitiveness of various sectors of the global market. They help improve the quality of products and services, increase the efficiency of production processes, and create new market opportunities. International cooperation and the integration of scientific research with industry are key factors in ensuring the successful development and implementation of nanotechnology.

THE MAIN RESULTS

Globalisation has greatly accelerated the spread of technological innovations across borders, contributing to the creation of a more interconnected and competitive global market. In this context, nanotechnology, defined as the manipulation of matter at the atomic and molecular levels, has become a transformative force. Globalisation is the process of increasing interconnectedness and interdependence of global markets and businesses. Technoglobalism, as a type of globalisation, emphasises the global nature of technology development and dissemination. Technoglobalism has contributed to the rapid spread of nanotechnology, allowing countries and companies to use these innovations to strengthen their competitive advantage. Nanotechnology has revolutionised industries ranging from electronics to healthcare, enabling the creation of products with unprecedented properties and capabilities. The global diffusion of these technologies is being driven by collaborative research, international investment and cross-border partnerships, which is the essence of technoglobalism.

Technological progress is crucial for innovation, economic growth and competitiveness. Shlapak et al. (2023). Nanotechnology, with its potential to create new materials, improve energy efficiency and revolutionise production processes, represents a significant technological leap. Innovative development in the field of nanotechnology is characterised by continuous research and development (R&D) leading to breakthroughs that can be quickly commercialised. Tananaiko et al. (2023), Yatsenko et al. (2018, 2022, 2023). The ability to innovate and bring new products to market faster than competitors is a key factor in global success. Nanotechnology enables this

by offering solutions that are not only superior in performance, but also more cost-effective and environmentally friendly.

Nanotechnology is impacting the global market in several important ways:

1) Improving product performance: nanomaterials can improve product performance and durability, leading to higher customer satisfaction and increased market share. For example, nanoparticles are used in coatings to create scratch-resistant surfaces, and nanocomposites increase the strength and durability of materials.

2) Cost-effectiveness: nanotechnology can reduce production costs by improving the efficiency of production processes and minimising material losses. This cost efficiency leads to competitive prices and higher profitability.

3) Sustainable development: Nanotechnology innovations contribute to sustainable development by enabling the development of environmentally friendly products and processes. In particular, nanotechnology is used to create lightweight materials for the automotive and aerospace industries, which leads to a reduction in fuel consumption and emissions.

4) Healthcare development: In the medical field, nanotechnology has led to the development of targeted drug delivery systems, advanced diagnostic tools and improved medical devices. These innovations not only improve patient care, but also open up new markets and sources of revenue for pharmaceutical companies and medical device manufacturers.

The history of industrial revolutions highlights the transformative power of technological innovation. The Fourth Industrial Revolution, or Industry 4.0, is characterised by the integration of digital technologies, cyber-physical systems and the Internet of Things (IoT) into manufacturing and industrial processes Tsygankova et al. (2021, 2023). Nanotechnology is playing a crucial role in this revolution, enabling the creation of smart materials and devices that can interact with their environment in real time. Industry 4.0 is using nanotechnology to increase automation, improve supply chain management, and facilitate the development of intelligent manufacturing systems. These advances lead to increased productivity, lower operating costs and greater flexibility in responding to market demands, thereby increasing competitiveness.

To provide a broader perspective on the topic, Ukraine was analysed and compared with the following countries:

- The United States of America. The USA is a leader in the field of nanotechnology due to significant investments in research and development. American companies and universities are actively implementing nanotechnology solutions in various industries, which significantly increases their competitiveness in the global market.

- Germany, which is known for its advanced technologies and industrial innovations. German companies are actively using nanotechnology to improve product quality and reduce costs, making them competitive in the global market.

- China is rapidly developing its nanotechnology capabilities thanks to government support and significant investments in R&D projects. Chinese companies are actively entering the global market with innovative products based on nanotechnology.

- Japan is one of the pioneers in the development of nanotechnology. Japanese companies use nanotechnology to create high-quality products, which ensures their competitiveness in the international market.

- Israel is one of the leaders in nanotechnology research and innovation. Israeli start-ups and research institutes are developing advanced nanotechnology solutions, which allows the country to remain competitive in the global market.

- Finland is a well-known innovation hub. Significant advances have been made in nanotechnology research, especially in biomedical applications and materials science. Close cooperation between universities and technology companies.

These countries may be interesting to compare with Ukraine in terms of the development and implementation of nanotechnology, as well as its impact on competitiveness in the global market. Each of these countries has its own unique achievements and strategies that can provide valuable insights for the study. Comparing Ukraine with these countries will help to identify the strengths and weaknesses of the national nanotechnology industry, as well as to identify potential areas for development and increase of Ukraine's competitiveness in the global market.

Table 1 presents the costs of education and business in the countries studied, providing a global overview of important indicators that may affect competitiveness in the global market. The findings from this table allow us to compare the level of investment in education and infrastructure in the countries studied and their impact on competitive position on a global scale. The key indicators presented in the table will help to identify the link between educational investment, access to modern technologies and the ability of countries to successfully integrate nanotechnology innovations into their economies.

Table 1

Education and business spending: global overview, average for 2000-2023

Country	Adjusted savings: education expenditure, % of GNI	Compulsory education, duration, years	Computer, communications and other services, % of commercial service exports	Computer, communications and other services, % of commercial service imports	Cost of business start-up procedures, % of GNI per capita	Labor force with advanced education, % of total working-age population with advanced education
China	1,79	9,00	57,96	28,96	1,41	73,35
United States	4,67	12,00	45,74	35,76	1,10	75,68
Ukraine	5,28	10,84	36,74	30,29	7,15	70,63
Israel	5,65	12,84	68,45	46,44	4,12	80,10
Germany	4,35	13,00	48,48	42,82	5,82	75,55
Finland	5,84	9,44	66,53	57,08	0,96	78,30
Japan	2,90	9,00	55,67	53,11	7,50	77,98

Source: compiled by the author according to the World Bank

Analysing the data presented in Table 1, it can be argued that Ukraine spends 5.28% of its GNI on education, which is one of the highest indicators among the countries under consideration. This indicates a significant focus on education, which is a positive factor for the development of a skilled workforce. However, it should be noted that Israel (5.65%) and Finland (5.84%) spend even more, which may serve as a benchmark for further increasing investment in education. In Ukraine, the average duration of compulsory education is 10.84 years, which is longer than in China (9 years) and Japan (9 years), but shorter than in Germany (13 years) and Israel (12.84 years). This indicates an average level of basic education provision, which requires further improvement to raise the overall level of education of the population.

The share of computer, communication, and other services in Ukraine's commercial exports is 36.74%, which is lower than in most of the countries considered, especially Israel (68.45%) and Finland (66.53%). At the same time, the share of imports is 30.29%, indicating the need for further development of these areas to strengthen competitiveness in the global market. The cost of business start-up procedures in Ukraine is 7.15% of GNI per capita, which is significantly higher compared to other countries such as Finland (0.96%) and the United States (1.10%). This points to the need to simplify regulatory procedures to encourage entrepreneurship. In Ukraine, 70.63% of the labour force has a university degree, which is a good indicator, but somewhat lower compared to Israel (80.10%) and Finland (78.30%). This indicates a high level of education among the population, but further efforts are needed to achieve higher standards.

Thus, Ukraine has significant potential for development in several key areas:

- Investments in education: further increasing investments in education and extending the duration of compulsory education can help to improve the skills of the workforce, which is critical for the development of innovative technologies, including nanotechnology.
- Improving the business environment: simplifying regulatory procedures and reducing the cost of starting a business can stimulate entrepreneurial activity, especially in the high-tech sector.
- Development of IT and communication technologies: Increasing the share of IT and communication services in exports can strengthen Ukraine's position on the global market. To do this, it is necessary to stimulate innovation and attract investment in these areas.
- Support for research and innovation: Support for research in nanotechnology could be an important factor in enhancing Ukraine's competitiveness on the global market. Investments in research and development (R&D) can contribute to the introduction of new technologies and products.

Thus, Ukraine has significant opportunities for development, especially in education, high technology and innovation support, which can significantly increase its competitiveness in the global market.

Table 2 presents international educational indicators and government spending on education on average for the period 2000-2023 for the countries studied. This information is important for studying the impact of nanotechnology innovations on global market competitiveness, as the level of education and the corresponding government spending on education can significantly affect the ability of countries to introduce and develop high-tech innovations.

Comparing educational indicators and government spending on education in the countries studied, the following conclusions can be drawn:

- In Ukraine, the share of the population aged 25+ with a doctorate is low (0.32%), which indicates a low level of training of highly qualified personnel compared to other countries. For example, in the US, this figure is 1.59%, in Israel - 1.46%, in Germany - 0.75%, and in Finland - 0.77%. Ukraine spends 5.62% of its GDP on

education, which is quite high and almost matches the average level of spending in countries such as the United States (5.82%) and Israel (5.88%). However, this figure is significantly higher than in China (3.47%) and Japan (3.37%).

Table 2.

International education indicators and government spending on education, average for 2000-2023

Country	Educational attainment, Doctoral or equivalent, population 25+, total (%) (cumulative)	Government expenditure on education, total (% of GDP)	Government expenditure on education, total (% of government expenditure)	Secondary education, duration (years)	Tertiary education, academic staff (% female)	Unemployment with advanced education (% of total labor force with advanced education)
China	0,12	3,47	11,86	6,00	43,66	3,84
United States	1,59	5,82	15,79	6,00	50,01	3,32
Ukraine	0,32	5,62	13,94	7,00	59,85	7,77
Israel	1,46	5,88	16,84	6,00	47,89	4,25
Germany	0,75	4,73	9,32	9,00	36,70	2,65
Finland	0,77	6,32	11,37	6,00	49,60	4,37
Japan	0,98	3,37	8,51	6,00	-	3,18

Source: compiled by the author according to the World Bank

In Ukraine, education expenditure accounts for 13.94% of total government spending, which is higher than in Germany (9.32%) and Japan (8.51%), but lower than in the US (15.79%) and Israel (16.84%). The duration of secondary education in Ukraine is 7 years, which is the longest among the countries under review. This may indicate a deeper level of preparation in secondary school, although it does not necessarily correlate with the quality of education. Ukraine has the highest proportion of women among higher education teachers (59.85%), which is higher than in other countries such as the United States (50.01%), Israel (47.89%), and Finland (49.60%). Ukraine has the highest unemployment rate among people with higher education (7.77%), which indicates serious problems with the employment of highly qualified specialists. By comparison, the figure is only 2.65% in Germany, 3.32% in the US, and 4.37% in Finland.

Opportunities for Ukraine's development include the following:

- raising the level of doctoral training: it is important to create conditions for raising the level of doctoral training, in particular by increasing funding for research and encouraging young scientists.
- Optimisation of education costs: although education costs in Ukraine are quite high, it is necessary to ensure their efficient use aimed at improving the quality of educational services and increasing the competitiveness of graduates in the labour market.
- Reducing unemployment among graduates: it is necessary to develop employment programmes for young professionals, as well as to stimulate the connection between educational institutions and the labour market to ensure that educational programmes meet the needs of the economy.
- Support for women in science: Given the high percentage of women among the teaching staff, it is necessary to continue to support gender equality and encourage women to pursue research and academic careers.

Implementation of these measures can help to increase the level of education and reduce unemployment among graduates, which in turn will increase Ukraine's competitiveness in the global market.

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

Nanotechnological innovations have a profound impact on the competitiveness of the global market. By promoting technological progress, stimulating innovative development, and contributing to the goals of Industry 4.0, nanotechnology increases productivity, economic efficiency, and sustainability of products. As globalisation and techno-globalism continue to shape the world market, the strategic integration of nanotechnology will be essential for countries and companies seeking to maintain and enhance their competitive position. The ongoing development of nanotechnology is opening up new opportunities and reshaping industries, highlighting its crucial role in future global competitiveness.

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